MDCAT PHYSICS

Written By: AZHAR IQBAL

COLORED EDITION

MDCAT PHYSICS

PREPARATION & PRACTICE BOOK

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- According to revised syllabus
- A strong emphasis on conceptual understanding
- Short cuts trick and techniques to solve problems quickly
- Urdu Explanation of Difficult Concepts
- A concise summary of formulas at the end of each chapter
- Practice book containing 2500 plus MCQ's
- Solution of difficult MCQ'S

Written By:
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HAFIZ M. SIDDIQUE

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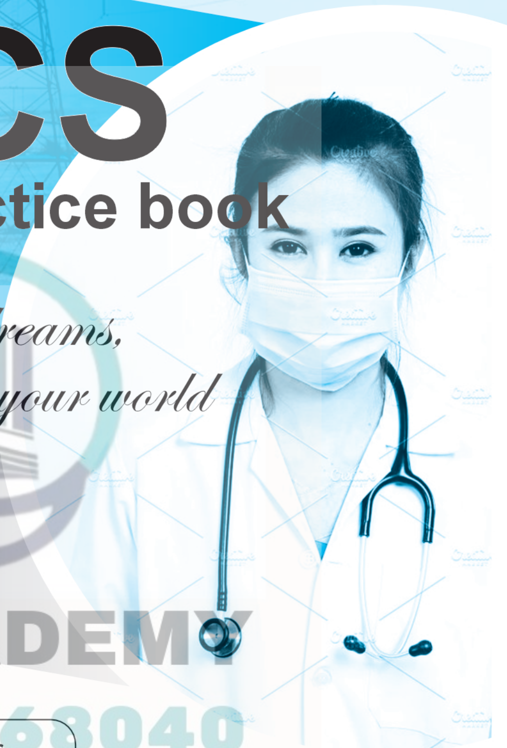
Preparation and practice book



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- According to new syllabus
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- Urdu explanations of concepts to understand easily.

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UNIT 00 BASIC TRICKS

IMPORTANT TIPS TO SOLVE PHYSICS MCQ's

فزکس کے زیادہ تر MCQ'S کا تعلق FORMULAE کے ساتھ ہوتا ہے
اس لئے جب بھی آپ کوئی TOPIC پڑھیں تو اس میں استعمال ہونے والے
FORMULAE کو اچھی طرح یاد کریں اور FORMULAE سے بننے
والے مندرجہ ذیل قسم کے سوالات کو ضرور مدِ نظر رکھیں۔

TYPE # 1

MDCATکے اکثر MCQ'S میں کسی QUANTITY کا FORMULA
ہی پوچھا گیا ہوتا ہے۔

EXAMPLE:

If source is moving away from the observer with velocity u then apparent frequency is given as

(a) $\frac{v+u}{v}f$ (b) $\frac{v}{v+u}f$ ✓

(c) $\frac{v-u}{v}f$ (d) $\frac{v}{v-u}f$

TYPE # 2

ایک QUANTITY کے بڑھنے یا کم ہونے سے کسی دوسری QUANTITYکی
VALUE پر کیا اثر ہوگا۔

EXAMPLE:

By increasing the distance from the positive point charge its potential:

(a) Increases (b) Decreases ✓

(c) remain same (d)either increases or decreases

SOLUTION:

As $V = \frac{Kq}{r}$ or $V \propto \frac{1}{r}$

By increasing distance V decreases.

TYPE # 3

یک QUANTITY کی VALUES میں RATIO دی گئ ہو تو دوسری
QUANTITYکی VALUES میں کیا RATIO ہو گی

EXAMPLE:

Two bodies having equal mass are moving with velocities 10 ms^{-1} and 20 ms^{-1} then the ratio between their K.E is

(a) 1 : 2 (b) 2 : 1 (c) 1 : 4✓ (d) 4 : 1

SOLUTION:

As $K.E = \frac{1}{2}mv^2$ or $K.E \propto v^2$

The ratio between velocity is 1 : 2 so ratio in K.E is 1 : 4

TYPE # 4

اگر کسی ایک QUANTITY کو DOUBLE یا HALF وغیرہ کر دیا جائے تو
دوسری QUANTITY پر کیا اثر ہو گا۔

EXAMPLE:

If length of pendulum is doubled then its time period will become

(a) Double (b) Half

(c) $\sqrt{2}\ times$✓ (d) $\frac{1}{\sqrt{2}}$ times

SOLUTION:

As $T = 2\pi\sqrt{\frac{\ell}{g}}$ or $T \propto \sqrt{\ell}$

If length is doubled T becomes $\sqrt{2}$ times the original.

TYPE # 5

اگر ایک QUANTITY کی دو ویلیوز اور دوسری QUANTITY کی ایک
VALUE دی گئی ہو تو اس کی دوسری VALUE کیا ہو گی۔

(TWO-TWO VALUES RELATIONSHIP)

EXAMPLE:

If at pressure 10 atm the volume of the gas is 2m^3. Then at what pressure the volume of the gas will be 5m^3.

(a) 5 atm (b) 4 atm✓ (c) 3 atm (d) 2 atm

SOLUTION: $As\ P \propto \frac{1}{V}$

$$\frac{P_2}{P_1} = \frac{V_1}{V_2} \Rightarrow P_2 = \frac{P_1V_1}{V_2} = \frac{10 \times 2}{5} = 4\ atm$$

TYPE # 6

ایک QUANTITY باقی کن QUANTITIES پر DEPENDENT یا
INDEPENDENTہے۔

EXAMPLE:

Speed of sound in air is independent of:

(a) density of air (b) pressure of air✓

(c) Temperature of air (d) None of these

SOLUTION: As $v = \sqrt{\frac{\gamma P}{\rho}}$ and $\rho \propto P$

So $\frac{P}{\rho}$ will always remain constant and v is independent of pressure.

$y \propto x^2$

EXAMPLE:

$K.E = \frac{1}{2}mv^2$

$\Rightarrow K.E \propto v^2$

- **If x increases, then y also increases** and if x decreases, then y also decreases.
- If x is doubled, then y becomes four times.

X کی VALUES کا SQUARE کرنے سے Y میں CHANGE کا پتا چلے گا۔

- If values of x are in ratio 2:3, then ratio in y is 4:9

X کی RATIO کا SQUARE کرنے سے Y میں RATIO ملے گی

- **Two-Two values relation**

$$\frac{y_2}{y_1} = \frac{{x_2}^2}{{x_1}^2}$$

$y \propto \sqrt{x}$

EXAMPLE:

$T = 2\pi\sqrt{\frac{\ell}{g}}$

$\Rightarrow T \propto \sqrt{\ell}$

- **If x increases, then y also increases** and if x decreases, then y also decreases.
- If x is doubled then y becomes $\sqrt{2}$ times

X کی VALUES کا $\sqrt{x}$ لینے سے Y میں CHANGE کا پتا چلے گا۔

- If values of x are in ratio 2:3, then ratio in y is $\sqrt{2} : \sqrt{3}$

x کی ratio کا √ لینے سے y میں ratio ملے گی

- **Two-Two values relation**

$$\frac{y_2}{y_1} = \frac{\sqrt{x_2}}{\sqrt{x_1}}$$

$y \propto \frac{1}{x}$

EXAMPLE:

$PV = Const.$

$\Rightarrow P \propto \frac{1}{V}$

- **If x increases, then y decreases** and if x decreases, then y increases.
- If x is doubled, then y becomes half.

جتنا X میں CHANGE آئے گا۔ Y میں اتنے TIME الٹا CHANGE آئے گا۔

- If values of x are in ratio 2:3 then ratio in y is 3:2

جو X میں RATIO ہو گی Y میں اس سے الٹی RATIO ہو گی

- **Two-Two values relation**

$$\frac{y_2}{y_1} = \frac{x_1}{x_2}$$

$y \propto \frac{1}{x^2}$

EXAMPLE:

$E = \frac{kq}{r^2}$

$\Rightarrow E \propto \frac{1}{r^2}$

- **If x increases, then y decreases** and if x decreases, then y increases
- If x is doubled, then y becomes one-fourth.

X کی VALUES کا SQUARE کرکے الٹا کرنے سے Y میں CHANGE کا پتا چلے گا۔

- If values of x are in ratio 2:3, then ratio in y is also 9:4

X میں RATIO کا SQUARE کرکے الٹا کرنے سے Y میں RATIO ملے گی

- **Two-Two values relation**

$$\frac{y_2}{y_1} = \frac{{x_1}^2}{{x_2}^2}$$

$y \propto \frac{1}{\sqrt{x}}$

EXAMPLE:

$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

$\Rightarrow f \propto \frac{1}{\sqrt{m}}$

- **If x increases, then y decreases** and if x decreases then y increases.
- If x is doubled then y becomes $\frac{1}{\sqrt{2}}$ times

X کی VALUES کا √ لے کر الٹا کرنے سے Y میں CHANGE کا پتا چلے گا۔

- If values of x are in ratio 2:3, then ratio in y is $\sqrt{3} : \sqrt{2}$

X کی RATIO کا √ لے کر الٹا کرنے سے Y میں RATIO ملے گی۔

- **Two-Two values relation**

$$\frac{y_2}{y_1} = \frac{\sqrt{x_1}}{\sqrt{x_2}}$$

HOW TO CHECK RELATION BETWEEN TWO QUANTITIES?

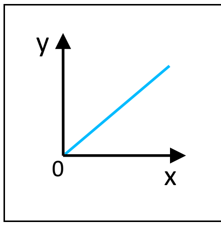
Consider an expression

$$R = \frac{PQ}{X}$$

RELATION	CONDITION
$R \propto P$	If Q and X ,are constant
$R \propto Q$	If P and X, are constant
$R \propto 1/X$	If P and Q, are constant
$X \propto P$	If Q and R, are constant
$X \propto Q$	If P and R, are constant

نوٹ: کوئی بھی دو QUANTITIES میں PROPORTIONALITY RELATION لگانے کیلئے باقی QUANTITIES کا CONSTANT ہونا ضروری ہے۔

HOW TO DETERMINE GRAPH?



1. اگر x اور y دونوں کی پاور ONE میں ہو تو گراف STRAIGHT LINE ہو گا اور ORIGIN سے پاس کرے گا۔

$y^1 \propto x^1$

SOLUTION: As $T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow T \propto \sqrt{\ell}$

کیونکہ LENGTH کی پاور $\frac{1}{2}$ ہے اس لیے LENGTH کی PERCENTAGE کو $\frac{1}{2}$ سے MULTIPLY کریں گے

$$\%change\ in\ T = \frac{1}{2}(\%change\ in\ \ell) = 3\%$$

IF PERCENTAGE CHANGE IS MORE THAN 10%

i. WHEN X INCREASES:

اگر دو QUANTITIES کے درمیان کچھ اس طرح کا RELATION ہو

$$Y \propto X^2$$

اور X میں %AGE CHANGE کی ویلیو 10% سے زیادہ ہو تو X کی PERCENTAGE کو X کی POWER سے MULTIPLY کرکے یہ والا $\left(\frac{\%\ change\ in\ X}{10}\right)^2$ FACTOR جمع کر دیں۔ تو Y میں PERCENTAGE مل جائے گی۔

$$\%\ change\ in\ Y = 2(\%\ change\ in\ X) + \left(\frac{\%\ change\ in\ X}{10}\right)^2$$

EXAMPLE:

If momentum of a body increases by 20% then its K.E will be increased by:

(a) 20% (b) 40% (c) 44% ✓ (d) 400%

SOLUTION: As $K.E = \frac{P^2}{2m} \Rightarrow K.E \propto P^2$

$$\%\ change\ in\ K.E = 2(20\%) + \left(\frac{20\%}{10}\right)^2 = 40\% + 4\%$$
$$= 44\%$$

ii. WHEN X DECREASES:

اگر دو QUANTITIES کے درمیان کچھ اس طرح کا RELATION ہو

$$Y \propto X^2$$

اور X میں %AGE CHANGE کی ویلیو 10% سے زیادہ ہو تو X کی PERCENTAGE کو X کی POWER سے MULTIPLY کرکے یہ والا $\left(\frac{\%\ change\ in\ X}{10}\right)^2$ FACTOR اس سے MINUS کر دیں۔ تو Y میں PERCENTAGE مل جائے گی۔

$$\%\ change\ in\ Y = 2(\%\ change\ in\ X) - \left(\frac{\%\ change\ in\ X}{10}\right)^2$$

EXAMPLE:

If momentum of a body decreases by 10% then its K.E will be decreased by:

(a) 9% (b) 5% (c) 10% (d) 19%✓

SOLUTION: As $K.E = \frac{P^2}{2m} \Rightarrow K.E \propto P^2$

% change in K.E= $2(10\%) - \left(\frac{10\%}{10}\right)^2 = 20\% - 1\%$
$= 19\%$

IF CHANGE IN X IS MULTIPLE OF 100%.

EXAMPLE:

If length of the pendulum is increased by 100% then its time period will become:

(a) Double (b) Half (c) $\frac{1}{\sqrt{2}}$ times (d) $\sqrt{2}$ times✓

SOLUTION: As $T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow T \propto \sqrt{\ell}$

If length increases by 100% its means that it is doubled. Then time period will become $\sqrt{2}$ times.

% Increase in quantity	100 %	200 %	300 %	400 %
Quantity becomes	Doubled	Three times	Four times	Five times

- اگر quantity کی ویلیو 100% بڑھ جائے تو یہ double ہو جائے گی۔
- اگر quantity کی ویلیو 200% بڑھ جائے تو یہ two times ہو جائے گی۔
- اگر quantity کی ویلیو 300% بڑھ جائے تو یہ three times ہو جائے گی۔
- اگر quantity کی ویلیو 50% کم ہو جائے تو یہ half ہو جائے گی۔

TRIGONOMETRIC RATIOS.

θ	$sin\theta$	$cos\theta$
0^o	0 (minimum)	1 (maximum)
30^o	$\frac{1}{2} = 0.5 = 50\%$	$\frac{\sqrt{3}}{2} = 0.86 = 86\%$
45^o	$\frac{1}{\sqrt{2}} = 0.7 = 70\%$	$\frac{1}{\sqrt{2}} = 0.7 = 70\%$
60^o	$\frac{\sqrt{3}}{2} = 0.86 = 86\%$	$\frac{1}{2} = 0.5 = 50\%$
90^o	1 (maximum)	0 (minimum)
180^o	0	-1

TRICK TO MEMORIZE

اگر numbers کو اس طرح ترتیب سے لکھ لیں

0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1

- دائیں طرف کو ترتیب سے Angle کی values پڑھیں تو $sin\theta$ کی values ملتی جائیں گے
- بائیں طرف کو ترتیب سے angle کی values پڑھیں تو $cos\theta$ کی values ملتی جائیں گے

EXAMPLE:

The magnitude of force $\vec{F} = 3\hat{\imath} + 4\hat{\jmath}$

$$F = \sqrt{(3)^2 + (4)^2} = 5$$

Direction of a vector is given as

$$\theta = Tan^{-1}\left(\frac{y - comp}{x - comp}\right)$$

NOTE: Angle θ is angle with x -axis

SCALAR PRODUCT OF TWO VECTORS

If the product of two vectors results a scalar quantity, then product is known as scalar or dot product.

$$\vec{A}.\vec{B} = ABcos\theta$$

جب دو vectors میں dot لگا ہو تو ان کا result ہمیشہ scalar آئے گا۔

یاد رکھیں۔

"Parallel Dot product میں ہمیشہ ایک ویکٹر کا magnitude دوسرے ویکٹر کے Component" کے magnitude سے multiply ہوتا ہے یا جب بھی دو vectors کے صرف parallel components کو multiply کرنا ہو تو ہم ان کا dot product کریں گے۔

1. **Work**

$$W = \vec{F}.\vec{d} = Fdcos\theta$$

2. **Power**

$$P = \vec{F}.\vec{v} = Fvcos\theta$$

3. **Electric Flux**

$$\emptyset_e = \vec{E}.\vec{A} = EAcos\theta$$

4. **Magnetic Flux**

$$\emptyset_B = \vec{B}.\vec{A} = BAcos\theta$$

جن formulas میں بھی $cos\theta$ آرہا ہو ان کی ویلیو 0^o پر maximum ہوگی اور 90^o پر minimum ہوگی

- **Dot product of two vectors in terms of rectangular components is given as**

$$\vec{A}.\vec{B} = (A_x\hat{\imath} + A_y\hat{\imath} + A_z\hat{k}).(B_x\hat{\imath} + B_y\hat{\imath} + B_z\hat{k})$$

$$= A_xB_x + A_yB_y + A_zB_z$$

دو vectors کا dot product لینے کے لیے x-component کو x سے multiply کریں، y کو y سے multiply کریں اور z کو z سے multiply کریں۔

VECTOR PRODUCT OF TWO VECTORS

If the product of two vectors results a vector quantity, then the product is called vector product of cross product. Mathematically cross product of two vectors is given as

$$\vec{A} \times \vec{B} = ABsin\theta\hat{n}$$

1- **Torque:**

$$\vec{\tau} = \vec{r} \times \vec{F}$$

2- **Angular momentum**

$$\vec{L} = \vec{r} \times \vec{P}$$

3- **Magnetic force on moving charge**

$$\vec{F} = q(\vec{v} \times \vec{B})$$

4- **Tangential velocity**

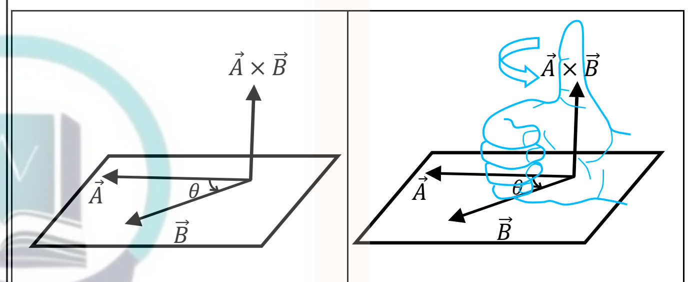
$$\vec{v}_t = \vec{\omega} \times \vec{r}$$

یادرکھیں

دو vectors کے cross product کرنے سے جو نیا vector بنے گا وہ ہمیشہ ان دونوں vectors کے perpendicular ہوگا۔

Direction is determined by right hand rule:

"Rotate first vector towards second vector through smaller angle. Then curl the fingers of your right hand in direction of rotation keeping the thumb erect. Erect thumb will point out direction of cross product."



- **Cross product of two vectors in terms of rectangular components is given as**

$$\vec{A} \times \vec{B} = \begin{vmatrix} \hat{\imath} & \hat{\imath} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

$$= (A_zB_x - A_xB_z)\hat{\imath} + (A_zB_x - A_xB_{yz})\hat{\jmath}$$

$$+(A_xB_y - A_yB_y)\hat{k}$$

PREFIXES

Prefix	Decimal Multiplier	Symbol	Prefix	Decimal Multiplier	Symbol
yotta	10^{24}	Y	deci	10^{-1}	d
zetta	10^{21}	Z	centi	10^{-2}	c
exa	10^{18}	E	milli	10^{-3}	m
peta	10^{15}	P	micro	10^{-6}	μ
tera	10^{12}	T	nano	10^{-9}	n
giga	10^{9}	G	pico	10^{-12}	p
mega	10^{6}	M	femto	10^{-15}	f
kilo	10^{3}	k	atto	10^{-18}	a
hecto	10^{2}	h	zepto	10^{-21}	z

UNIT 01 FORCE AND MOTION

IMPORTANT TIPS TO SOLVE PHYSICS MCQ'S

MECHANICS:

Study of motion of objects is called mechanics. It is divided into two types.

(i) Kinematics (ii) Dynamics

i. **KINEMATICS:** Study of motion of objects without referring the force.

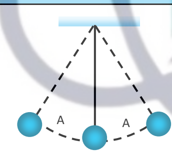
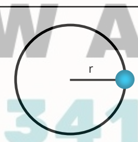
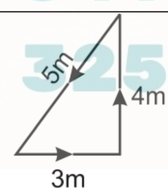
ii. **DYNAMICS:** Study of motion of objects taking into consideration of force (the cause of motion)

DISTANCE

Total length of path followed by body is called distance.

- It is scalar quantity.
- Its SI unit is meter.
- It may be zero or positive but never negative.
- Distance of a body in motion can never be zero.

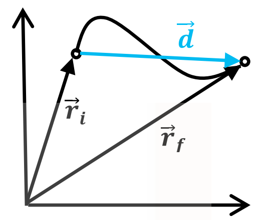
EXAMPLES

1: Distance covered by a body in one vibration if its amplitude is A Distance = $A + A + A + A$ **Distance =** $\mathbf{4A}$	
2: Distance covered by a body moving in a circle in 1 revolution **Distance =** $2\pi r$	
3: Consider an object moves in a closed path Distanceمعلوم کرنے کے لیے تمام path کی length کو add کریں۔	 TOTAL DISTANCE = 3+4+5 = 12m

DISPLACEMENT

Change in position of a body from its initial position to final position is called displacement.

- It is vector quantity and its direction is from initial to final position.
- Its SI unit is meter.
- It may be **positive**, **negative** or **zero**.
- It is shortest distance between initial and final position.
- Displacement is **always less than or equal to distance.**
- If a body moves in **straight line** its displacement and distance are equal.
- The ratio of distance to displacement for body is always greater or equal to one.



$$\vec{d} = \vec{r}_f - \vec{r}_i$$

(Displacement = Final pos. vector − Initial pos. vector)

EXAMPLE:

Find magnitude of displacement, if a body moves from point P(2, 3) to a point Q(5,7).

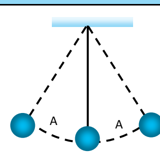
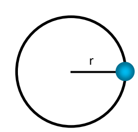
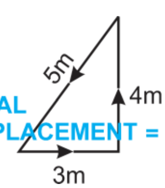
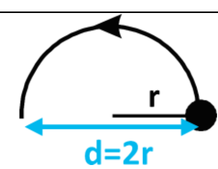
(a) 4m (b) 5m (c) 7m (d) 17m

Solution:

$$\vec{d} = \vec{r}_f - \vec{r}_i = (5\hat{\imath} + 7\hat{\jmath}) - (2\hat{\imath} + 3\hat{\jmath}) = 3\hat{\imath} + 4\hat{\jmath}$$

$$|\vec{d}| = \sqrt{(3)^2 + (4)^2} = \mathbf{5m}$$

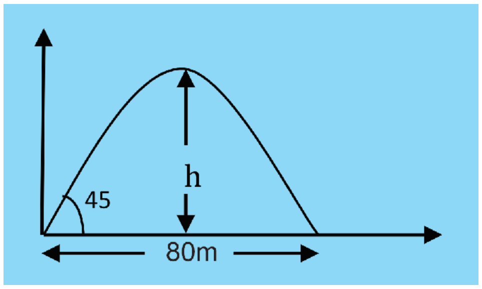
EXAMPLES

1: Displacement covered by a body in one vibration if its amplitude is A **Displacement =** $\mathbf{0}$	
2: Displacement covered by a body moving in a circle in one revolution **Displacement =** $\mathbf{0}$	
3: Consider an object moves in a closed path **Displacement =** $\mathbf{0}$ اگر کوئی باڈی اپنی Initial position پر واپس آجائے تو اس کا Displacement زیرو ہوگا	 TOTAL DISPLACEMENT = 0
4: Displacement covered by a body moving in a circle in half revolution **Displacement =** $\mathbf{2r}$	

Displacement ہمیشہ دو points کے درمیان shortest distance کے برابر ہوگا

EXAMPLE:

Trajectory of a body is shown in the figure below. What is its time of flight?



(a) 4sec (b) 8sec (c) 16 sec (d) $\sqrt{8}sec$

SOLUTION:

$$R\ tan\theta = \frac{1}{2}gt^2$$

$$80 \times Tan45 = \frac{1}{2} \times 10 \times t^2$$

$$t^2 = 16$$

$$t = 4 \text{ sec}$$

BALLISTIC FLIGHT:

Ballistic flight is that in which projectile is given an initial push and then allowed to move freely due to inertia and under action of gravity.

BALLISTIC MISSILE:

The unpowered and unguided missile is called ballistic missile.

- The ballistic missiles are useful only for short ranges.
- Powered and remote controlled guided missiles are used for long ranges and greater precision.

BALLISTIC TRAJECTORY:

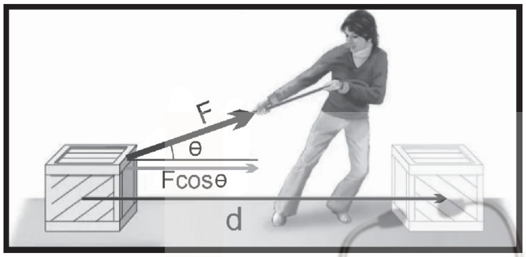
The path followed by ballistic missile is called ballistic trajectory.

- If we consider earth as a ***flat surface*** (short range), the shape of trajectory is ***parabolic***.
- If we consider ***earth spherical*** (long range), the shape of trajectory is ***elliptical.***

UNIT 02 WORK AND ENERGY

WORK DONE BY CONSTANT FORCE

"The product of magnitude of displacement and component of force in the direction of displacement is called work done on the body." OR "The scalar product of force and displacement is called work done on a body."



- Fcosθ is component of force in the direction of displacement.

$$W = (F\cos\theta)(d)$$

$$W = Fd\cos\theta = \vec{F}.\vec{d}$$

اگر work کے بارے میں بتایا گیا ہو تو ہم angle بتا سکتے ہیں اور اگر angle بتایا گیا ہو تو ہم work بتا سکتے ہیں۔

EXAMPLE:
At what angle between force and displacement more work is done.
(a) 20^o ✓(b) 40^o
(c) 60^o (d) 80^o

SOLUTION: Smaller the angle, larger the value of Cosθ
Work will be maximum when angle is smallest.

- **For different values of angles work is given as**

θ	0^o	30^o	45^o	60^o	90^o	180^o
W	Fd	$\frac{Fd}{2}$	$\frac{Fd}{\sqrt{2}}$	$\frac{\sqrt{3}Fd}{2}$	0	$-Fd$

EXAMPLE:
At what angle between force and displacement the work done on the body is just 50% of maximum work
(a) 30^o (b) 45^o
(c) 60^o✓ (d) 90^o

SOLUTION:
As value of $Cos\ 60^o = 1/2$ (50%)
Hence work done is 50% when θ = 60°

- Work may be positive, negative and zero.
- Work is **scalar quantity** and its SI unit is Joule.
- In terms of base units its unit is Kgm^2s^{-2}.

$$1J = Kgm^2s^{-2}$$

- In cgs system unit of work is erg.

$$1erg = 10^{-7}J$$

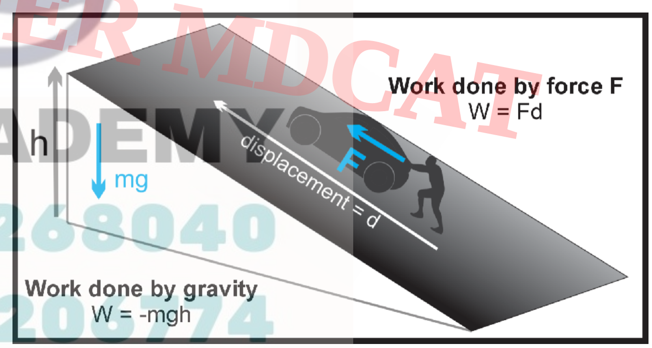
IMPORTANT CONVERSION OF UNITS

1 Wh	3.6kJ	1 kWh	3.6MJ
1 Cal	4.18J	1 Cal	4.18J

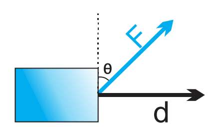
EXAMPLE:
Which of the following is smallest unit of work?
(a) kWh (b) J (c) erg **(d) eV**✓

SOLUTION: $kWh > J > erg > eV$

Work معلوم کرنے کے لیے ہمیشہ displacement کو اس force سے multiply کریں جو displacement کے parallel ہو گی۔ یا جس force کا work لینا ہو اس force کو ایسے displacement سے multiply کریں گے جو اس force کے parallel ہو گا۔

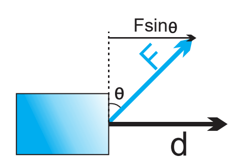


EXAMPLE: If a body is moving under the action of constant force as shown in the figure below then the work done on the body is



(a) $Fd\ Cos\theta$ (b) $Fd\ Sin\theta$✓
(c) $Fd\ Tan\theta$ (d) $-\ Fd\ Cos\theta$

SOLUTION:
W=displacement(component of force parallel to displacement)
W= Fd sinθ



جو کمپونینٹ angle کے سامنے ہو گا اس کے ساتھ sinθ آئے گا۔

POSITIVE WORK

If the **angle** between force and displacement is **less than 90°** then work is positive.

جب بھی کسی BODY پر POSITIVE-WORK کریں گے اس کی TOTAL-ENERGY ہمیشہ بڑھے گی۔

EXAMPLE:
If the angle between force and displacement of the body is 30° then work done will b

(a)positive ✓ (b) maximum
(c)negative (d) minimum

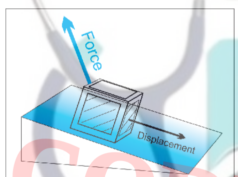
NEGATIVE WORK

If the **angle** between force and displacement is **greater than 90o** then work is negative.

- Work done by friction is always negative.

جب بھی کسی BODY پر NEGATIVE-WORK کریں گے اس کی TOTAL-ENERGY ہمیشہ کم ہو گی۔

EXAMPLE:
If a block is moving under the action of constant force as shown in the figure, then the work done on the body is



(a) positive **(b)** negative✓
(c) maximum **(d)** minimum

SOLUTION:
Since the angle between force and displacement is greater than 90°**.** Hence work done will be negative.

ZERO WORK

Work done on a body may be zero in three ways

1. If the **angle** between force and displacement is **90° or 270°** then work is zero.

EXAMPLE:
Work done by magnetic force on a moving charge in a magnetic field is always

(a) positive **(b)** negative **(c)** zero✓ **(d)** none of these

SOLUTION:
As

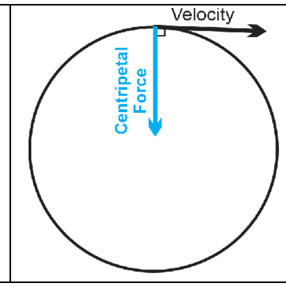
$$\vec{F}_m = q(\vec{v} \times \vec{B})$$

Magnetic force on a moving charge is always perpendicular to velocity or displacement. **So** work is zero.

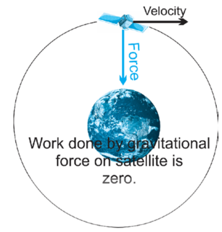
جب بھی دو vectors کا cross-product لیں گے تو بننے والا vector ہمیشہ ان دونوں کے perpendicular ہو گا۔

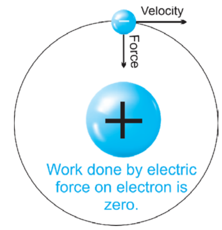
Work done by centripetal force is always zero because force is always Perpendicular to velocity or displacement of the body.

$$W = Fd\cos 90^\circ$$
$$W = 0$$



EXAMPLES:





- Work done by **gravitational force on satellite** revolving around the earth is always zero.
- Work done by **electric force on electrons** revolving around the nucleus is always zero.
- Work done by **magnetic force on moving charge** in a magnetic field is always zero.

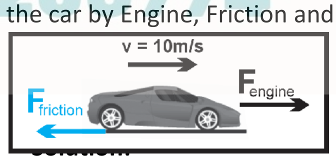
2. If the body covers no displacement.

EXAMPLE:
Work done by a man pushing the rigid wall is zero because

(a) force is zero
(b) displacement is zero
(c) force and displacement are parallel
(d) force and displacement are perpendicular

3. If net force acting on the body is zero (body is moving with uniform velocity or speed).

EXAMPLE:
If a car is moving with uniform velocity then work done on the car by Engine, Friction and net force is respectively



(a) positive, negative, positive
(b) positive, negative, negative
(c) positive, negative, zero
(d) positive, zero, positive

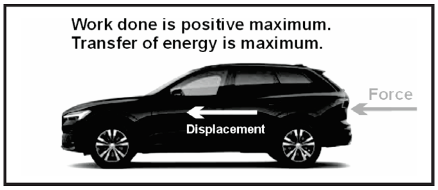
SOLUTION:
Work done by Engine $= Fd\cos 0^\circ = +Fd$.
Work done by Friction $= Fd\cos 180^\circ = -Fd$.
Net work done $= 0$

(As car is moving with uniform velocity so $\mathbf{a} = \mathbf{0}$ and $\mathbf{F_{net}} = \mathbf{0}$)

MAXIMUM WORK

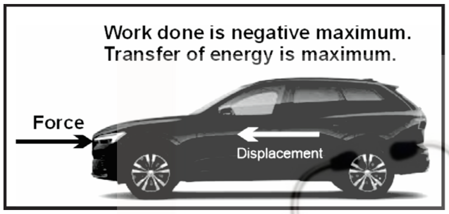
- If **displacement and force are parallel** to each other

$$W = Fd\cos 0^o = Fd$$



- If **displacement and force are anti-parallel** to each other

$$W = Fd\cos 180^o = -Fd$$



Work done in term of rectangular components:

$$W = \vec{F}.\vec{d} = (F_x d_x + F_y d_y + F_z d_z)$$

1. x-component کو x سے multiply کریں۔
2. y-component کو y سے multiply کریں۔
3. z-component کو z سے multiply کریں۔ پھر تینوں کو add کر دیں۔

EXAMPLE:

If a force $\vec{F} = 4\hat{i} + 6\hat{j}$ displaces the body from point $p(2,3)$ to a point $Q(5,-2)$ then what is work done.

(a) 9 J (b) -9 J (c) 18 J (d) -18 J✓

SOLUTION:

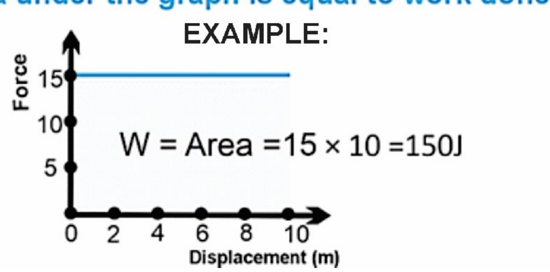
$$\vec{d} = \vec{r}_f - \vec{r}_i$$
$$= (5\hat{i} - 2\hat{j}) - (2\hat{i} + 3\hat{j}) = 3\hat{i} - 5\hat{j}$$
$$W = \vec{F}.\vec{d} = (4\hat{i} + 6\hat{j}).(3\hat{i} - 5\hat{j})$$
$$= (4)(3) + (6)(-5) = -18\ J$$

- Area under force- displacement graph is equal to work done on the body.

$$\text{Area of rectangle} = \text{length} \times \text{width} = (F\cos\theta)(d)$$
$$= Fd\cos\theta = \text{work done}$$

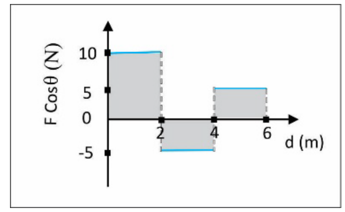
EXAMPLE:

Area under the graph is equal to work done



EXAMPLE:

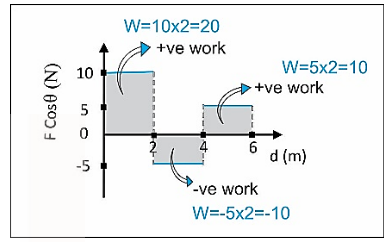
The graph between displacement and component of force in the direction of displacement for a body is shown in the figure. Work done on the body is



(a) 20J ✓ (b) 30J (c) 40J (d) 50J

SOLUTION:

$$W = \text{total area}$$
$$= (10 \times 2) - (2 \times 5) + (2 \times 5)$$
$$= 20 - 10 + 10$$
$$W = 20J$$



“DISPLACEMENT AXIS” سے اوپر والا AREA پوزیٹو اور نیچے والا AREA نیگیٹو لکھیں گے۔

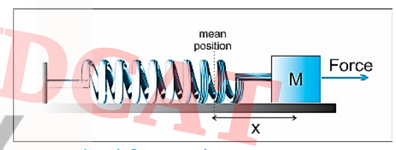
WORK DONE BY VARIABLE FORCE

In most cases force is not constant throughout the displacement but it is variable.

EXAMPLES:

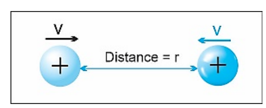
1- In stretching a spring. Work is done by variable force.

$$F \propto x$$



As the extension increases applied force also increases.

2- Two positive point charges are brought closer to each other. Work is done by variable force



$$F \propto \frac{1}{r^2}$$

As the distance decreases, electric force between the charges increases.

2- A rocket moving away from earth. Work is done by variable force

$$F \propto \frac{1}{r^2}$$

As the distance increases, gravitational force between earth and rocket decreases.

To calculate work done by variable force there are two methods.

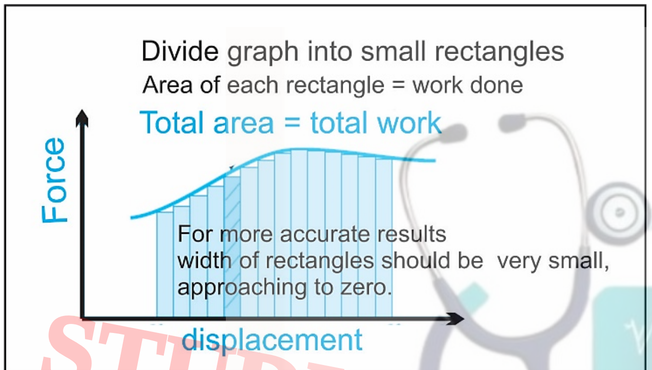
i. **We divide the path into small intervals** so that in each interval force approximately remains constant then we calculate work done during each interval, Then finding the total work.

$$W_i = \vec{F_i}.\Delta\vec{d_i} = F_i \Delta d_i \cos\theta_i$$

$$W_t = \sum_{i=1}^{n} F_i \Delta d_i \cos\theta_i$$

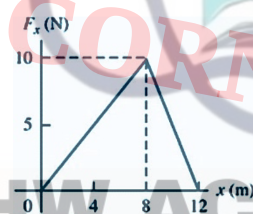
ii. **We plot a graph between force and displacement and then finding the total area under the graph.**

$$W_t = \text{Total area under the graph.}$$



EXAMPLE:

Force – displacement graph for a body is shown in the figure. Work done on the body is



(a) 15J (b) 30J (c) 60J (d) 120J

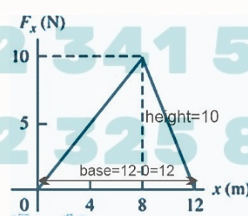
SOLUTION:

$$W = \text{area of triangle}$$

$$W = \frac{1}{2} \times \text{base} \times \text{height}$$

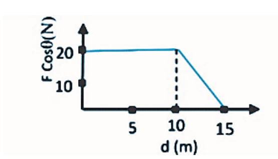
$$W = \frac{1}{2} \times 12 \times 10$$

$$W = 60J$$



EXAMPLE:

Force – displacement graph for a body is shown in the figure. Work done on the body is



(a) 50J (b) 200J (c) 150J (d) 250J✓

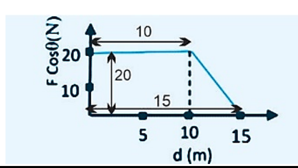
SOLUTION:

$$W = \text{area of trapezium}$$

$$W = \frac{10+15}{2} \times 20$$

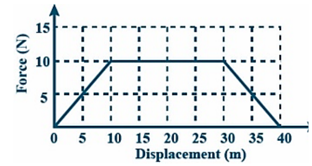
$$W = 25 \times 10$$

$$W = 250J$$



EXAMPLE:

Force - displacement graph for a body is shown in the figure. Work done on the body is



(a) 100J (b) 200J (c) 300J (d) 600J

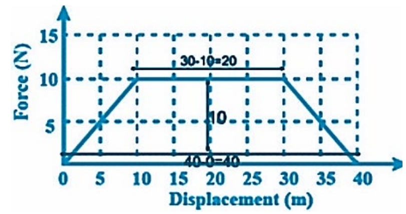
SOLUTION:

Work done is equal to area of trapezium.

$$W = \frac{20+40}{2} \times 10$$

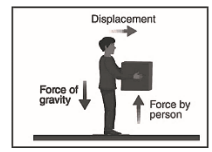
$$W = 30 \times 10$$

$$W = 300J$$



EXAMPLE:

A person holding a 10kg bag covers a displacement 5m in horizontal direction. How much work is done by gravity?



(a) 50J (b) 500J (c) -500J (d) zero✓

SOLUTION:

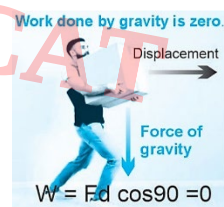
Since force of gravity is perpendicular to displacement. Hence work done by gravity is zero. Work done by person is also zero.

WORK DONE BY GRAVITATIONAL FORCE

Region or space around the earth in which its gravitational force acts on the body is called gravitational field.

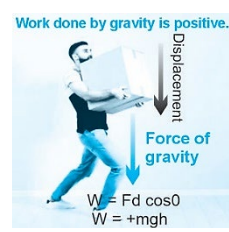
CASE:1

If a body is displaced in **horizontal** direction, work done by gravity is **zero**.



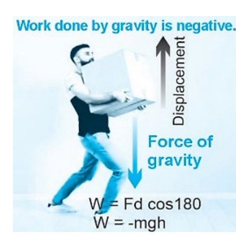
CASE:2

If body is displaced in **downward** direction, then work done by gravity is **positive.**

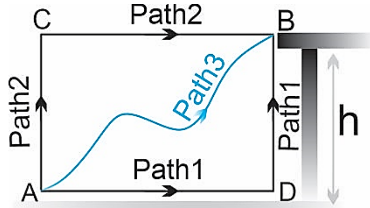


CASE:3

If body is displaced in **upward** direction, then work done by gravity is **negative.**



Work done by gravity is independent of path followed.



Along path1:

$$W_{AB} = W_{AD} + W_{DB} = 0 + (-mgh) = -mgh$$

Along path2:

$$W_{AB} = W_{AC} + W_{CB} = (-mgh) + 0 = -mgh$$

Along path3:

$$W_{AB} = -mg(\text{total verical displacement})$$

$$W_{AB} = -mgh$$

اگر کوئی body مختلف path سے کسی height پر لے کر جائیں گے تو ہر path میں gravity کا work برابر ہو گا اور path کی لمبائی پر depend نہیں کرے گا ۔

Work done only depends upon

- Mass or weight of the body.
- Acceleration due to gravity.
- Height or vertical distance.

$$W = mgh$$

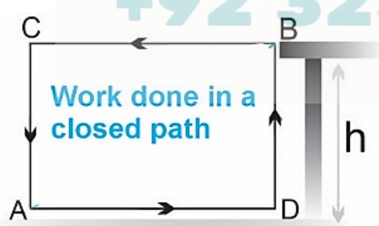
Work done in staking "n" number of bricks one on the top of another is

$$W = \frac{n(n-1)}{2} \times mgh$$

- m is mass of the brick.
- h is thickness of the brick.

Work done by Gravity in a closed path is zero.

Consider a body of mass m, moved in a closed path ABCDA at height h.



$$W_{ADBCA} = W_{AD} + W_{DB} + W_{BC} + W_{CA}$$

$$W_{ADBCA} = 0 + (-mgh) + 0 + (+mgh)$$

$$W_{ADBCA} = 0$$

CONSERVATIVE FORCE:

- The force for which work done in closed path is zero is called conservative force.
- The force for which work is independent of the path followed by the body is called conservative force.

EXAMPLES:

Gravitational force, Electric force, **Elastic force**. are conservative forces.

NON-CONSERVATIVE FORCE:

- Work done depends upon the path followed (Longer the path, larger the work).
- **Work done in closed path is not equal to zero.**

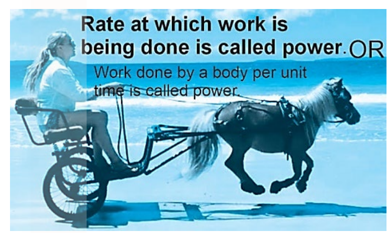
Work done on aero plane by air friction is not zero in a closed path and longer the path followed by aero plane, larger the work done by air friction.

EXAMPLES:

Friction, Viscous force, Normal force, Tension, Air resistance, Propulsive force of rocket and motor are non-conservative forces.

POWER

"Rate at which work is being done." OR "Work done by a body per unit time is called power of the body."



کوئی باڈی ہر سکینڈ میں جتنا work کرے گی یہ اس کی power کہلائے گی۔

- It is a scalar quantity. It is equal to dot product of force and velocity.
- Its SI unit is watt $(1W = Js^{-1} = kgm^2s^{-3})$.
- **Power is one watt if one joule work is done in one second.**
- Power is also measured in **horse power**.

(1hp = 746 W)

AVERAGE POWER:

$$P_{av} = \frac{Total\ work}{Total\ time} = \frac{W}{t}$$

If work done is equal to change in K.E

$$P = \frac{\frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2}{t}$$

If work done is equal to change in P.E

$$P = \frac{mgh_2 - mgh_1}{t}$$

If a body of mass m or volume V is lifted to a height h

$$P = \frac{mgh}{t} \qquad P = \frac{\rho Vgh}{t}$$

IN TERMS OF FORCE AND VELOCITY:

If a body is moving with **constant velocity** $\vec{v}$ under the action of **constant force** $\vec{F}$ exerted by engine or propeller **required to** sustain the motion or **overcome the friction**, then power of engine or propeller is given as

$$P = \vec{F}.\vec{v} = Fv\cos\theta$$

- θ is angle between force and velocity.

ENERGY DISSIPATION:

If P is power of a body or device, then the energy dissipated by device in time t is given as

$$Energy = P \times t$$

NOTE:

- Work done = Power × time
- Unit of power × unit of time = unit of work
- W.s, Wh, kWh, MWh etc. are units of work or energy.

POWER اور TIME کے UNITS کا PRODUCT ہمیشہ ENERGY کا UNIT ہو گا

KILO-WATT HOUR:

"One Kilowatt hour is work done in one hour by an agency whose power is one kilowatt."

1Wh = 3.6 kJ	1kWh = 3.6MJ	1MWh = 3.6GJ

Kilowatt-hour is commercial unit of electrical energy.

ENERGY

Capacity of a body to do work is called energy.

- It is a scalar quantity
- Its SI unit is joule (1J = Nm = kg m^2s^{-2})
- Work and energy have same units.

There are many types of energy such as **K.E**, P.E, **sound energy**, heat energy, **electrical energy**, chemical energy, **solar energy,** nuclear energy etc.

➢ Mechanical energy can either be K.E or P.E

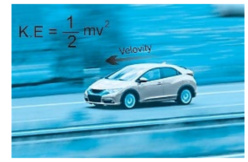
All the food you eat in one day has about the same energy as 1/3 liter of petrol.

DO YOU KNOW?
It takes about $9 \times 10^9 J$ **to make a car** & the car then use about 1×10^{12} J of energy from petrol in its life time.

There is more energy reaching earth in 10 days of sunlight then in all the fossil fuel on the earth.

KINETIC ENERGY:

"Energy possessed by a body due to its motion is called kinetic energy."



➢ Kinetic energy cannot be negative.

In terms of mass and velocity K.E is given as

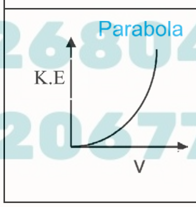
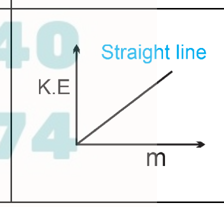
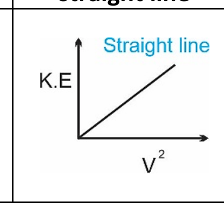
$$K.E = \frac{1}{2}mv^2$$

- **K.E depends upon mass and velocity of the body.**

THREE CASES:

If two moving bodies have same mass	$K.E \propto v^2$	جس body کی speed زیادہ ہو گی اس کی K.E بھی زیادہ ہو گی۔
If two moving bodies have same speed	$K.E \propto m$	جس body کا mass زیادہ ہو گا اس کی K.E بھی زیادہ ہو گی۔
If two moving bodies have same K.E	$v^2 \propto \frac{1}{m}$	جس body کا mass زیادہ ہو گا اس کی speed کم ہو گی۔

GRAPHS:

Graph between K.E and velocity is **parabola**	Graph between K.E and mass is **straight line**	Graph between K.E and square of velocity is **straight line**
		

If velocity vector is given, then K.E is given as

$$K.E = \frac{1}{2}m(\vec{v}.\vec{v})$$

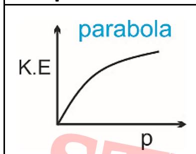
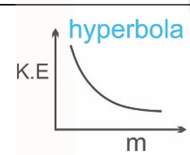
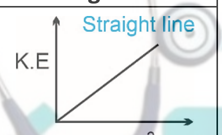
In terms of mass and momentum K.E is given as

$$K.E = \frac{p^2}{2m}$$

THREE CASES:

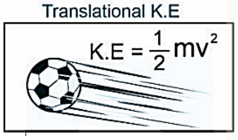
If two moving bodies have **same mass**	$K.E \propto p^2$	جس body کا momentum زیادہ ہو گا اس کی K.E بھی زیادہ ہو گی۔
If two moving bodies have **same momentum**	$K.E \propto \frac{1}{m}$	جس body کا mass زیادہ ہو گا اس کی K.E کم ہو گی۔
If two moving bodies have **same K.E**	$p^2 \propto m$	جس body کا mass زیادہ ہو گا اس کا momentum بھی زیادہ ہو گا۔

GRAPHS:

Graph between K.E and momentum is **parabola**	Graph between K.E and mass is **hyperbola**	Graph between K.E and square of momentum is **straight line**
 m = constant	 p = constant	 m = constant

TYPES OF K.E

Translational K.E



Rotational K.E

Vibrational K.E

POTENTIAL ENERGY:

"Energy possessed by a body due to its position in the force field or due to its constrained state(حالت مجبور)."

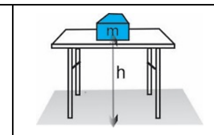
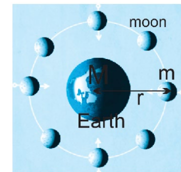
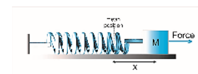
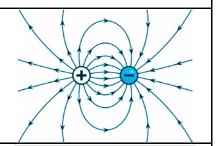
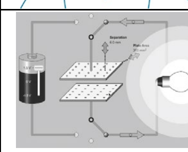
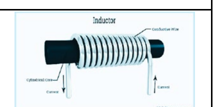
جب بھی کوئی BODY کسی ایسے FIELD میں پڑی ہو جو FORCE لگائے یا BODY ایسی حالت میں ہو جس میں BODY رہنا نہیں چاہتی لیکن اسکو مجبور کر کے رکھا جائے تو اس کے اندر P.E موجود ہو گی۔

- Gravitational field, electric field and magnetic field are force fields.

A mass placed in gravitational field possess gravitational P.E.	A charge placed in electric field possess electrical P.E.	A magnet placed in magnetic field possess magnetic P.E

- P.E is always determined relative to some reference point where P.E is taken zero.
- Reference point can be chosen anywhere.

TYPES OF POTENTIAL ENERGY

Gravitational P.E (if surface of earth is taken as a reference point)	$P.E = mgh$	
Absolute gravitational P.E (if reference point is taken at infinity where force of gravity is zero)	$P.E = -\frac{GMm}{r}$	
Elastic potential energy Energy stored in compressed or stretched spring is called elastic P.E.	$P.E = \frac{1}{2}kx^2$	
Electrical P.E between two point charges	$P.E = \frac{kq_1q_2}{r}$	
Electrical P.E stored in capacitor	$P.E = \frac{1}{2}CV^2$	
Magnetic P.E stored in an Inductor	$P.E = \frac{1}{2}LI^2$	

- **P.E may be positive, negative or zero.**

P.E due to force of attraction is taken negative.

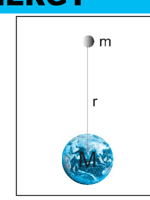
- If attraction increases P.E decreases.
- If attraction decreases P.E increases

P.E due to force of repulsion is taken positive.

- If repulsion increases P.E also increases.
- If repulsion decreases P.E also decreases.

ABSOLUTE POTENTIAL ENERGY

"Absolute P.E at any point is defined as work done by gravitational field in moving the object from that point to infinity where force of gravity becomes zero."



- Absolute P.E at any distance r from the center of earth is given as

$$P.E = -\frac{GMm}{r}$$

- Absolute P.E is always negative.

یاد رکھیں:
P.E جتنی زیادہ negative ہو گی اتنی زیادہ low ہو گی۔

- Absolute P.E on the surface of earth is given as

$$P.E = -\frac{GMm}{R}$$

- Absolute P.E at any height h from the surface of earth is given as

$$P.E = -\frac{GMm}{R+h}$$

- By increasing the height absolute P.E increases
- Absolute P.E **at the center** of earth is zero.
- Absolute P.E at infinity is zero.

> **Gravitational potential** is defined as gravitational P.E per unit mass.
> $$G.potential = \frac{P.E}{m} = \frac{-GM}{r}$$

WORK ENERGY PRINCIPLE

Work done on a body is equal to change in its energy.

$$W = \Delta K.E + \Delta P.E$$

If work is +ve	If work is -ve	If work is zero
Total energy increases	Total energy decreases	Total energy remains constant or conserved.

CASE 1:

If P.E of the body remains constant and **change in P.E is zero**, then work done is only equal to change in K.E.

$$W = \Delta K.E$$

$$Fd = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

- If **work** done on the body is **positive**, then its K.E increases.
- If **work** done on the body is **negative**, then its K.E decreases.
- If **work** done on the body is **zero**, then its K.E remains constant.

If body is accelerated from rest then $v_i = 0$	If body is brought to rest $v_f = 0$
$Fd = \frac{1}{2}mv_f^2$	$Fd = -\frac{1}{2}mv_i^2$

CASE 2:

If K.E of the body remains constant and **change in K.E is zero**, then work done is only equal to change in P.E.

$$W = \Delta P.E$$

$$W = mgh_2 - mgh_1$$

- If **work** done on the body is **positive**, then its P.E increases.
- If **work** done on the body is **negative**, then its P.E decreases.
- If **work** done on the body is **zero**, then its P.E remains constant.

> **Note:**
> Work done in conservative field = change in P.E

EXAMPLE: If 1000N force is required to stop a car moving with velocity $10ms^{-1}$ then the force required to stop the car in same distance when it is moving with velocity $20ms^{-1}$ will be

(a) 500N (b) 1000N
(c) 2000N **(d) 4000N**

SOLUTION:

Final velocity is zero. So $Fd = -\frac{1}{2}mv_i^2$

As mass and distance remains same so $F \propto v^2$.

If velocity is doubled, force will become four times

$$(F' = 4 \times 1000 = 4000N)$$

EXAMPLE: What is force required to accelerate an object of mass 1kg from rest to a velocity $4ms^{-1}$ in a distance 10m

(a) 0.4 N **(b) 0.8 N** (c) 4 N (d) 8 N

SOLUTION:

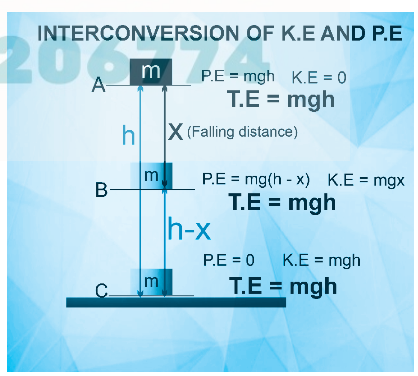
As body accelerate from rest, so initial velocity is zero.

$$Fd = \frac{1}{2}mv_f^2 \Rightarrow F \times 10 = \frac{1}{2} \times 1(4)^2 \Rightarrow F = 0.8N$$

INTERCONVERSION OF K.E AND P.E

IN ABSENCE OF AIR FRICTION:

If a body of mass m falls under the action of gravity from a height h as shown in the figure.



Loss in P.E is equal to gain in K.E.
Total energy always remains constant.

AFTER FALLING DOWNWARD DISTANCE X:

- Loss in $P.E = mgx$
- $\% \, loss \, in \, P.E = \frac{x}{h} \times 100$
- $Gain \, in \, K.E = mgx$
- $\% \, Gain \, in \, K.E = \frac{x}{h} \times 100$

- Gain in speed/velocity = $\sqrt{2gx}$

یاد رکھیں: یہاں x سے مراد falling-body کا vertical-distance ہے

اگر کوئی باڈی h_1 اونچائی سے گرے تو h_2 پر

$X = h_1 - h_2$

VELOCITY OF OBJECT FALLING UNDER GRAVITY:

$$\text{Gain in K.E} = \text{loss in P.E}$$

$$\frac{1}{2}m(v_2^2 - v_1^2) = mg(h_1 - h_2)$$

- If at height h_1 body is moving with velocity v_1 then at height h_2 velocity of the body will be

$$v_2 = \sqrt{2g(h_1 - h_2) + v_1^2}$$

- If body falls from rest then $v_1 = 0$

$$v_2 = \sqrt{2g(h_1 - h_2)}$$

Velocity of falling body only depends upon vertical distance OR initial and final height.

$$v \propto \sqrt{(h_1 - h_2)}$$

$$v \propto \sqrt{\text{vertical distance}}$$

Velocity is independent of mass of the body, weight of the body and path followed by body.

- If body reaches the ground then $h_1 = 0$

$$v = \sqrt{2gh} \qquad v \propto \sqrt{h}$$

EXAMPLE:

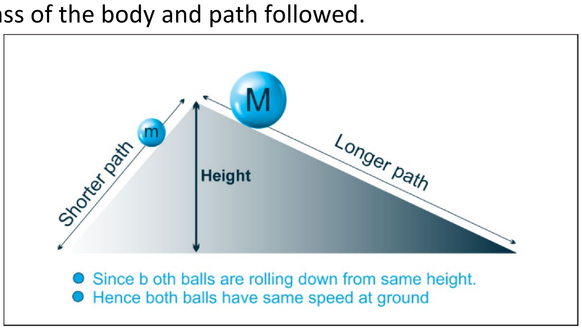
Two balls of different masses roll down from a frictionless plane as shown in the figure below then which balls is moving faster at the ground

(a) bigger ball **(c)** both are moving with same speed

(b) smaller ball (d) depend upon path length

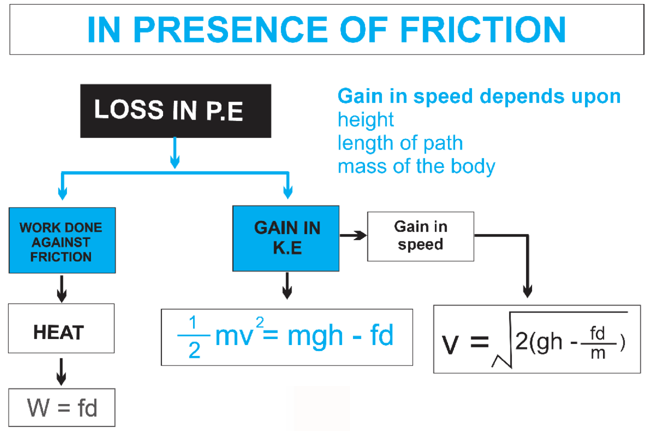
SOLUTION: As $v = \sqrt{2gh}$

Velocity only depends upon height and is independent of mass of the body and path followed.



IN PRESENCE OF FRICTION:

If body is moving downward, then



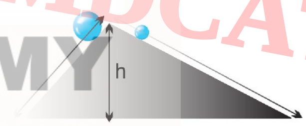
Loss in P.E = Gain in K.E + Work done against the friction

$$mgh = \frac{1}{2}mv^2 + fd$$

- Gain in speed: $v = \sqrt{2\left(gh - \frac{fd}{m}\right)}$
- Larger the mass, greater the speed.
- Larger the path length , smaller the speed.
- Larger the friction, smaller the speed.

EXAMPLE:

Two balls of different masses roll down from a rough plane as shown in the figure below then which balls is moving faster



(a) bigger ball (c) both are moving with same speed

(b) smaller ball (d) depend upon path length

SOLUTION:

Rough plane means friction is present and in presence of friction

- Larger the mass, greater the speed.
- smaller the path , larger the speed

If body is thrown upward then

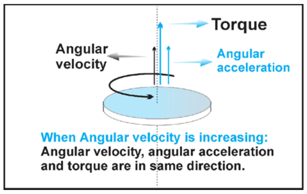
Loss in K.E = Gain in P.E + Work done against the friction

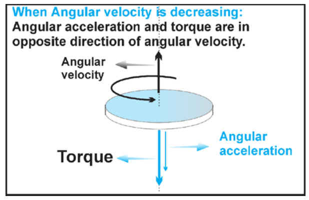
$$\frac{1}{2}mv^2 = mgh + fd$$

LAW OF CONSERVATION OF ENERGY:

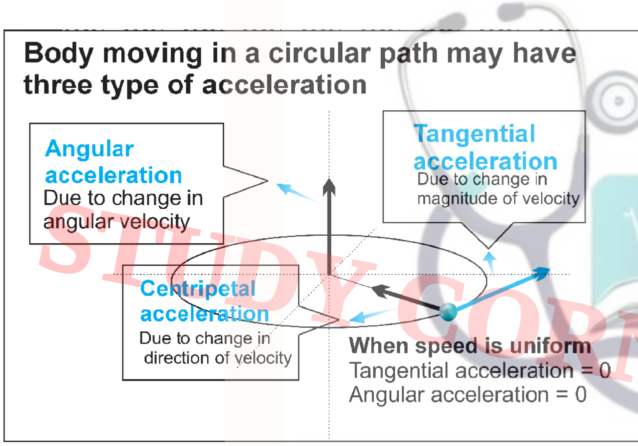
Energy cannot be destroyed. It can be transformed from one kind to another but total amount of energy always remains constant.

- Average and instantaneous angular acceleration are equal. ($\alpha_{ins} = \alpha_{av}$)





- **If angular velocity is increasing,** then angular acceleration is positive and parallel to angular velocity.
- **If angular velocity is decreasing,** then angular acceleration is negative and opposite to angular velocity.
- **If angular velocity is constant,** then angular acceleration is zero.



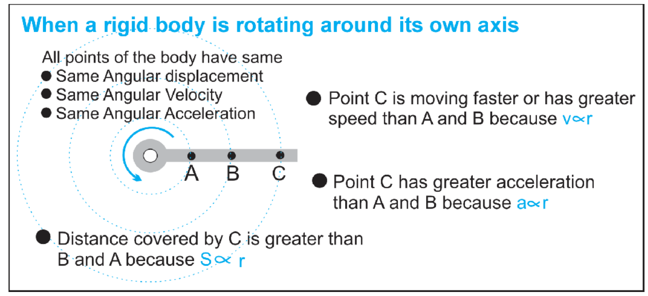
Tangential acceleration, angular acceleration and centripetal acceleration **are always mutually perpendicular**.

RELATION BETWEEN LINEAR AND ANGULAR VARIABLES

Quantities	Relation	In vector form
Linear and angular displacement	$S = r\theta$	$\vec{S} = \vec{\theta} \times \vec{r}$
Linear and angular velocity	$v_t = r\omega$	$\vec{v}_t = \vec{\omega} \times \vec{r}$
Linear and angular acceleration	$a_t = r\alpha$	$\vec{a}_t = \vec{\alpha} \times \vec{r}$

- $\vec{v}_t, \vec{r}$ *and* $\vec{\omega}$ are always perpendicular to each other.
- $\vec{a}_t, \vec{r}$ *and* $\vec{\alpha}$ are always perpendicular to each other.

جب بھی دو VECTORS کے درمیان CROSS-PRODUCT ہو تو ان سے بننے والا VECTOR ہمیشہ ان دونوں کے PERPENDICULAR ہو گا۔



EQUATIONS OF MOTION FOR ANGULAR MOTION

1ST EQUATION:	$\omega_f = \omega_i + \alpha t$	اگر angular–displacement نہ دیا گیا ہو تو باقی کوئی بھی quantity معلوم کرنے کے لیے 1st –equation استعمال کریں
2ND EQUATION:	$\theta = \omega_i t + \frac{1}{2}\alpha t^2$	اگر Final– angular–velocity نہ دی گئی ہو تو باقی کوئی بھی quantity معلوم کرنے کے لیے 2nd – equation استعمال کریں ۔
3RD EQUATION:	$2\alpha\theta = \omega_f^2 + \omega_i^2$	اگر time نہ دیا گیا ہو تو باقی کوئی بھی quantity معلوم کرنے کے لیے 3rd – equation استعمال کریں

LIMITATIONS:

These equations are applicable only if

- Angular acceleration α is uniform.
- Axis of rotation **does not change**.

QUANTITY IN LINEAR MOTION	ANALOGOUS QUANTITY IN ANGULAR MOTION	REPLACEMENT
Displacement	Angular Displacement	S by θ
Velocity	Angular Velocity	v by ω
Acceleration	Angular Acceleration	a by α
Mass (inertia)	Moment of inertia	m by I
Force	Torque	F by τ
Momentum	Angular Momentum	p by L
Kinetic energy	Rotational Kinetic energy	K.E by K.Erot

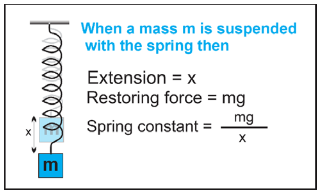
اوپر TABLE میں دی گئی REPLACEMENTS کی مدد سے ہم کسی بھی LINEAR-MOTION والے FORMULA سے ANGULAR-MOTION کے لیے FORMULA معلوم کر سکتے ہیں۔

SOLUTION:

$$k = \frac{F}{x} = \frac{mg}{x}$$

$$= \frac{5 \times 10}{2 \times 10^{-2}}$$

$$= 2500 \text{ Nm}^{-1}$$



SERIES COMBINATION OF SPRINGS:

If **springs are connected end to end** this combination is known as series combination.

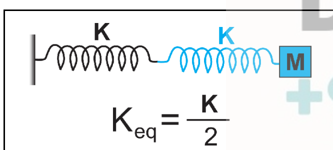
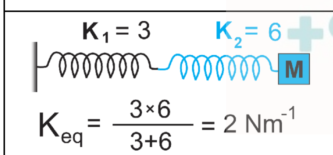
SHORT TRICKS:

EQUIVELENT CONSTANT	SITUATIONS
$K_{eq} = \frac{K}{n}$	اگر n سپرنگ same-value والے series میں لگے ہوں تو Keq معلوم کرنے کے لیے تعداد پر divide کریں۔
$K_{eq} = \frac{K_1K_2}{K_1+K_2} = \frac{Product}{sum}$	اگر دو سپرنگ different-value والے series میں لگے ہوں تو
$\frac{1}{K_{eq}} = \frac{1}{K_1} + \frac{1}{K_2} + \frac{1}{K_3} + \cdots$	اگر دو سے زیادہ سپرنگ different-value والے series میں لگے ہوں تو

- To decrease spring constant springs are connected in series. **OR** when springs are connected in series, spring constant always decreases.
- In series combination **equivalent spring constant is always less than minimum value.**

$$K_{eq} < K_{min}$$

EXAMPLES:

	کیونکہ دونوں springs کی value برابر ہو اس لیے Kکو 2 پر divide کریں گے۔
	کیونکہ دونوں springs کی value برابرنہیں ہیں اس لیے اوپر دونوں کا product اور نیچے دونوں کا sum کریں گے۔

PARALLEL COMBINATION OF SPRINGS:

If **springs are connected side by side**, then this combination is known as parallel combination.

ہر springکا ایک end سپورٹ کے ساتھ اور دوسرا end ماس کے ساتھ جڑا ہو۔

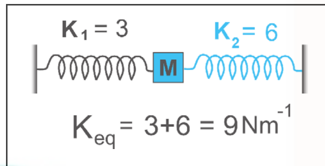
- To increase spring constant springs are connected in parallel. **OR** when springs are connected in parallel, spring constant always increases.
- In parallel combination **equivalent spring constant is always greater than maximum value.**

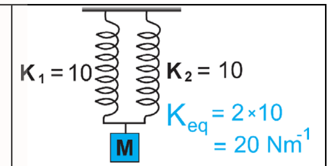
$$K_{eq} > K_{max}$$

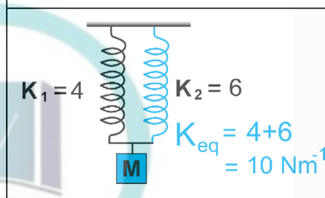
SHORT TRICKS:

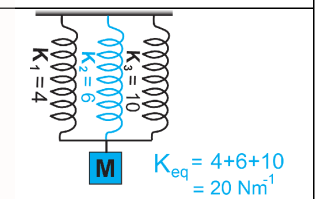
EQUIVELENT CONSTANT	SITUATIONS
$K_{eq} = nK$	اگر n سپرنگ same-value والے parallel میں لگے ہوں تو Keq معلوم کرنے کے لیے تعداد سے multiply کریں۔
$K_{eq} = K_1 + K_2 + \cdots + K_n$	اگر دو سے زیادہ سپرنگ different-value والے parallel میں لگے ہوں تو

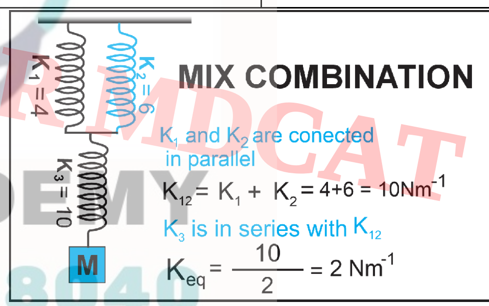
EXAMPLES:









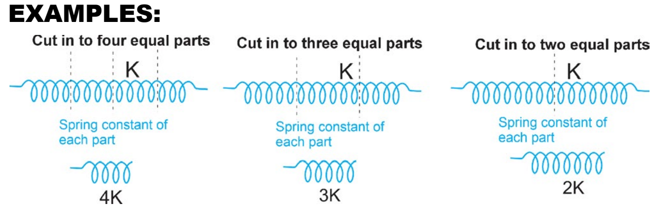


IF SPRING IS CUT INTO PARTS:

If a spring of spring constant K is cut into 'n' equal parts then spring constant of each part will be 'nK'

Cutکرنے سے spring کی length جتنے گنا کم ہو گی K کی value اتنے گنا زیادہ ہو جائے گی۔

EXAMPLES:

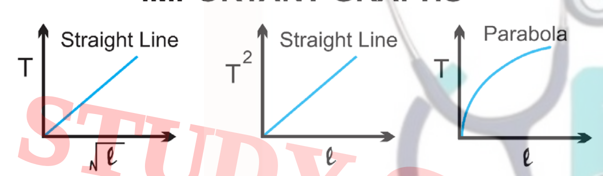


EXAMPLES: If spring is cut into two parts having length in the ratio 1:2 then the ratio between spring constants of the parts will be.

a) 1:2 ✓b) 2:1 c) 1:4 d) 4:1

TIME PERIOD	FREQUENCY
$T = 2\pi\sqrt{\frac{\ell}{g}}$ $T \propto \sqrt{\ell}$ and $T \propto \frac{1}{\sqrt{g}}$ **DEPENDENCE:** **(i)** Time period only depends upon length of pendulum and acceleration due to gravity. **(ii)** It is independent of amplitude and mass of the bob.	$f = \frac{1}{2\pi}\sqrt{\frac{g}{\ell}}$ $f \propto \sqrt{g}$ and $f \propto \frac{1}{\sqrt{\ell}}$ **DEPENDENCE:** **(i)** Frequency only depends upon length of pendulum and acceleration due to gravity. **(ii)** It is independent of amplitude and mass of the bob.

IMPORTANT GRAPHS



NOTE:

Length of pendulum varies in two ways.

- When temperature changes
- When position of center of gravity changes.

SECOND PENDULUM:

A pendulum whose time period is two seconds is called second pendulum.

- $T = 2sec$
- $\omega = 2\pi\ rads^{-1}$
- $f = 0.5\ Hz$
- $\ell = 99.3\ cm$

(when $g = 9.8ms^{-2}$)

PENDULUM CLOCK

Time period of pendulum clock is two seconds. It takes one second from one extreme position to other.

EXAMPLE1:

If time period of second pendulum on surface of earth is two seconds. Then time period of second pendulum on surface of moon will be

(a) 2sec (b) $2\sqrt{6}$ sec (c)$2/\sqrt{6}$ sec (d)infinity

SOLUTION: Two second

کسی بھی جگہ second pendulum کا ٹائم پریڈ پوچھا جائے تو وہ ہمیشہ 2 sec ہوگا ۔

EXAMPLE2:

The time period of a pendulum on earth is two seconds if it is shifted to moon, then its time period will be

(value of $g_{moon} = \frac{g_{earth}}{6}$)

(a) 2sec (b) $2\sqrt{6}$ sec (c)$2/\sqrt{6}$ sec (d)infinity

SOLUTION:

$$T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow T \propto \frac{1}{\sqrt{g}}$$

As $g' = \frac{g}{6} \Rightarrow T' = \sqrt{6}\,T = 2\sqrt{6}\,s$

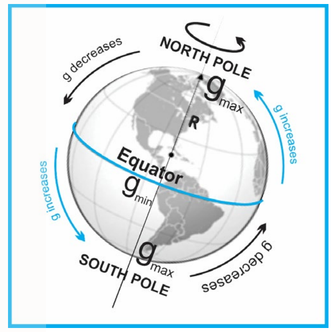
اگر pendulum کو کسی ایسی جگہ shift کیا جائے جہاں 'g' کی ویلیو مختلف ہو تو اس pendulum کا ٹائم پریڈ بھی change ہو جائے گا

VARIATION IN VALUE OF 'g'

ON SURFACE OF EARTH

Expression for 'g' on the surface of earth is

$$g = \frac{GM}{R^2}$$

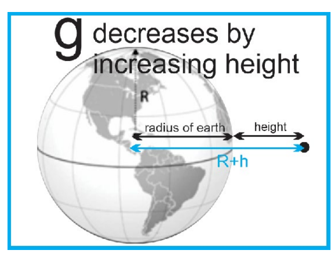


At north and south poles	g_{max} Because distance from center of earth is minimum	No effect of rotation of earth
At equator	g_{min} Because distance from center of earth is maximum	g varies inversely with rotation of earth
Moving from equator to poles	g increases	g varies inversely with rotation of earth
Moving from poles to equator	g decreases	g varies inversely with rotation of earth

ABOVE THE SURFACE OF EARTH

At height h value of 'g' is given as

$$g' = \frac{GM}{(R+h)^2}$$



NOTE:

If speed becomes n-times then absolute temperature will become n^2 times ($T' = n^2T$)

Speed of sound in humidity air is greater in dry air.

Humidity بڑھنے سے Air کی Density کم ہو جاتی ہے جس کی وجہ سے sound کی speed زیادہ ہو جاتی ہے۔

SPEED OF SOUND AT ANY TEMPERATURE t (°C)

$$v_t = v_o + 0.61t$$

if $t \ll 273$

کسی بھی 'Degree Celsius temperature' پر 'speed' کو معلوم کرنے کے لیے اس فارمولے کو استعمال کریں۔

EXAMPLE:

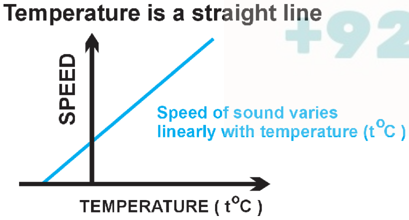
TEMPERATURE	SPEED OF SOUND
10 °C	$332 + 0.61 \times 10 = 338\ ms^{-1}$
20 °C	$332 + 0.61 \times 20 = 344\ ms^{-1}$
30 °C	$332 + 0.61 \times 30 = 350\ ms^{-1}$

With one degree or one Kelvin rise in temperature speed of sound increases by 0.61 m/s or 61 cm/s.

EXAMPLE:

INCREASE IN TEMPERATURE	SPEED OF SOUND ICREASES BY
1 °C	$0.61 \times 1 = 0.61\ ms^{-1}$
2 °C	$0.61 \times 2 = 1.22\ ms^{-1}$
3 °C	$0.61 \times 3 = 1.83\ ms^{-1}$

The graph between speed and celsius Temperature is a straight line

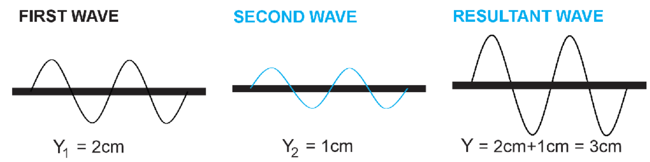


PRINCIPLE OF SUPERPOSITION

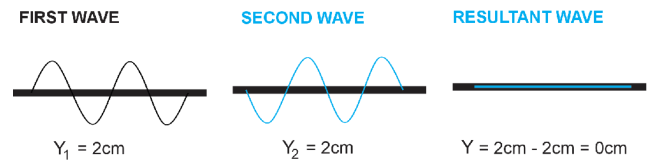
If two or more waves are simultaneously acted on medium particle, then resultant displacement of particle is algebraic sum of their individual displacements.

$$Y = Y_1 + Y_2 + \cdots \ldots . + Y_n$$

EXAMPLE:1



EXAMPLE:2



THREE CASES:

PHENOMENON	SUPPERPOSITION OF TWO WAVES
INTERFERENCE	Having **same frequency** and travelling in same direction
BEATS	Having slightly **different frequencies** but travelling in same direction
STATIONARY WAVES	Having **same frequency** but travelling in opposite direction

INTERFERENCE

Superposition of two waves of same frequency and travelling in same direction results a phenomenon called interference.

جب دو ویوز Interfere کرتی ہیں تو کچھ جگہ پر permanent maxima اور کچھ جگہ پر permanent minima بن جاتے ہیں۔

CONDITION:

- Two waves must have same frequency.
- Two waves must have same direction.
- Two waves must be coherent.

COHERENT SOURCES:

Coherent sources are two or more wave sources that emit waves with a constant phase difference and the same frequency.

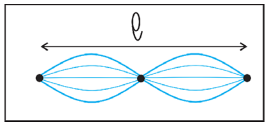
TYPES OF INTERFERENCE

- **CONSTRUCTIVE INTERFERENCE:** When two waves are in phase, their amplitudes add up, producing a wave with a larger amplitude.
- **DESTRUCTIVE INTERFERENCE:** When two waves are out of phase, their amplitudes subtract, potentially canceling each other out.

Frequency is inversely proportional to square root of mass per unit length.(**Law of mass**)	$f \propto \frac{1}{\sqrt{m}}$

2nd - MODE OF VIBRATION:

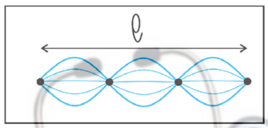
If a string is plucked from length $\frac{\ell}{4}$ it vibrates in two loops.



- Number of loops formed = 2
- Number of nodes formed = 3
- Number of Anti-nodes formed = 2
- String vibrates with wavelength i.e. $\lambda_2 = \frac{\lambda_1}{2} = \ell$
- String vibrates with frequency $f_2 = 2f_1$

3rd - MODE OF VIBRATION:

If a string is plucked from length $\frac{\ell}{6}$ it vibrates in two loops.



- Number of loops formed = 3
- Number of nodes formed = 4
- Number of Anti-nodes formed = 3
- String vibrates with wavelength i.e. $\lambda_3 = \frac{\lambda_1}{3} = \frac{2\ell}{3}$
- String vibrates with frequency $f_3 = 3f_1$

HARMONICS:

Such oscillations in which each frequency is integral multiple of fundamental frequency are called harmonics.

EXAMPLES:

Frequency of 1st harmonic = f_1

Frequency of 2nd harmonic = $2f_1$

Frequency of 3rd harmonic = $3f_1$

HARMONIC SERIES:

Stationary waves in string can have discrete set of frequencies $f_1, 2f_1, 3f_1, 4f_1 ...$ and wavelength $\lambda_1, \frac{\lambda_1}{2}, \frac{\lambda_1}{3}, \frac{\lambda_1}{4}$ ... known as harmonic series.

'HARMONIC SERIES' میں ہر دو 'CONSECUTIVE
'FREQUENCIES' کا difference لیں تو f_1 کے برابر ہوگا۔

OTHER FREQUNCIES:

Frequencies other than harmonics are damped out quickly.

EXAMPLE: If fundamental frequency is 20Hz then which of the following frequency waves cannot be produced in stretched string.

(a) 40 Hz (b) 60 Hz (c) 70 Hz (d) 80 Hz

SOLUTION:

70 Hz is not integral multiple of 20 Hz.

nth-HARMONIC:

- String is plucked from = $\frac{\ell}{2n}$
- Number of loops formed = n
- Number of nodes formed = $n + 1$
- Number of antinodes formed = n

Frequency:

$$f_n = nf_1 \quad or \quad f_n = \frac{nv}{2\ell} \quad or \quad f_n = \frac{n}{2\ell}\sqrt{\frac{F}{m}}$$

Where n= 1,2,3, ...

Wavelength:

$$\lambda_n = \frac{\lambda_1}{n} \quad or \quad \lambda_n = \frac{2\ell}{n}$$

String میں loops کی تعداد بڑھنے سے فریکونسی بڑھتی ہے اور wavelength کم ہوتی ہے۔
لیکن فریکونسی اور wavelength کا product ہمیشہ speed کے برابر رہے گا۔

OVER TONES:

An overtone is any frequency among harmonic series that is greater than fundamental frequency.

EXAMPLES:

Frequency of 1st overtone = $2f_1$

Frequency of 2nd overtone = $3f_1$

Frequency of 3rd overtone = $4f_1$

FREQUENCY	f_1	$2f_1$	$3f_1$	$4f_1$	$5f_1$
MODE OF VIBRATION	First	Second	Third	Fourth	Fifth
HARMONIC	First	Second	Third	Fourth	Fifth
OVER TONE	Fundamental tone	First	Second	Third	Fourth

EXAMPLE: If frequency of 5th over tone is 60 Hz then frequency 2nd harmonic will be

(a) 10 Hz (b) 20 Hz (c) 25 Hz (d) 30 Hz

SOLUTION:

5th over tone = $6f_1 = 60$

$$\Rightarrow f_1 = 10\ Hz$$

Frequency 2nd harmonic = $2f_1 = 20\ Hz$

کوئی ایک 'harmonic frequency' دی ہو تو سب سے پہلے f_1 معلوم کریں پھر جو
مرضی 'harmonic frequency' معلوم کر سکتے ہیں

EXAMPLE:

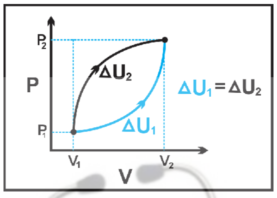
GAS	INTERNAL ENERGY	
MONOATOMIC	$U = \frac{3}{2}nRT$	$U = \frac{3}{2}NkT$
DIATOMIC	$U = \frac{5}{2}nRT$	$U = \frac{5}{2}NkT$
POLYATOMIC	$U = 3nRT$	$U = 3NkT$

STATE FUNCTION:

A function which only depends upon initial and final states and independent of path followed is called state function.

If a system changes state (P_1, V_1) to (P_2, V_2) along two different path as shown in figure then $\Delta U_1 = \Delta U_2$

Change in internal energy is a state function.



Temperature, pressure, volume, internal energy, entropy etc. all are thermodynamic state functions or variables.

- Work and heat are not state function.

WORK DONE AT CONSTANT PRESSURE:

Work done at constant pressure P is given as

$$Work = (pressure)(change\ in\ volume)$$

$$W = P\Delta V \text{ or } W = P(V_f - V_i)$$

- Work done by the system (expansion) is taken positive.
- Work done on the system (compression) is taken negative.

EXAMPLE:

If volume V of gas increased by 200% at pressure P then the work done by the system is

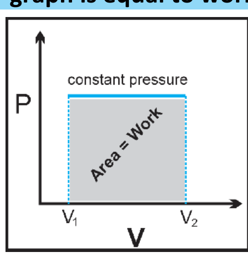
(a) PV (b) $2PV$ (c) $3PV$ (d) $4PV$

SOLUTION:

$$V_f = V + \frac{200V}{100} = 3V$$

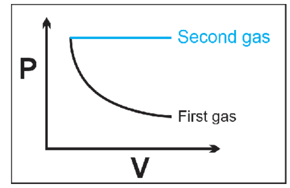
$$W = P(V_f - V_i) = P(3V - V) = 2PV$$

Area under $\mathbf{P-V}$ graph is equal to work done.



EXAMPLE:

If W_1 is work done on 1st gas and W_2 is work done on 2nd gas as shown in P-V diagram, then which of the following is true.



(a) $W_1 = W_2$ (b) $W_1 < W_2$

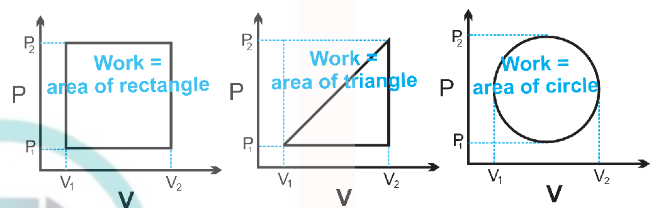
(c) $W_1 > W_2$ (d) $W_2 > W_1$ and $W_1 = 0$

SOLUTION: $W_1 < W_2$

جس گراف کے نیچے area زیادہ ہو گا اس case میں work بھی زیادہ ہو گا۔

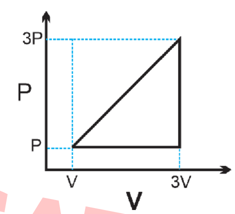
IN CASE OF CUCLIC PROCESS:

Work done is equal to area inside the cycle.



EXAMPLE:

A system undergoes a cycle process as shown in the figure below then work done will be



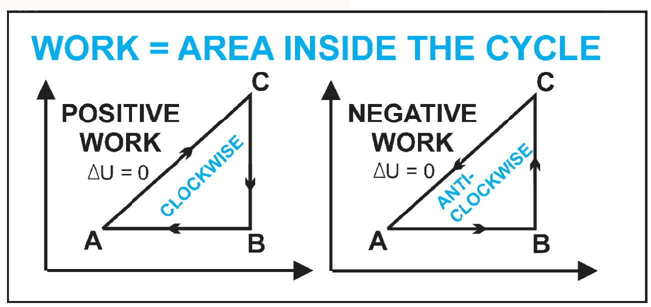
(a) PV (b) $2PV$ (c) $3PV$ (d) $4PV$

SOLUTION:

$$W = Area\ of\ triangle$$

$$= \frac{1}{2}(3P - P)(3V - V) = \frac{1}{2}(2P)(2V) = 2PV$$

‘CYCLIC PROCESS’ میں WORK DONE معلوم کرنے کیلئے CYCLE کے اندر والا AREA معلوم کریں



(مطلب جو MECHANICAL ENERGY ہم دیں گے وہ HEAT کی شکل میں خارج ہو گی)

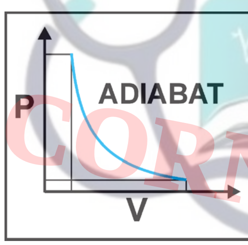
ADIABATIC PROCESS

A process in which no heat enters or leaves from the system $Q = 0$.

TEMPERATURE	May increase or decrease
INTERNAL ENERGY	May increase or decrease
CHANGE IN INTERNAL ENERGY	Positive or negative ($\Delta U \neq 0$)
BOYLE'S LAW	Not Valid
P-V RELATION	$PV^{\gamma} = constant$
1st LAW TAKES FORM	$W = -\Delta U$
ENERGY CONVERSION	Internal energy into work **OR** Work into Internal energy.
BULK MODULUS OF GAS	$(E = \gamma P)$
CURVE REPRESENTING THE ADIABATIC PROCESS	Adiabat

- Adiabat is γ times steeper than isotherm.

$$Slope = \frac{-\gamma P}{V}$$

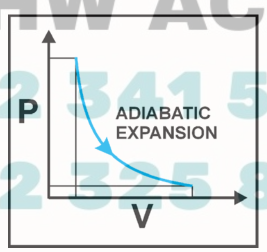


ADIABATIC EXPANSION:

- $Q = 0$
- Work done is positive.
- Internal energy is converted into work.

$$W = -\Delta U$$

(مطلب گیس جتنا WORK کرے گی اتنی اس کی INTERNAL ENERGY کم ہو جائے گی)



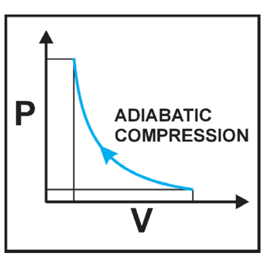
- Internal energy decreases so temperature decreases.
- **Adiabatic expansion cause cooling.**

ADIABATIC COMPRESSION:

- $Q = 0$
- Work done is negative.
- Work is converted into Internal energy.

$$\Delta U = -W$$

(مطلب جتنا WORK کریں گے اتنی INTERNAL ENERGY بڑھ جائے گی)



- Internal energy increases so temperature increases.
- **Adiabatic compression cause heating.**

EXAMPLES:

i. Compressions and rarefactions of air through which sound waves are passing.
ii. Rapid escape of air from burst tyre.
iii. Cloud formation.

Mostly process which are carried out rapidly are adiabatic.

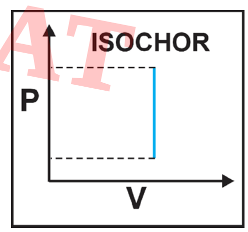
ISOCHORIC PROCESS (ISOMETRIC PROCESS):

A process which is carried out at constant volume is called isochoric process $(\Delta V = 0)$.

TEMPERATURE	May increase or decrease
INTERNAL ENERGY	May increase or decrease
CHANGE IN INTERNAL ENERGY	Positive or negative ($\Delta U \neq 0$)
BOYLE'S LAW	Not Valid
P-V RELATION	$V = constant$
1st LAW TAKES FORM	$W = 0$ **AND** $Q = \Delta U$
ENERGY CONVERSION	Internal energy into heat OR Heat into Internal energy.
BULK MODULUS OF GAS	$(E = \infty)$
CURVE REPRESENTING THE ISOCHORIC PROCESS	Isochor

- The P-V graph for isochoric process is a vertical straight line.

$$Slope = \infty$$



If heat is added to system	Internal energy increases, thus temperature increases
If heat is removed from system	Internal energy decreases, thus temperature decreases.

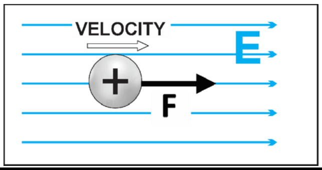
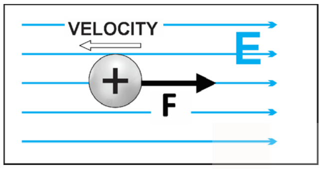
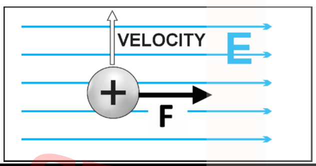
EXAMPLE: Pressure cooker is an example of isochoric process in which volume is kept constant so $W = 0$ and heat added is entirely converted into internal energy.

ISOBARIC PROCESS:

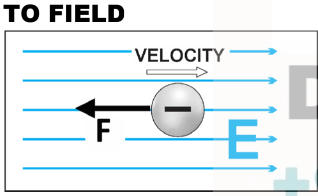
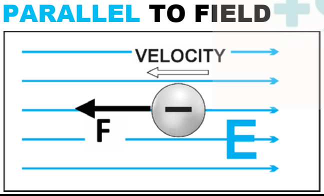
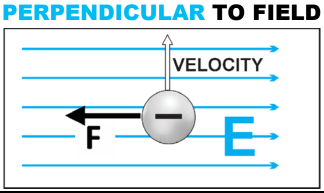
A process carried out at constant pressure is called isobaric process.

TEMPERATURE	May increase or decrease

MOTION OF POSITIVE CHARGE IN ELECTRIC FIELD

VELOCITY IS PARALLEL TO FIELD 	• **Work** is done is positive • Electric field accelerate the charge • **Speed and K.E** increases but **P.E** decreases.
VELOCITY IS ANTI-PARALLEL TO FIELD 	• **Work** is done is negative. • Electric field decelerate the charge • **Speed** and **K.E** decreases but P.E increases.
VELOCITY IS PERPENDICULAR TO FIELD 	• Work is done is zero • Electric field only deflect the charge. (changes direction) • Speed, K.E and P.E remains same.

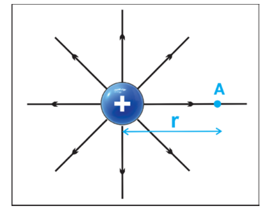
MOTION OF NEGATIVE CHARGE IN ELECTRIC FIELD

VELOCITY IS PARALLEL TO FIELD 	• Work is done is negative • Electric field decelerate the charge • Speed and K.E decreases but P.E increases.
VELOCITY IS ANTI-PARALLEL TO FIELD 	• Work is done is positive • Electric field accelerate the charge • Speed and K.E increases but P.E decreases.
VELOCITY IS PERPENDICULAR TO FIELD 	• Work is done is zero • Electric field only deflect the charge. (changes direction) • Speed, K.E and P.E remains same.

ELECTRIC FIELD INTENSITY DUE TO POINT CHARGERGE:

Electric field intensity due to point charge at any distance r is given as

$$E = \frac{Kq}{r^2}$$

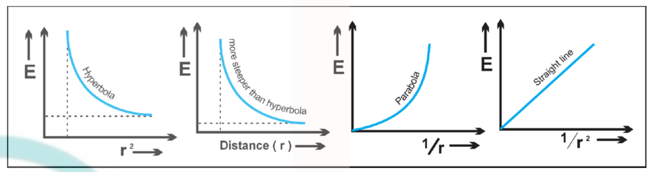


DEPENDENCE:

It only depends upon

- Charge. $E \propto q$
- Distance from the charge. $E \propto \frac{1}{r^2}$
- Nature of the Dielectric Medium. $E \propto \frac{1}{\epsilon_r}$

GRAPHS:



IN VECTOR FORM:

$$\vec{E} = \frac{kq}{r^2}\hat{r} \quad \text{or} \quad \vec{E} = \frac{kq}{r^3}\vec{r}$$

EFFECT OF MEDIUM:

Presence of **dielectric medium** always reduces the electric field intensity by factor ϵ_r times. $(E_{med} < E_{vac})$

$$E_{med} = \frac{E_{vac}}{\epsilon_r}$$

(اگر کوئی دو Quantities معلوم ہوں تو
اس relation سے تیسری کو معلوم کریں)

$$E_{med} = \frac{1}{4\pi\epsilon_o\epsilon_r}\frac{q}{r^2}$$

ELECTRIC FLUX DENSITY:

Electric field intensity is also known as electric flux density

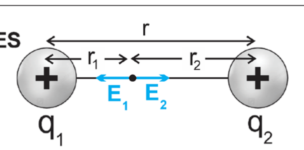
Electric flux per unit perpendicular area is called electric flux density.

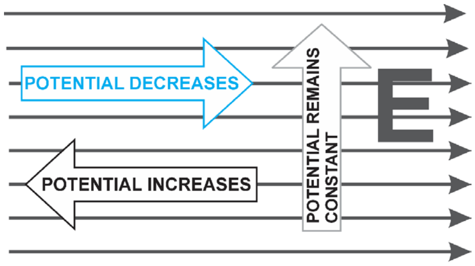
$$E = \frac{\emptyset_e}{A_\perp}$$

ZERO FIELD LOCATION:

Let $(q_1 < q_2)$

IN CASE OF SIMILAR CHARGES ZERO FIELD LOCATION LIES INSIDE NEAR THE SMALLER CHARGE

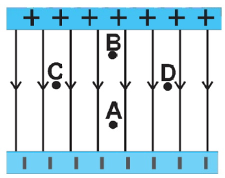




- If electric field is constant it means that electric potential is changing at constant rate in this region.

EXAMPLE:

Potential difference between two oppositely charged parallel plates is 12V as shown in the figure then which of the following is true:

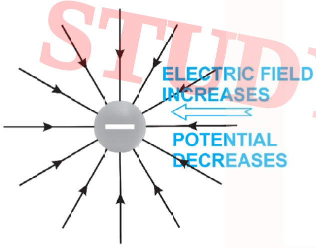


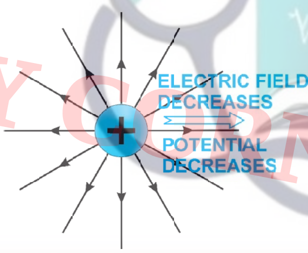
(a) Potential is maximum at B
(b) Potential is minimum at A
(c) Potential is same at C & D
(d) All of these✓

SOLUTION:

In direction of electric field potential decreases but in perpendicular direction potential remains constant.

If we follow the electric field lines



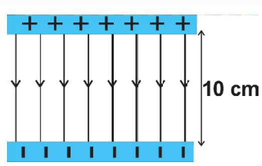


If V is Potential difference between two points separated by distance d then magnitude of electric field between the points is

$$E = \frac{V}{d}$$

اگر V, E یا d میں سے کوئی دو QUANTITIES معلوم ہوں تو اس RELATION سے تیسری کو معلوم کریں۔

EXAMPLE: Potential difference between two oppositely charged parallel plates is 12V as shown in the figure then electric field between the plates will be



(a) $1.2NC^{-1}$ (b) $12NC^{-1}$ (c) $120NC^{-1}$ (d) Zero

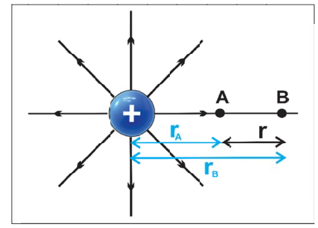
SOLUTION:

$$E = \frac{V}{d} = \frac{12}{10 \times 10^{-2}} = 120NC^{-1}$$

ELECTRIC POTENTIAL DUE TO POINT CHARGE

Electric potential at any distance r due to a point charge q is given as

$$V = \frac{kq}{r}$$



DEPENDENCE:

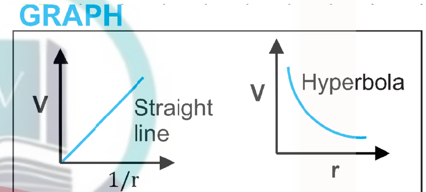
- Charge. ($V \propto q$)
- Distance from charge.($V \propto \frac{1}{r}$)
- Nature of dielectric.
- In presence of dielectric medium potential decreases by ϵ_r times

$$V_{med} = \frac{V_{vac}}{\epsilon_r} \quad OR \quad V_{med} = \frac{1}{4\pi\epsilon_o\epsilon_r}\frac{q}{r}$$

NOTE:

i. *Potential due to +ve charge is +ve*
ii. *Potential due to –ve charge is –ve*

GRAPH

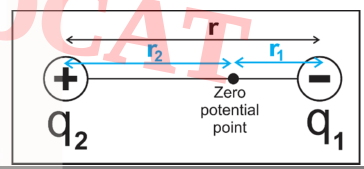


POTENTIAL کی جتنی VALUE زیادہ NEGAIVE ہو گی اتنی ہی زیادہ LOW ہو گی۔

ZERO POTENTIAL LOCATION:

WHEN CHARGES ARE OPPOSITE

$(let\ q_1 < q_2)$



یاد رکھیں:

اگر چارجز OPPOSITE ہوں تو ZERO POTENTIAL ہمیشہ چارجز کے درمیان ہو گا اور SMALLER چارج کے قریب ہو گا۔

- Distance of zero potential point from first charge

$$r_1 = \frac{q_1 r}{q_1 + q_2}$$

- Distance of zero potential point from second charge

$$r_2 = \frac{q_2 r}{q_1 + q_2}$$

EXAMPLE: Potential at a point midway between two equal and opposite charges is

(a) $\frac{kq}{r}$ (b) $\frac{2kq}{r}$ (c) $\frac{kq}{2r}$ (d) zero

DEPENDENCE:

i. Distance between electrodes ($r \propto d$).

ii. Area between electrodes $\left(r \propto \frac{1}{A}\right)$.

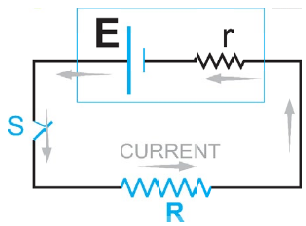
iii. Nature or concentration of electrolyte.

iv. Temperature

THREE IMPORTANT CASES:

1. CLOSED CIRCUIT:

Consider an external resistance R is connected across a battery of EMF 'E' and internal resistance 'r'.



Current drawn from the battery is	$I = \frac{E}{r+R}$
Potential drop across external resistance or terminal Potential difference is	$V_t = IR$
Potential drop across internal resistance is	$V' = Ir$
Terminal potential and EMF are related as	$E = V_t + Ir$
Terminal potential will be less than EMF	$(V_t < E)$
Power dissipated in external resistance or output power is	$P = V_t I = I^2 R = \frac{V_t^2}{R} = \frac{E^2 R}{(r+R)^2}$

When two different terminal potentials are given for two different currents the

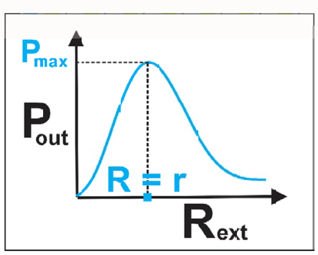
- **Internal resistance**

$$r = \frac{V_1 - V_2}{I_2 - I_1}$$

- **EMF of the battery**

$$E = \frac{V_2 I_1 - V_1 I_2}{I_1 - I_2}$$

GRAPH BETWEEN OUTPUT POWER AND EXTERNAL RESISTANCE



WHEN INTERNAL RESISTANCE = EXTERNAL RESISTANCE

OUTPUT POWER	Maximum and 50% of power supplied by battery	$P_{max} = \frac{E^2}{4r} = \frac{E^2}{4R}$
CURRENT DRAWN	50% of Maximum Current	$I = \frac{E}{2r} = \frac{E}{2R}$
TERMINAL POTENTIAL	Half of EMF	$V_t = \frac{E}{2}$

NOTE: when battery is being charged i.e. current is given to battery then

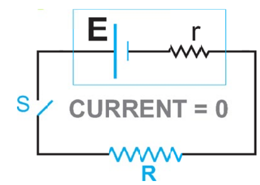
$$V_t = E + Ir \text{ and } V_t > E$$

2. OPEN CIRCUIT:

When no current is being drawn from battery or cell it is said to be open circuit.

Terminal potential difference is equal to EMF ($V_t = E$).

Potential drop across internal resistance and external resistance is zero.



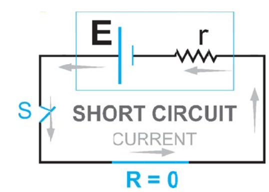
3. SHORT CIRCUIT:

When two terminals of cell or battery are joined together by thick wire.

- Maximum current is drawn from battery

$$I_{max} = \frac{E}{r}$$

- Terminal potential difference is zero ($V = 0$)



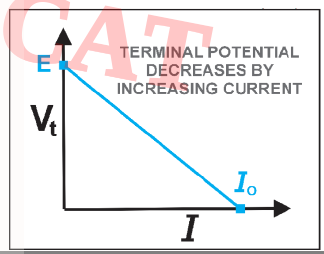
The graph between Terminal Potential and current is a straight line

For x-intercept V= 0

So $E = Ir$ or $r = \frac{E}{I}$

For y-intercept I= 0

$$V_t = E$$



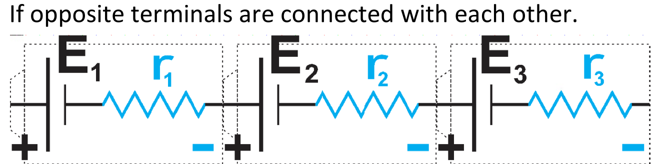
گراف سے EMF اور INTERNAL RESISTANCE دونوں معلوم کیے جا سکتے ہیں

NOTE: The emf is the "cause" and potential difference is its effect. The emf is always present even when no current is draw through the battery/cell.

GROUPING OF CELLS

SERIES GROUPING:

If opposite terminals are connected with each other.



UNIT 08 ELECTROMAGNETISM

ELECTROMAGNETISM:

Branch of physics which deals with study of magnetic effects produced by motion of charges is called electromagnetism.

In 1820 Oersted discovered that current passing through a conductor produces magnetic field around the conductor.

If a magnetic compass is placed near current carrying conductor, the magnetic field will deflect the compass needle.

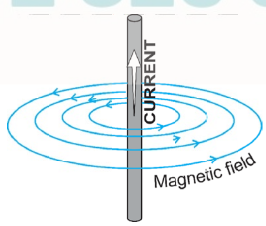
NOTE: When potential difference is applied across the conductor, it produces electric field inside the conductor which causes current.
When a steady current is passing through a conductor, it produces magnetic field around the conductor.

- Magnetic field lasts only as long as current is flowing through conductor.
- **Direction of field** depends upon direction of current.
- When current is reversed, the direction of field is also reversed.
- **The pattern of field** depends upon the shape of conductor.
- **Magnitude of field** is proportional to current passing through the conductor.

MAGNETIC FIELD DUE TO CURRENT CARRYING STRAIGHT CONDUCTOR

PATTERN:

Magnetic field produced by current carrying straight conductor is circular (concentric circles)



MAGNITUDE OF FIELD:

If 'I' is current passing through conductor then at any distance 'r' from the conductor magnetic field given as

$$B = \frac{\mu_o I}{2\pi r}$$

Where $\mu_o = 4\pi \times 10^{-7}\ Wbm^{-1}A^{-1}$ and known as permeability of free space.

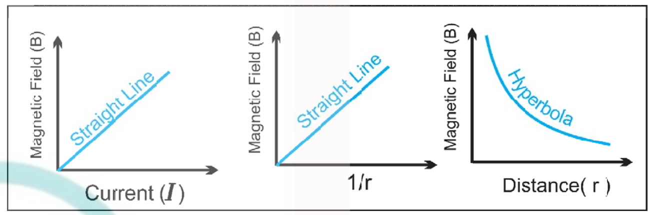
NOTE: r is distance from the conductor and it is not radius of wire of conductor.

DEPENDENCE:

Magnetic field depends upon three factors

- Magnitude of current $(B \propto I)$
- Distance from the conductor $(B \propto \frac{I}{r})$
- Nature of medium

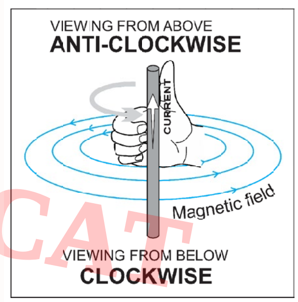
GRAPHS:



DIRECTION OF FIELD:

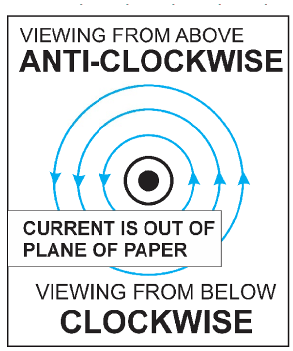
Direction of magnetic field depends upon direction of current and it is determined by right hand rule.

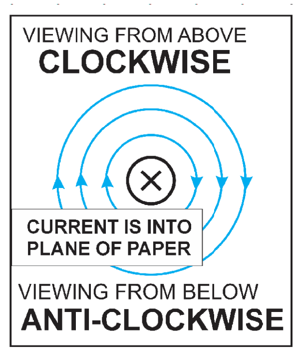
"Grasp the conductor in your right hand with thumb pointing in the direction of current then curling fingers represents the direction of magnetic field".



SHORT CUT METHOD

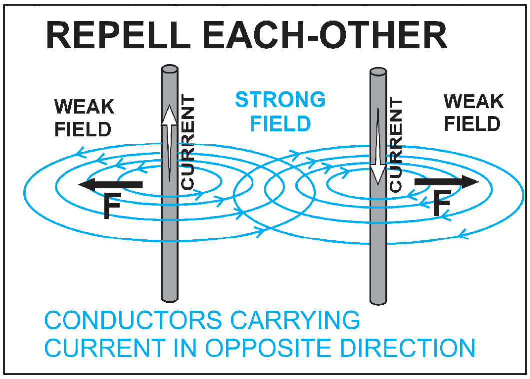
1. کرنٹ کی طرف اپنا THUMB کریں۔
2. THUMB والی SIDE سے فیلڈ ANTI-CLOCKWISE DIRECTION میں ہوگا۔
3. اور دوسری SIDE سے CLOCKWISE ہوگا۔





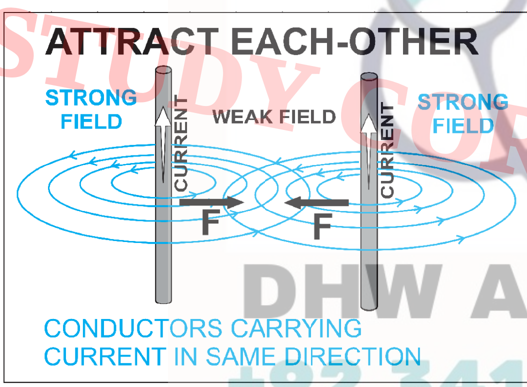
When two current carrying wires are placed near each other.

WHEN CURRENT IS IN OPPOSITE DIRECTION:



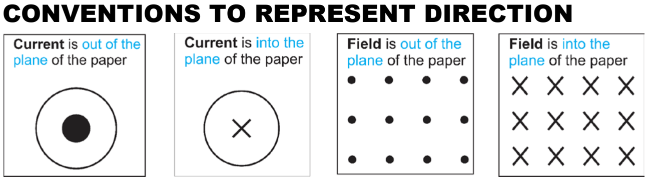
- Between the conductors, fields are in same direction. So resultant field is strong and it is given as
$$(B_{net} = B_1 + B_2)$$
- In outer regions, the fields are in opposite direction. So resultant field is weak and it is given as
$$(B_{net} = B_1 - B_2)$$

WHEN CURRENT IS IN SAME DIRECTION:



- In outer regions, fields are in same direction. So resultant field is strong and it is given as
$$(B_{net} = B_1 + B_2)$$
- Between the conductors, the fields are in opposite direction. So resultant field is weak and it is given as
$$(B_{net} = B_1 - B_2)$$

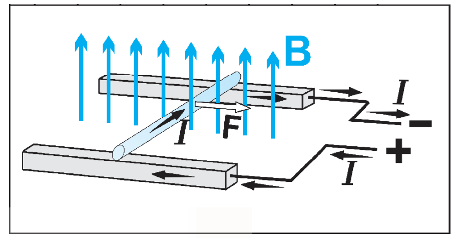
CONVENTIONS TO REPRESENT DIRECTION



FORCE ON CURRENT CARRYING CONDUCTOR IN A UNIFORM MAGNETIC FIELD

When a current carrying conductor is placed in magnetic field it will experience force given as

$$F = ILB\sin\theta$$



DEPENDENCE:

Force on the conductor is directly proportional to current passing through conductor.	$F \propto I$
Force on the conductor is directly proportional to length of conductor inside the magnetic field	$F \propto L$
Force on the conductor is directly proportional to external magnetic field.	$F \propto B$
Force on the conductor is directly proportional to $\sin\theta$ where 'θ' is angle between magnetic field and direction of current through conductor.	$F \propto \sin\theta$

MAGNETIC INDUCTION:

Magnetic induction is defined as magnetic force acting on one-meter length of conductor, placed perpendicular to the magnetic field lines when one ampere current is passing through the conductor.

$$B = \frac{F}{IL\sin\theta}$$

- Its SI unit is Tesla.
- Its dimensions are $[ML^oT^{-2}A^{-1}]$

TESLA:

Magnetic induction is one tesla if one newton force is acting on one-meter length of conductor placed perpendicular to magnetic field lines when one ampere current is passing through the conductor.

$$T = Nm^{-1}A^{-1} = kgm^os^{-2}A^{-1}$$

VECTOR FORM:

Magnetic force on current carrying conductor in vector form is given as

$$\vec{F} = I(\vec{L} \times \vec{B})$$

Magnetic force is always perpendicular to length of conductor and magnetic field lines $F \perp L$ and $F \perp B$.

یاد رکھیں: جب بھی دو VECTORS کا CROSS -PRODUCT کرتے ہیں تو اس سے بننے والا VECTOR ہمیشہ ان دونوں کے PERPENDICULAR ہوتا ہے۔

MAXIMUM FORCE:

Magnetic force is maximum when conductor is placed perpendicular to magnetic field lines.

$$F_{max} = ILB$$

MINIMUM FORCE:

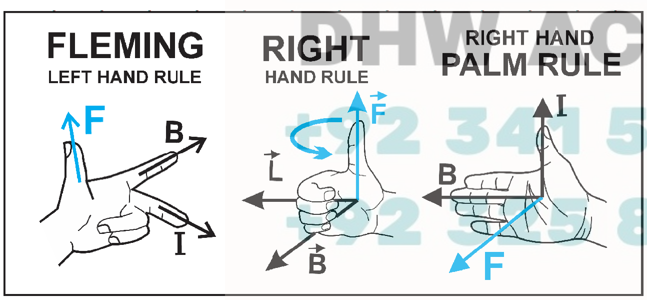
Magnetic force is zero or minimum when conductor is placed parallel or anti-parallel to magnetic field lines.

$$F_{min} = ILB\sin 0^o = 0$$

DIRECTION OF FORCE:

Direction of force can be determined by following rules.

i. Fleming left hand rule.
ii. Right hand rule for cross product.
iii. Right hand palm rule



How to Apply Right Hand Palm Rule

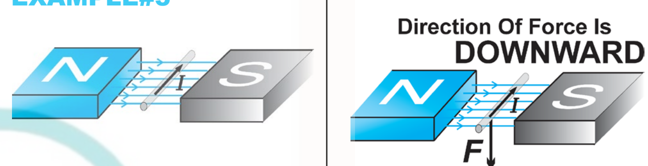
1. سب سے پہلے Right hand کا تھپڑ بنائیں۔
2. Fingers کی direction فیلڈ کی طرف set کریں۔
3. ہاتھ کو Rotate کر کے thumb کی direction کرنٹ کی طرف set کریں۔
4. تو جس طرف Palm کی direction ہو گی اس طرف Force عمل کرے گی۔

SOME IMPORTANT PRACTICE EXAMPLE FOR RIGHT HAND PALM RULE

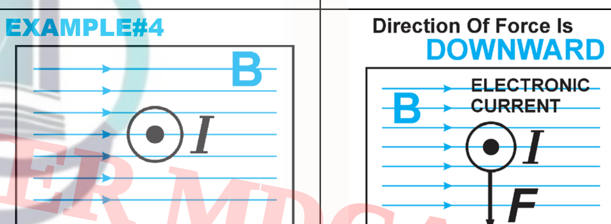
EXAMPLE#1

EXAMPLE#2

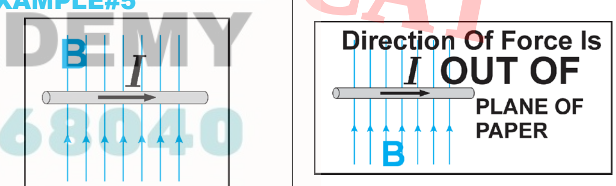
EXAMPLE#3



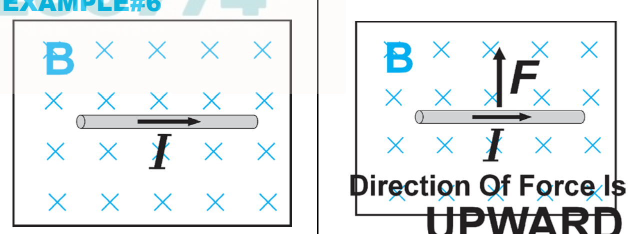
EXAMPLE#4



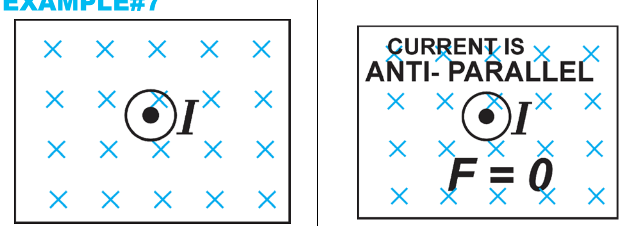
EXAMPLE#5



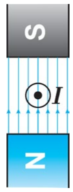
EXAMPLE#6

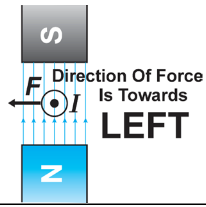


EXAMPLE#7

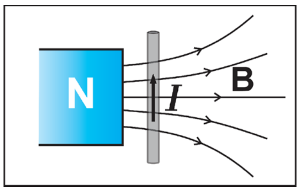


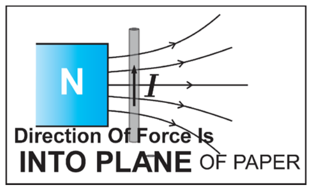
EXAMPLE#8





EXAMPLE#9





MAGNETIC FLUX

"Number of magnetic field lines passing through certain area is called magnetic flux through that area."

- Magnetic flux is denoted by $\emptyset_B$ and

$$\emptyset_B = \vec{B}.\vec{A} = BA\cos\theta$$

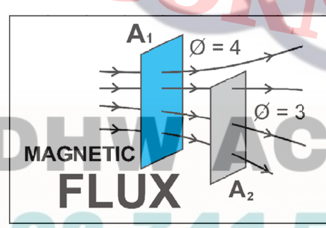
(Where θ is angle between $\vec{B}$ and vector area)

- It is a scalar quantity.
- **Its SI unit is Weber**
  $(Wb = T.m^2 = NmA^{-1} = kgm^2s^{-2}A^{-1})$
- Its dimensions are $[ML^2T^{-2}A^{-1}]$.

EXAMPLE:

➢ Flux passing through A_1 is four.

➢ Flux passing through A_2 is three.

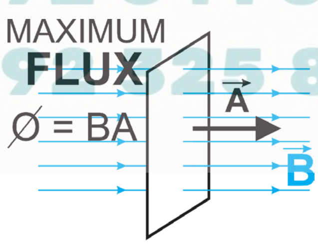


MAXIMUM FLUX:

Magnetic flux is maximum when vector area is parallel to magnetic field lines.

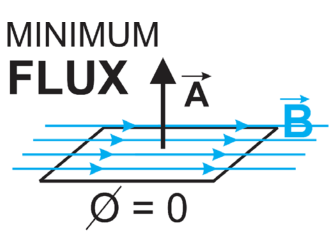
OR

Magnetic flux is maximum when area or plane is held perpendicular to magnetic field lines.



MINIMUM FLUX:

Flux is minimum when vector area is perpendicular to magnetic field lines.



OR Flux is minimum when area is held parallel to magnetic field lines.

θ	0^o	30^o	45^o	60^o	90^o
$Cos\theta$	1	$\frac{\sqrt{3}}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{2}$	0
$Sin\theta$	0	$\frac{1}{2}$	$\frac{1}{\sqrt{2}}$	$\frac{\sqrt{3}}{2}$	1

Short Cut Method

When plane or surface makes an angle 'θ' with magnetic field lines then use the relation.

$$\emptyset = BA\sin\theta$$

MAGNETIC FLUX DENSITY:

Magnetic flux per unit area when area is held perpendicular to magnetic field lines is called magnetic flux density.

$$B = \frac{\emptyset}{A_\perp}$$

- SI unit is Tesla ($T = Wbm^{-2}$)

AMPERE'S LAW

STATEMENT:

" Sum of all the quantities $(\vec{B}.\Delta\vec{L})$ for all path elements into which complete loop has been divided is equal to μ_o times the total current enclosed by loop"

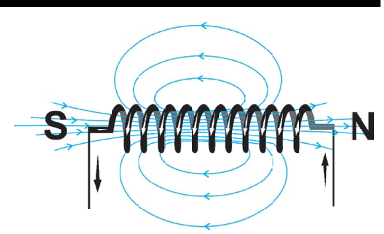
$$\sum_{i=1}^{n}(\vec{B}.\Delta\vec{L})_i = \mu_o I$$

- Where μ_o is permeability of free space and
  $\mu_o = 4\pi \times 10^{-7} Wbm^{-1}A^{-1}$
- Ampere's law is used to determined magnetic flux density.
- Ampere's law in electromagnetism is similar to Gauss's law in electrostatics.

FIELD DUE TO A CURRENT CARRYING SOLENOID

SOLENOID:

"Solenoid is a long, tightly wound cylindrical coil which behaves like a bar, magnet when current passes through it."



OUTSIDE THE SOLENOID:

Magnetic field outside the solenoid is non-uniform and weak (can be neglected).

INSIDE THE SOLENOID:

Magnetic field produced inside the solenoid strong and nearly uniform.

$$B = \mu_o nI$$

OR

$$B = \frac{\mu_o NI}{L}$$

- L is length of the solenoid
- I is current passing through the solenoid.
- μ_o is permeability of free space.
- n is number of turns per unit length.

AT ENDS OF SOLENOID:

Magnetic field produced at the ends of solenoid is non-uniform and

$$B_{end} = \frac{B_{center}}{2}$$

$$\Rightarrow B_{end} = \frac{\mu_o nI}{2}$$

DEPENDENCE:

Magnetic field inside the solenoid depends upon.

(i). Number of turns of solenoid $(B \propto N)$

(ii). Current passing through solenoid $(B \propto I)$

(iii). Length of solenoid $\left(B \propto \frac{1}{L}\right)$

(iv). Nature of core material.

By inserting the iron core inside the solenoid magnetic field increases.

IF SOLENOID IS STRECHED:

If solenoid is stretched, then its **length increases** but no. of turns remains same so magnetic field decreases.

$$\left(B \propto \frac{1}{L}\right)$$

IF SOLENOID IS COMPRESSED:

If solenoid is compressed, then its **length decreases** but no. of turns remains same so its magnetic field increases.

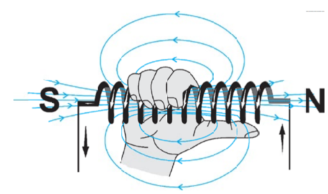
IF SOLENOID IS CUT INTO PARTS:

If solenoid is cut into two parts and same current passes through each part, then magnetic field will remain same because **both Number of turns and length become half**.

DIRECTION OF FIELD:

The field B is along the axis of the solenoid and its direction is given by right hand grip rule stated as

"Hold the solenoid in the right hand with fingers curling in the direction of the current, the thumb will point in the direction of the field".

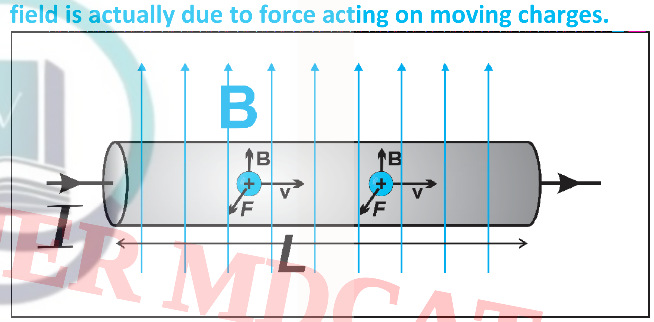


یادرکھیں

- SOLENOID کے باہر MAGNETIC فیلڈ کی DIRECTION ہمیشہ NORTH سے SOUTH ہو گی۔
- SOLENOID کے اندر MAGNETIC فیلڈ کی DIRECTION ہمیشہ SOUTH سے NORTH ہو گی۔

FORCE ON MOVING CHARGE IN A MAGNETIC FIELD

Force acting on a current carrying conductor in magnetic field is actually due to force acting on moving charges.



When charges are moving in the magnetic field they experience the magnetic force and the resultant of magnetic forces acting on moving charges is the magnetic force acting on current carrying conductor.

No. of charge carriers per unit volume	n
No. of charge carriers in volume AL of the conductor	$n\,A\,L$
Total charge in the conductor of volume AL	$nqAL$
Time taken by charges to pass through conductor	L/v
Current passing through the conductor	$nqAv$

MAGNETIC FORCE:

If a charge q is moving with velocity v in a magnetic field B, then magnetic force is given as

$$\vec{F}_m = q\,(\vec{v} \times \vec{B})$$

MAGNITUDE OF FORCE:

The magnitude of Magnetic force is

$$F_m = qvBsin\theta$$

DEPENDENCE:

Magnetic force depends upon

- Charge of the particle $(F \propto q)$
- Velocity of the particle $(F \propto v)$
- Magnetic field $(F \propto B)$
- Direction of motion of charged particle OR angle between velocity and magnetic field lines.

$$(F \propto Sin\theta)$$

NOTE: Magnetic force on moving charges is independent of length area or dimensions of the conductor.

MAXIMUM FORCE:

Force acting on a moving charge is maximum when charge is moving perpendicular to magnetic field lines.

$$F_{max} = qvB$$

MINIMUM FORCE:

Force acting on a particle is zero or minimum when

1-	Charge is zero. (neutral particle)	$F = 0$
2-	Charged particle is at rest $(v = 0)$	$F = 0$
3-	Magnetic field is zero $(B = 0)$	$F = 0$
4-	Charge is moving either parallel or anti-parallel to magnetic field lines.	$F = 0$

MAGNETIC FORCE ON PROTON:

The charge on proton is $+e$, So

$$\vec{F}_m = +e\,(\vec{v} \times \vec{B})$$

MAGNETIC FORCE ON ELECTRON:

The charge on electron is $-e$, So

$$\vec{F}_m = -e\,(\vec{v} \times \vec{B})$$

VECTOR FORM:

Magnetic force on moving charge in vector form is given as

$$\vec{F}_m = q\,(\vec{v} \times \vec{B})$$

Magnetic force is always perpendicular to velocity of charge and magnetic field.

WORK DONE:

Work done by magnetic force is **always zero** because magnetic force is perpendicular to velocity or displacement.

DEFLECTING FORCE:

Magnetic force is just deflecting force and it cannot accelerate or decelerate the charge.

MAGNETIC FORCE DOES NOT CHANGE:

When charge in moving in uniform magnetic field its speed, K.E, angular velocity, time period, frequency and angular momentum **remain constant.**

- **Angular acceleration and torque** by magnetic force is always zero.

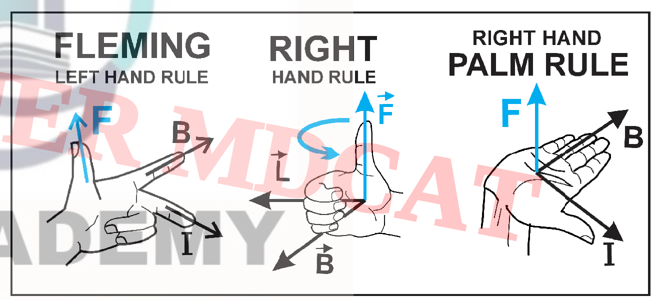
MAGNETIC FORCE CHANGES:

Magnetic force changes only direction of velocity, momentum and acceleration.

DIRECTION OF FORCE:

Direction of force acting on a moving charge in a magnetic field is determined by

(i). Right hand rule
(ii). Right hand palm rule
(iii). Fleming left hand rule

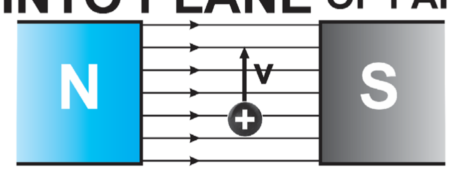


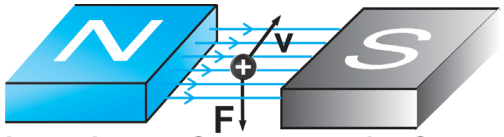
یادرکھیں: اگرچارج +VE کی بجائے –VE ہوتو RIGHT کی بجائے LEFT- HAND PALM- RULE استعمال کریں۔

HOW TO APPLY RIGHT HAND PALM RULE

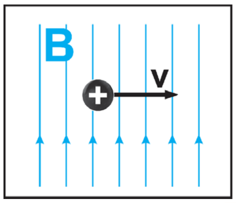
1. سب سے پہلے Right hand کا تھپڑ بنائیں۔
2. Fingers کی direction فیلڈ کی طرف set کریں۔
3. ہاتھ کو Rotate کرکے thumb کی direction کو velocity کی طرف set کریں۔
4. توجس طرف Palm کی direction ہو گی اس طرف Force عمل کرے گی۔

Direction Of Force Is
INTO PLANE OF PAPER

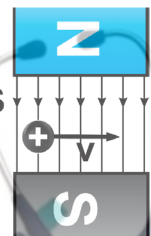




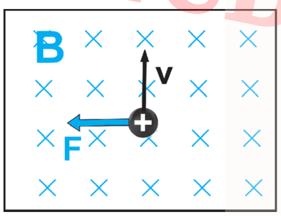
Direction of magnetic force is
DOWNWARD



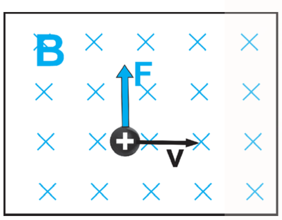
Direction of magnetic force is **OUT OF PLANE** of the paper



Direction of magnetic force is **INTO PLANE** of the paper

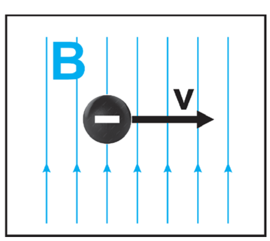


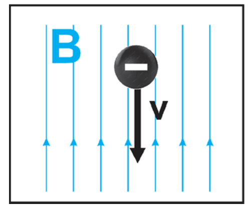
Direction of magnetic force is **TOWARDS LEFT** of the paper



Direction of magnetic force is **UPWARD**

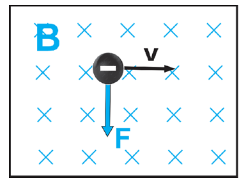
Direction of magnetic force is **INTO PLANE** of the paper





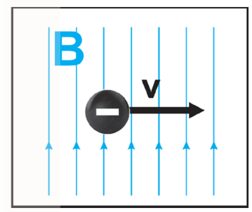
F = 0

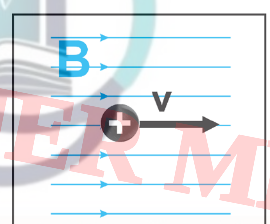
MOTION IS ANTI-PARALLEL TO MAGNETIC FIELD



Direction of magnetic force is **DOWNWARD**

Direction of magnetic force is **INTO PLANE** of the paper

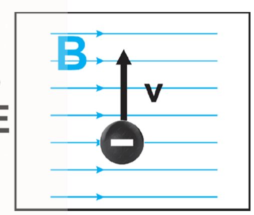


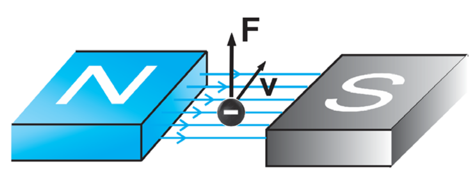


F = 0

MOTION IS PARALLEL TO MAGNETIC FIELD

Direction of magnetic force is **OUT OF PLANE** of the paper



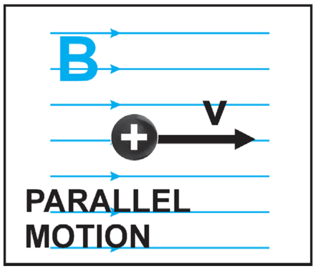


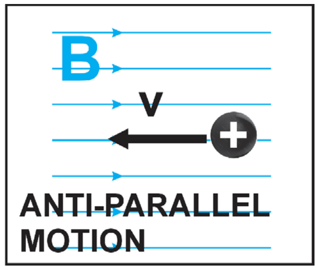
Direction of magnetic force is
VERTICALLY UPWARD

TRAJECTORY OF A CHARGE PARTICLE IN MAGNETIC FIELD

1. STRAIGHT PATH:

When charge is moving either parallel or anti-parallel to magnetic field lines its trajectory will be straight line.





$F_m = qvBsin0° = 0$ $F_m = qvBsin180° = 0$

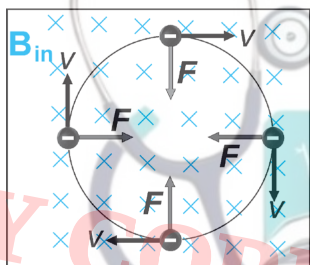
2. CIRCULAR PATH:

When charge is moving perpendicular to uniform magnetic field lines then its trajectory will be circular.

$$F_m = F_c$$

$$qvB = \frac{mv^2}{r}$$

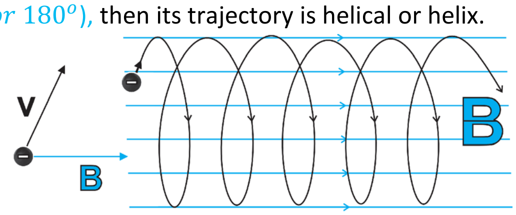
$$\boxed{\frac{q}{m} = \frac{v}{Br}}$$



RADIUS OF CIRCULAR PATH	$r = \frac{mv}{qB}$
ANGULAR FREQUENCY OR ANGULAR VELOCITY	$\omega = \frac{qB}{m}$
TIME PERIOD	$T = \frac{2\pi m}{qB}$
FREQUENCY	$f = \frac{qB}{2\pi m}$

3. HELICAL PATH:

When charge is moving neither parallel, anti-parallel or perpendicular to magnetic field lines (θ is other than 0^o, 90^o or 180^o), then its trajectory is helical or helix.



COMPARISON BETWEEN ELECTRIC AND MAGNETIC FORCE

ELECTRIC FORCE	MAGNETIC FORCE
Electric force is given as $\vec{F}_e = q\vec{E}$	Magnetic force is given as $\vec{F}_m = q(\vec{v} \times \vec{B})$
Electric force only depends upon charge and electric field and independent of velocity and direction of motion.	Magnetic force depends upon charge, velocity, magnetic field and direction of motion.
Electric force is always along the direction of electric field.	Magnetic force is always perpendicular to direction of magnetic field and velocity.
Electric force can accelerate, decelerate and deflect the charge.	Magnetic force is only deflecting force and cannot accelerate or decelerate the charge.
Work done by electric force may or may not be zero.	Work done by magnetic force is always zero.

LORENTZ FORCE

"If a charge q is moving with velocity $\vec{v}$ in a region where electric field is $\vec{E}$ and magnetic field is $\vec{B}$ are present, then the net force on the charge is vector sum of electric force $q\vec{E}$ and magnetic force $q(\vec{v} \times \vec{B})$."

$$\boxed{\vec{F} = q\vec{E} + q(\vec{v} \times \vec{B})}$$

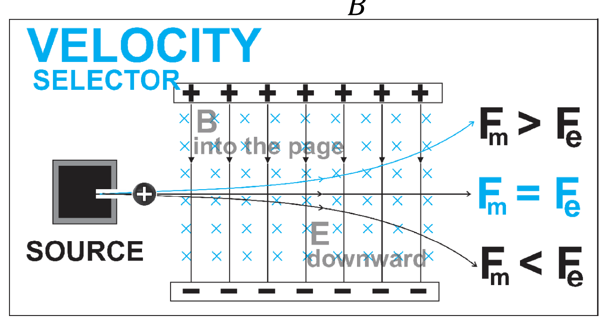
It is known as Lorentz force.

VELOCITY SELECTOR:

- $\vec{v}$, $\vec{E}$ and $\vec{B}$ are set mutually perpendicular.
- $\vec{E}$ and $\vec{B}$ are applied in a such a way that they may exert force on moving charge in opposite direction.
- Only these charges pass un-deviated for which

$$F_m = F_e \Rightarrow qvB = qE$$

$$v = \frac{E}{B}$$



EXAMPLE:
Alpha particles ranging in speed from 1000ms^{-1} to 2000 ms^{-1} enter into a velocity selector where electric field intensity is 300 Vm^{-1} and magnetic induction is 0.20T. The particles which move un-deviated will have speed
(a)1000 ms^{-1} (b) 1250 ms^{-1} (c) 1500 ms^{-1} (d) 2000 ms^{-1}
SOLUTION:

$$v = \frac{E}{B} \Rightarrow v = \frac{300}{0.2} = 1500\ \text{ms}^{-1}$$

EXAMPLE: A velocity selector has magnetic field of 0.30Tand a perpendicular electric field of 10000 Vm^{-1} is applied. Then the particles which move un-deviated will have speed
(a)330 ms^{-1} (b) 3300 ms^{-1}
(c)33000 ms^{-1} (d) 3000 ms^{-1}
SOLUTION:

$$v = \frac{E}{B} \Rightarrow v = \frac{10000}{0.3} = 33000\ \text{ms}^{-1}$$

EXAMPLE: If a charge q is moving in a velocity selector. The charge will move in a straight path if:
(a)$v = \frac{E}{B}$ (b) E is perpendicular to B.
(c) $F_m = F_e$ (d) All of these✓

CHARGE TO MASS RATIO OF AN ELECTRON

CHARGE TO MASS RATIO:

The ratio between charge of a particles and its mass is known as charge to mass ratio.

- Charge to mass ratio $\left(\frac{q}{m}\right)$ of a particle only depends upon nature of particle.
- In case of **neutron** or any other neutral particle

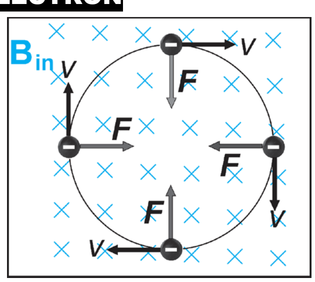
Charge to mass ratio	$\frac{q}{m} = 0$
Mass to charge ratio	$\frac{m}{q} = \infty$

A COMPARISON:

$$\left(\frac{q}{m}\right)_{electron} > \left(\frac{q}{m}\right)_{proton} > \left(\frac{q}{m}\right)_{\alpha-particle}$$

DETERMINATION OF CHARGE TO MASS RATIO OF AN ELECTRON

To determined charge to mass ratio of electron, beam of electrons is projected in uniform magnetic field in perpendicular direction.



Magnetic field exerts the force on electrons and bends the beam in a circular path.

$$F_m = F_c$$

$$qvB = \frac{mv^2}{r}$$

$$\boxed{\frac{q}{m} = \frac{v}{Br}}$$

RADIUS OF CIRCULAR PATH:

Radius of circular path is given as

$$r = \frac{mv}{qB}$$

It depends **upon** four factors:

- Mass of the particle. $(r \propto m)$
- Charge of the particle. $(r \propto {}^{1}/_{q})$
- Velocity of the particle. $(r \propto v)$
- Magnitude of magnetic field. $(r \propto {}^{1}/_{B})$
- جس Particle کا Mass زیادہ ہو گا اس کے لیے Radius بھی زیادہ ہو گا۔

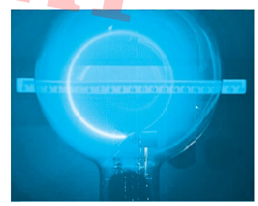
DEFLECTION OR CURVATURE:

Deflection or curvature of a particle varries inversely with radius of circular path. So, Deflection or curvature of a particle is inversely proportional to mass of the particle.

- جس particle کا mass زیادہ ہو گا اس کی deflection کم ہو گی۔

DERERMINATION OF RADIUS:

To determine the radius of circular path beam of electrons is projected in a glass bulb filled with H_2 gas at low pressure due to ionization and de-excitation path of electrons becomes visible.



DERERMINATION OF RADIUS:

If beam of electrons is accelerated through potential difference V then

Gain in K.E through potential difference V	$K.E = qV$
Gain in momentum through potential difference V	$P = \sqrt{2mqV}$
Gain in speed through potential difference V	$v = \sqrt{\frac{2qV}{m}}$

Charge to mass ratio in terms of voltage V is given as

$$\frac{q}{m}=\frac{2V}{B^2r^2}$$

Accurately Known value of e/m for electron is $1.7588\times10^{11}Ckg^{-1}$

FOR ELECTRON:

$$\left(\frac{q}{m}\right)_e=\frac{e}{m_e}$$
$$=1.7588\times10^{11}ckg^{-1}$$

FOR PROTON:

$$\left(\frac{q}{m_p}\right)=\frac{e}{m_p}=\frac{e}{1836m_e}$$
$$=9.6\times10^{7}ckg^{-1}$$

Proton کی چارج to ماس ratio الیکٹران سے 1836 گنا کم ہے۔

FOR $\alpha-Particle$:

$$\frac{q_\alpha}{m_\alpha}=\frac{2e}{4m_p}=\frac{e}{2m_p}$$
$$=4.8\times10^{7}ckg^{-1}$$

α کی چارج to ماس ratio پروٹان سے 2 گنا کم ہے اور electron سے تقریبا 7000 گنا کم ہے۔

REMEMBER:

When a charged particle is moving in circular path in magnetic field, its

ANGULAR VELOCITY	TIME PERIOD	FREQUENCY
$\omega=\frac{qB}{m}$	$T=\frac{2\pi m}{qB}$	$f=\frac{qB}{2\pi m}$

1. جس Particle کا charge زیادہ ہو گا اس کی angular velocity بھی زیادہ ہو گی۔
2. جس Particle کا mass زیادہ ہو گا اس کی angular ولاسٹی کم ہو گی۔
3. Magnetic فیلڈ بڑھانے سے angular ولاسٹی بھی بڑھے گی۔

EXAMPLE:

A charge particle is moving in a circular path in a perpendicular magnetic field. By increasing the magnetic field charge to mass ratio of electron

(a)Increases (b) decreases
(c)Remains same✓ (d) none

SOLUTION:

Charge to mass ratio only depends upon nature of particles.

مندرجہ ذیل steps کو ترتیب سے follow کریں:

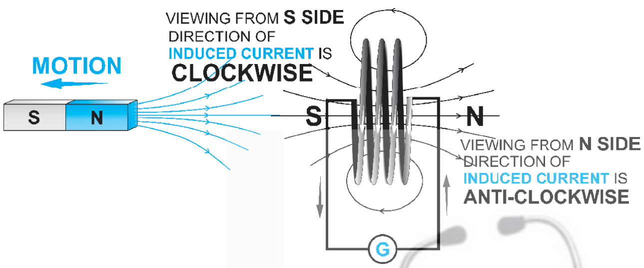
(i). اگر دور جارہے ہوں تو ان میں Attraction پیدا ہو گی۔

(ii). Magnet والی side پر Opposite پول (s) اور دوسری side پر same پول (n) پیدا ہو گا۔

(iii). N والی side سے دیکھیں تو کرنٹ anticlockwise اور 's' والی side سے دیکھیں تو current کلاک وائز نظر آئے گا۔

EXAMPLE 2:

Magnet is moving towards the coil



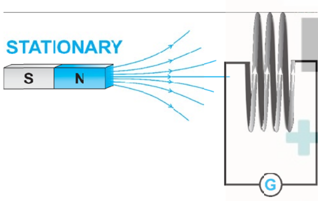
مندرجہ ذیل steps کو ترتیب سے follow کریں:

(i). اگر قریب آرہے ہوں تو ان میں repulsion پیدا ہو گی۔

(ii). Magnet والی side پر same میگنیٹک پول (N) بنے گا اور دوسری side پر opposite پول (S) پیدا ہو گا۔۔

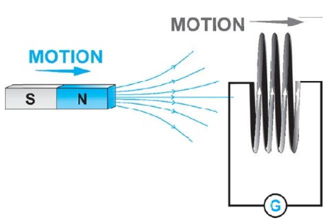
(iii). N والی side سے دیکھیں تو کرنٹ anticlockwise اور 'S' والی side سے دیکھیں تو current کلاک وائز نظر آئے گا۔

EXAMPLE 3: Magnet and coil are stationary



Since magnetic flux is not changing and no current is induced. Hence Lenz's law is not applicable

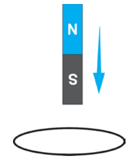
Example 4: They are moving in same direction with same velocity



Since magnetic flux is not changing and no current is induced. Hence Lenz's law is not applicable

EXAMPLE 3:

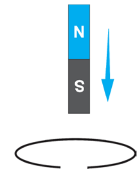
A magnet is falling over a loop as shown in the figure below viewing from above direction of field is



(a) clockwise
(b) anti-clockwise
(c) either clockwise or anti clockwise
(d) no current is induced

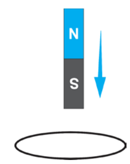
ANSWER clockwisw

When magnetic falls over a open coil



- No current is induced.
- No repulsion b/w coil and magnet.
- Acceleration of magnet is equal to 'g'.

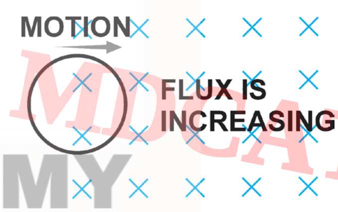
When magnet falls over a closed coil



- Current is induced.
- Coil repels the falling magnet.
- Acceleration of magnet becomes less than g.

CASE-II:
When magnetic flux is increasing or decreasing:

EXAMPLE 1: When magnetic flux is increasing:



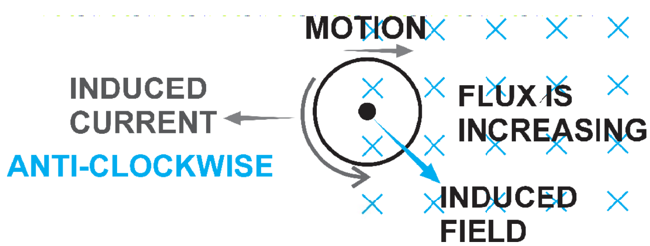
مندرجہ ذیل steps کو ترتیب سے follow کریں:

(i). جب کوئل enter ہو گی تو اس میں سے flux بڑھے گا۔

(ii). Induced کرنٹ flux کو کم کرنے کے لیے opposite میگنیٹک فیلڈ پیدا کرے گا

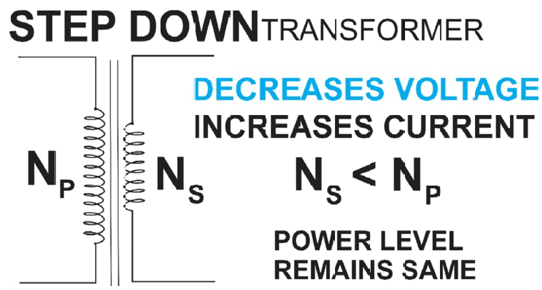
(iii). کیونکہ پہلے فیلڈ into the paper ہے تو نیا فیلڈ out of paper پیدا ہو گا۔

(iv). انگوٹھا out of paper کر کے دائیں ہاتھ کی انگلیاں گھمائیں کرنٹ کی direction مل جائے گی۔



STEP-UP TRANSFORMER:

A transformer which is used to change a given alternating emf into larger alternating emf.

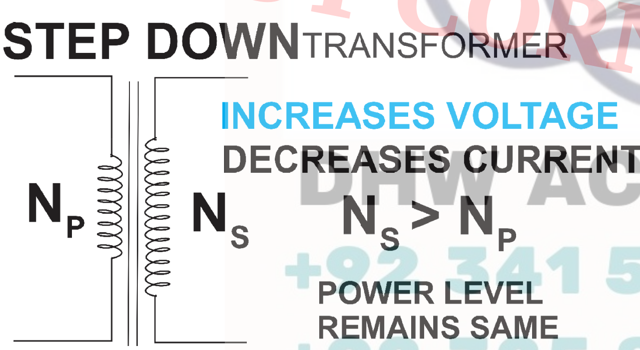


- Increases the voltage level $(V_s > V_p)$
- Decreases the current level $(I_s < I_p)$
- Power level remains same $(P_{in} = P_{out})$
- Time period or frequency of A.C remains same.

سیکنڈری کوئل کی turns جتنے گنا پرائمری کوئل سے زیادہ ہوں گی سیکنڈری کا voltage اتنے گنا زیادہ ہو جائے گا اور کرنٹ اتنے گنا کم ہو جائے گا۔

STEP-DOWN TRANSFORMER:

A transformer which is used to change a given alternating emf into smaller alternating emf.



- $N_s < N_p$
- Decreases the voltage level $(V_s < V_p)$
- Decreases the current level $(I_s > I_p)$
- Power level remains same $(P_{in} = P_{out})$
- Time period or frequency of A.C remains same.

سیکنڈری کوئل کی turns جتنے گنا پرائمری کوئل سے کم ہوں گی سیکنڈری کا voltage اتنے گنا کم ہو جائے گا اور کرنٹ اتنے گنا زیادہ ہو جائے گا۔

NOTE:

Step Up Transformer	Step down Transformer
$\frac{N_s}{N_p} > 1 \ or \ \frac{N_p}{N_s} < 1$	$\frac{N_s}{N_p} < 1 \ or \ \frac{N_p}{N_s} > 1$
$\frac{V_s}{V_p} > 1 \ or \ \frac{V_p}{V_s} < 1$	$\frac{V_s}{V_p} < 1 \ or \ \frac{V_p}{V_s} > 1$
$\frac{\varepsilon_s}{\varepsilon_p} > 1 \ or \ \frac{\varepsilon_p}{\varepsilon_s} < 1$	$\frac{\varepsilon_s}{\varepsilon_p} < 1 \ or \ \frac{\varepsilon_p}{\varepsilon_s} > 1$
$\frac{I_s}{I_p} < 1 \ or \ \frac{I_p}{I_s} > 1$	$\frac{I_s}{I_p} > 1 \ or \ \frac{I_p}{I_s} < 1$

IDEAL TRANSFORMER:

A transformer in which output power is equal to its input power $(P_{loss} = 0)$ is known as ideal transformer.

$$P_{in} = P_{out}$$

$$V_p I_p = V_s I_s$$

$$OR \quad \frac{V_s}{V_p} = \frac{I_p}{I_s} \quad OR \quad \frac{I_s}{I_p} = \frac{N_p}{N_s}$$

If a primary coil of a transformer is connected to A.C mains then $V_p = Constant$

$$and \quad I_p \propto P_{out}$$

USE OF TRANSFORMER IN POWER TRANSMISSION:

- If R is resistance of transmission line then power loss in transmission line due to heating effect is given by I^2R.
- The power loss can be reduced by decreasing current level.
- Step-up transformer is used at power generating stations.
- Power is transmitted at high voltage and at low current and thus power loss in transmission line is considerably reduced.
- At other end a step-down transformer is used to decrease the voltage level and increases the current level.

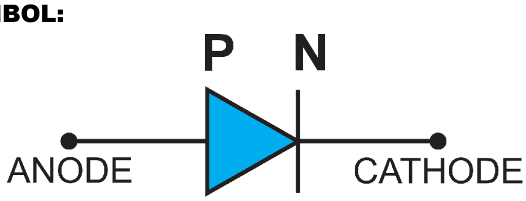
PRACTICAL TRANSFORMER:

In case of real transformer output power is always less than the input power due to power losses in the transformer.

DIODE

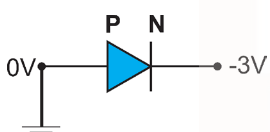
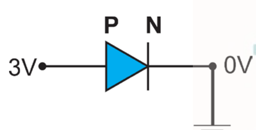
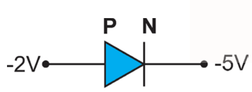
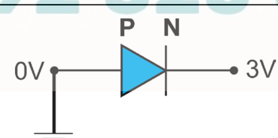
A P-n junction is known as semi-conductor diode.

SYMBOL:



Arrow کرنٹ کی direction کو ظاہر کر رہی ہے مطلب Arrow والی direction سے کرنٹ گزر سکتا ہے اور دوسری direction سے کرنٹ نہیں گزر سکتا۔

- Arrowhead represents the p-region and also known as Anode and vertical line represents the n-region and is also known as cathode.

FORWARD BIASED DIODE	REVERSE BIASED DIOD
EXAMPLES	**EXAMPLES**
Forward biased ہونے کیلئے anode کا پوٹینشل high اور cathode کا پوٹینشل low ہونا چاہیئے۔	Reverse biased ہونے کیلئے anode کا پوٹینشل low اور cathode کا پوٹینشل high ہونا چاہیئے۔
	
	
	
	

RECTIFICATION

Conversion of alternating current (A.C) into direct current (D.C) is called rectification.

- Device which is used to convert A.C into D.C is called rectifier.
- Diode can be used as rectifier.
- There are two types of rectification.

(i) Half wave rectification (ii) Full wave rectification

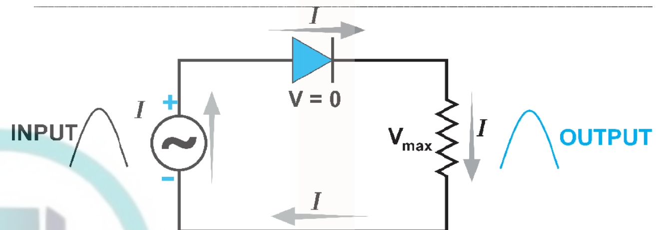
HALF WAVE RECTIFICATION:

"A type of rectification in which **only one half** of A.C cycle is converted into D.C is called half wave rectification."

- Minimum one diode is required for half wave rectification.

DURING +VE HALF CYCLE: $(0 - T/_2)$

- Diode is forward biased.
- Resistance of diode will become very small.
- Output pulse is $+ve$.
- Voltage drop across the diode is approximately zero.
- Voltage drop across the load resistance R is equal to source voltage.



i. اگر R میں کرنٹ downward ہو تو +ve output pulse بنائیں گے۔

ii. اگر R میں کرنٹ upward ہو تو −ve output pulse بنائیں گے

یاد رکھیں

i. +ve half دینے سے A.C source کا اوپر والے Terminal کو +ve لیں گے۔

ii. −ve half دینے سے A.C source کا اوپر والے Terminal کو −ve لیں گے۔

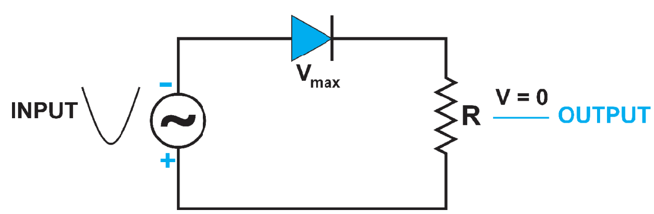
NOTE

Peak Inverse Voltage: (PIV)

PIV is maximum reverse voltage that a diode rectifier can block in reverse biased state.

DURING –VE HALF CYCLE: $(T/_2 - T)$

- Diode is reverse biased.
- Resistance of diode will become very large.
- Output voltage is zero.
- Voltage drop across load resistance R is zero.
- Voltage drop across the diode is maximum equal to source voltage.

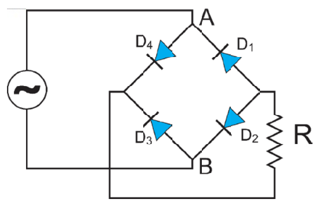


$T_{in} = 20ms$ And $T_{out} = 10ms$

کیونکہ Output Ripples کا ٹائم پریڈ Input سے Half ہوتا ہے۔

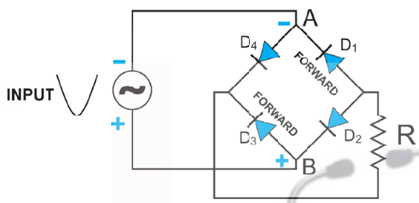
EXAMPLE:

In the following figure what happens during negative half cycle of the input signal?



(a) D_1 and D_3 conduct (b) D_4 and D_2 conduct
(c) D_1 and D_2 conduct (d) D_4 and D_3 conduct

SOLUTION:



EXAMPLE:

A full wave rectifier is being used to rectify an A.C voltage of 110 V, 60 Hz. The number of pulses of rectified current obtained in five seconds is:
(a) 300 (b) 60 (c) 600✓ (d) 120

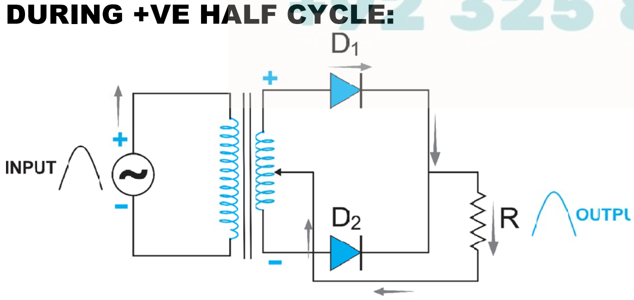
SOLUTION:

Output pulse frequency is twice than input frequency in full wave rectifier. So
Output pulses in one second $= 60 \times 2 = 120$
Output pulses in five seconds $= 5 \times 120 = 600$

CENTER TAPE TRANSFORMER RECTIFIER

A center-tap transformer rectifier uses transformer with center-tapped secondary winding which splits the secondary voltage into two parts and two diodes which conduct alternatively.

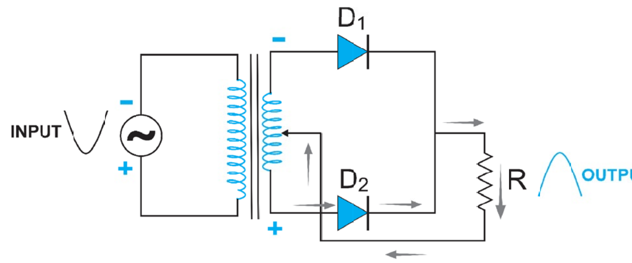
DURING +VE HALF CYCLE:



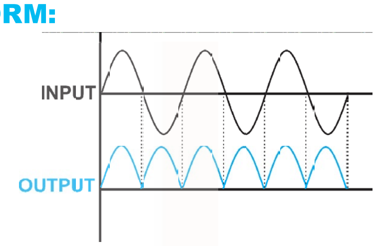
- Diode D_1 becomes forward biased.
- Diode D_2 becomes reverse biased.
- Only diode D_1 conduct the current.
- Output is $+ve$ pulse.

DURING –VE HALF CYCLE:

- Diode D_1 becomes reversed biased.
- Diode D_2 becomes forward biased.
- Only diode D_2 conducts the currents.
- Output is a $+ve$ pulse.



WAVEFORM:



- If 'f' is frequency of input signal, then output ripples have frequency '2f'.
- If 'T' is time period of input signal, then output ripples have time period 'T/2'.

EXAMPLE:

If a full wave rectifier circuit is operating from 50 Hz mains, then the time period of output ripples will be:
(a) 20 ms (b) 40 ms (c) 10ms (d) 30ms

SOLUTION:

NOTE

- A circuit which converts pulsating D.C into smooth D.C is called filter.
- Capacitor, inductor or their combination can be used as filter.

EXAMPLE:

In case of center tape transformer full wave rectifier which of the following statement is true
(a) minimum two diodes are required
(b) only one diode conducts at a time
(c) frequency of output ripple is double of input signal
(d) all of these ✓

EXAMPLE:

In a full-wave center tap transformer rectifier, how many diodes conduct at a time?
(a) 1✓ (b) 2 (c) 3 (d) 4

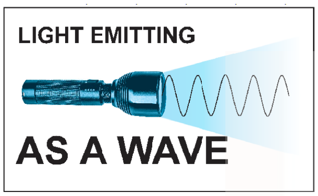
UNIT 11 MODERN PHYSICS

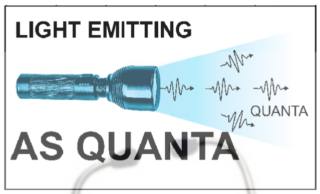
CLASSICAL ELECTROMAGNETIC THEORY:

According to classical electromagnetic theory of radiations energy was emitted or absorbed by atoms as a continuous wave. And energy is uniformly distributed over the wave.

PLANK'S ASSUMPTION:

"Energy is emitted or absorbed by atoms in discrete packets called quanta rather than as a continuous wave."





A COMPARISON BETWEEN CLASICAL THEORY ANFD PLANK'S THEORY

ORIGIN	Developed by James Clerk Maxwell	Introduced by Max Planck
NATURE	Treats electromagnetic waves as continuous waves.	Proposes that radiation is emitted and absorbed in discrete energy packets
PRINCIPLE	Energy is continuous	Energy is quantized
APPLICATIONS	Explains macroscopic electromagnetic phenomena	explaining atomic and subatomic processes.

PLANK'S LAW:

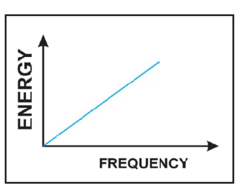
Energy of each quantum is directly proportional to its frequency.

$E \propto f$ *OR* $E = hf$

Where 'h' is plank's constant and

- $h = 6.626 \times 10^{-34}\, J.s$ or $h \approx 6.63 \times 10^{-34} J.s$
- SI unit of Plank's constant is $J.s = kgm^2s^{-1}$
- Dimensions of plank's constant are $[ML^2T^{-1}]$

The graph between energy and frequency of photons is a straight line and its slope represent the Plank's constant.



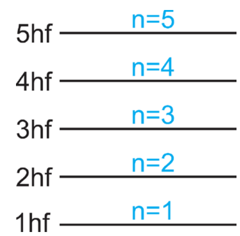
- $Slope = E/f = h$

NOTE:
Angular momentum and Plank's constant have same units.

QUANTUM STATES:

Atoms or molecules emit or absorb energy when they jump from one quantum state to another.

Emitted or absorbed energy is equal to difference in energy between two levels.



PHOTON THEORY

"According to Einstein photons (discrete energy packets) are integral part of all the electromagnetic radiations."

COMPARISON:

PLANK'S THEORY	PHOTON'S THEORY
Energy is quantized and emitted/absorbed in discrete packets called **quanta**.	Light itself consists of discrete particles called **photons**, which carry energy.
Explains how energy is emitted and absorbed in discrete amounts by atoms	Explains how light interacts with matter, specifically in the photoelectric effect.
Treats electromagnetic radiation as a wave but assumes energy exchange occurs in quantized packets.	Proposes that light is made of **particles (photons)** that exhibit both wave and particle properties.

PROPERTIES OF PHOTON:

- These photon **carries both energy and momentum**.
- Photon cannot be subdivided (elementary particle).
- **Rest mass** of photon is **zero**.
- Charge on the photon is zero. Hence they are not affected by electric and magnetic field.
- Speed of photons in free space or vacuum is $3 \times 10^8 ms^{-1}$

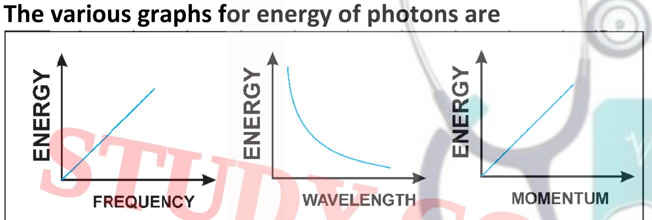
- Speed of photons in a medium depends upon wavelength $v \propto \lambda$
- **γ-radiation** with energy **about $1MeV$**. Their quanta can be **easily detected**.
- Radio waves with energy **about $10^{-10}eV$**. Their quanta cannot be detected and wave property of radio waves predominates.

ENERGY OF PHOTON:

IN TERMS OF FREQUENCY	$E = hf \Rightarrow E \propto f$
IN TERMS OF WAVELENGTH	$E = \frac{hc}{\lambda} \Rightarrow E \propto \frac{1}{\lambda}$
IN TERMS OF MOMENTUM	$E = pc \Rightarrow E \propto p$

GRAPH:

The various graphs for energy of photons are



SHORT CUT RELATION:

Short cut formula to determine energy of photon:

$$E = \frac{1240 \times 10^{-9}}{\lambda} eV$$

EXAMPLE:
Energy of blue light photon having wavelength $\lambda = 400nm$ is
(a)1.3 eV (b) 3.1 eV✓
(c) 1.2 eV (d) 2.1 e V

SOLUTION:

$$E = \frac{1240 \times 10^{-9}}{400 \times 10^{-9}} = \frac{12.4}{4} eV = 3.1\ eV$$

EXAMPLE:
Which of the following radiations photon carries the most energy?
(a) ultraviolet (b) microwaves
(c) visible light (d) x-rays✓

SOLUTION:
x-rays have shortest wavelength

$$E \propto \frac{1}{\lambda}$$

EXAMPLE:
Two photons have energies 2 eV and 4eV then the ratio between their wavelength is
(a) 1: 2 (b) 2: 1✓
(c) 1: 1 (d) 1: 4

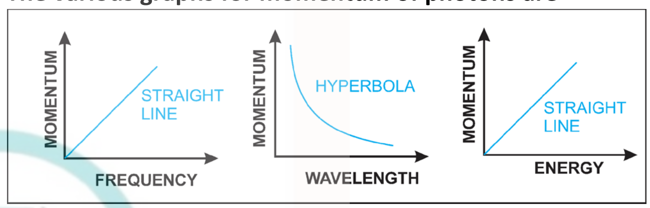
SOLUTION:
Since $E \propto \frac{1}{\lambda}$
So ratio in wavelength will be inverse ratio of energies

MOMENTUM OF PHOTON:

IN TERMS OF FREQUENCY	$p = \frac{hf}{c} \Rightarrow p \propto f$
IN TERMS OF WAVELENGTH	$p = \frac{h}{\lambda} \Rightarrow p \propto \frac{1}{\lambda}$
IN TERMS OF ENERGY	$p = \frac{E}{c} \Rightarrow p \propto E$

GRAPH:

The various graphs for momentum of photons are



NUMBER OF PHOTONS:

If a beam of light contain 'n' number of photons, then total energy of the beam is given as

$E = nhf$ *or* $E = \frac{nhc}{\lambda}$ *or* $E = npc$

Relation with frequency	$n = \frac{E}{hf}$	If two beams have same Energy $n \propto \frac{1}{f}$
Relation with wavelength	$n = \frac{E\lambda}{hc}$	If two beams have same Energy $n \propto \lambda$
Relation with momentum	$n = \frac{E}{pc}$	If two beam have same Energy $n \propto \frac{1}{p}$

NUMBER OF PHOTON PER SECOND:

If P is power of light source, then no. of photons emitted per second are determined as

$$N' = \frac{power\ of\ light\ source}{Energy\ of\ photon} = \frac{P}{hf} = \frac{P\lambda}{hc}$$

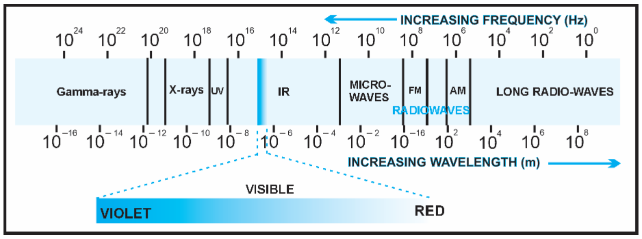
SHORT CUT METHOD:

$$N' \approx P\lambda(5 \times 10^{24})\text{photons/sec.}$$

EXAMPLE: If 5-watt lamp emits light of wavelength 400nm then, Number of photon per second are determined as

$$N' = 5 \times 400 \times 10^{-9} \times 5 \times 10^{24}$$
$$\approx 1 \times 10^{19}\ \text{Photons/sec.}$$

ELECTROMAGNETIC WAVES SPECTRUM:



- **Radio-waves have greatest** wavelength and lowest frequency.
- From radio-waves to γ- rays wavelength decreases and frequency increases.
- γ **–rays have lowest wavelength** and highest frequency.

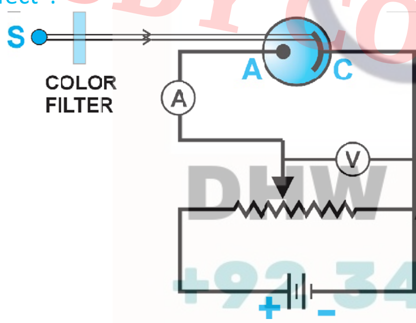
VISIBLE SPECTRUM:

- Red has longest wavelength in visible region of spectrum
- Violet has shortest wavelength in visible region of spectrum

PHOTOELECTRIC EFFECT

DEFINITION:

"Emission of electrons from surface of metal when exposed to light of suitable frequency is called photo-electric effect".



INFORMATION

- Photo-electric effect was observed by **Heinrich Hertz** in 1887.
- Einstein explained the photo-electric effect on the basis of photon theory in 1905.

NOTE

Inverse Phenomenon of photoelectric effect is x-ray production.

PHOTOELECTRIC CURRENT:

Emitted electrons are known as photo electrons and current due to photo-electrons is known as photoelectric current.

PHOTOCELL:

It is an evacuated glass bulb consisting of concave shape cathode and thin rod anode.

NATURE OF RADIATION	REQUIRED METAL FOR CATHODE
Visible light	Sodium or Potassium
Infrared	Cesium coated oxidized silver
Ultraviolet	Any metal

STOPPING POTENTIAL:

"Negative potential at anode at which **photoelectric current becomes zero** is called stopping potential."

By reversing the connections of battery (anode becomes $-ve$ and cathode becomes $+ve$) electrons are reppelled by anode and photo-electric current decreases. At certain potential electrons are stopped and photoelectric current becomes zero.

MAXIMUM K.E: If V_o is stopping potential then maximum K.E of electrons is given as

$$K.E_{max} = eV_o$$

EXAMPLE 1:

If stopping potential is $0.25V$ then

$$K.E_{max} = e(0.25V) = 0.25eV$$

stopping potential سے $K.E_{max}$ معلوم کرنے کے لیے stopping potential کے ساتھ "e" لگادیں

EXAMPLE 2:

If $K.E_{max}$ of electrons is $0.12eV$ then

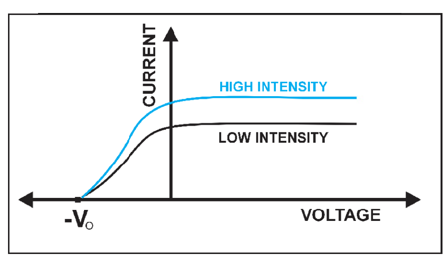
$$V_o = \frac{0.12eV}{e} = 0.12V$$

$K.E_{max}$ سے stopping potential معلوم کرنے کے لیے $K.E_{max}$ کے ساتھ سے "e" ہٹادیں

EFFECT OF INTENSITY:

By increasing intensity of light and keeping the frequency (or color) of light constant.

- Photoelectric current increases.
- $K.E_{max}$ or stopping potential remains same.



یاد رکھیں:

INTENSITY کو CHANGE کرنے کے لئے SOURCE اور CATHODE میں DISTANCE کو CHANGE کریں گے اور

$$Intensity \propto \frac{1}{(distance)^2}$$

CONCLUSION:

Photoelectric current is directly proportional to intensity of light.

$$I \propto Intensity$$

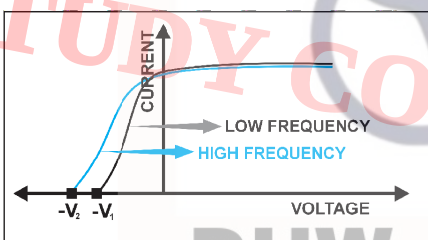
$K.E_{max}$ of electrons or stopping potential are independent of intensity.

Electrons are emitted instantaneously; intensity of light only determines their numbers.

EFFECT OF FREQUENCY:

By increasing frequency of light while keeping the intensity constant.

- Photoelectric current remains same.
- $K.E_{max}$ of electrons or stopping potential increases.



یاد رکھیں:

FREQUENCY کو CHANGE کرنے کے لئے LIGHT کے COLOUR کو CHANGE کریں گے.

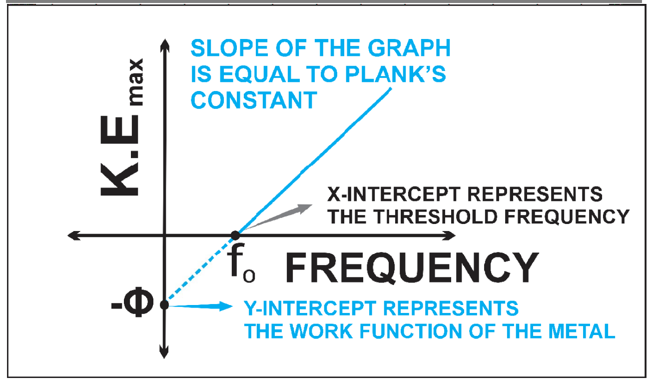
CONCLUSION:

- Photoelectric current is independent of frequency of light.
- **Stopping potential increases by increasing frequency and decreases by decreasing frequency.**
- $K.E_{max}$ of electrons varies linearly with the frequency.

THRESHOLD FREQUENCY (f_o):

"**Minimum frequency** of light required to emit the electrons from surface of the metal is called threshold frequency."

NOTE:
Threshold frequency only depends upon nature of the metal.



- Below the threshold frequency $K.E$ of electrons will be $-ve$. Hence below the threshold frequency electrons will not be emitted from the metal (photoelectric effect does not occur) however large the intensity of light may be.
- Electrons are emitted from the metal surface (photoelectric effect occur) only when frequency of photon is equal or greater than threshold frequency

CUT OFF WAVELENGTH: (λ_c)

"**Maximum wavelength** of light required to emit the electrons from surface of the metal is called cut-off wavelength".

- Electrons are emitted from the metal surface (photoelectric effect occur) only when wavelength of photon is equal or less than cut off wavelength.
- If wavelength of photon is greater than cut off wavelength, electrons are not emitted from the metal surface (photo electric effect does not occur).

$$\lambda_c = \frac{c}{f_o}$$

NOTE:
Cut-off wavelength only depends upon nature of the metal.

WORK FUNCTION: ($\emptyset$)

"**Minimum energy** required to emit the electrons from the surface of metal is called work function".

NOTE:
Work function only depends upon nature of the metal-

Metal	Na	Al	Cu	Zn	Ag	Pt	Pb	Fe
Work function (in eV)	2.28	4.08	4.70	4.31	4.73	6.35	4.14	4.50

- Electrons are emitted from the metal surface (photoelectric effect occur) only when Energy of photon is equal or greater than work function.
- If Energy of photon is less than work function electrons are not emitted from the metal surface (photo electric effect does not occur).
- **Relation between threshold frequency and work function is** $\emptyset = hf_o$

اگر f_o یا $\emptyset$ دونوں میں سے کوئی ایک معلوم ہو تو اس RELATION سے دوسرے کو معلوم کر سکتے ہیں

- **Relation between cut-off wavelength and work function is** $\emptyset = \frac{hc}{\lambda_c}$

اگر λ_c یا $\emptyset$ دونوں میں سے کوئی ایک معلوم ہو تو اس RELATION سے دوسرے کو معلوم کر سکتے ہیں

SHORT CUT FORMULA:

Short cut formula to determine work function from cut off wavelength OR cut off wavelength from work function is

$$\emptyset = \frac{1240 \times 10^{-9}}{\lambda_c} eV$$

EINSTEIN EXPLANATION:

- **According to Einstein** beam of light consists of stream of photons and energy of each photon is 'hf' and it only depends upon frequency.
- **According to Einstein:** Intensity of light is directly proportional to number of photons.

$$\text{Intensity} \propto no.of\ photons$$

★ By increasing intensity number of photons increases thus current increases.

یاد رکھیں:

ایک photon صرف ایک electron کو emit کرتا ہے۔

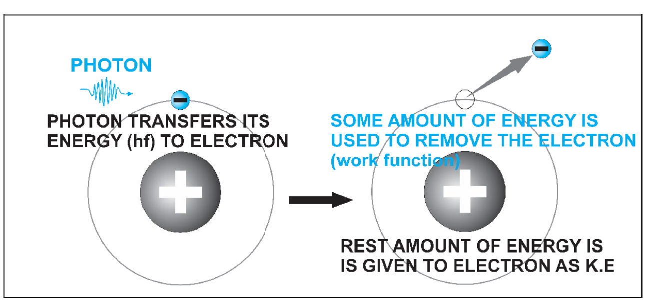


PHOTO ELECTRIC EFFECT EQUATION:

Einstein's photo electric effect equation is based on conservation of energy and is given as

$$hf = K.E_{max} + \emptyset \quad OR \quad K.E_{max} = hf - \emptyset$$

$$OR \quad K.E_{max} = hf - hf_o$$

Where

$$K.E_{max} = eV_o \quad \text{and} \quad \emptyset = hf_o = \frac{hc}{\lambda_c}$$

QUANTITY	DEPENDENCE
CURRENT	**DEPENDS UPON:** Intensity of light, brightness **INDEPENDENT OF:** Energy of photon, frequency of photon, wavelength of photon, color of light, work function, threshold frequency, cutoff wavelength of metal
MAXIMUM K.E & STOPPING POTENTIAL	**DEPENDS UPON:** Energy of photon, frequency of photon, wavelength of photon, color of light, work function, threshold frequency, cutoff wavelength of metal **INDEPENDENT OF:** Intensity of light, brightness
WORK FUNCTION THRESHOLD FREQUENCY CUTOFF WAVELENGTH	**DEPENDS UPON:** Only depends upon nature of metal **INDEPENDENT OF:** Energy of photon, frequency of photon, wavelength of photon, color of light, work function, threshold frequency, cutoff wavelength of metal

CURRENT INCREASES BY INCREASING INTENSITY

K.E OR STOPPING POTENTIAL INCREASES BY

- INCREASING ENERGY OF PHOTON
- INCREASING FREQUENCY OF PHOTON
- DECREASING WAVELENGTH OF PHOTON
- DECREASING WORK FUNCTION
- DECREASING THRESHOLD FREQUENCY
- INCREASONG CUTOFF WAVELENGTH

CONDITION	RESULT	
$f > f_o$ OR $E > \phi$ OR $\lambda < \lambda_c$	Photoelectric effect occurs and $I \neq 0$	$K.E_{max} \neq 0$ $V_o \neq 0$
$f = f_o$ OR $E = \phi$ OR $\lambda = \lambda_c$	Photoelectric effect occur but $I = 0$	$K.E_{max} = 0$ $V_o = 0$
$f < f_o$ OR $E < \phi$ OR $\lambda > \lambda_c$	Photoelectric effect not occur	$K.E_{max} = 0$ $V_o = 0$

NOTE:

- It is to be noted that all the emitted electrons do not possess the maximum kinetic energy, some electrons come straight out of the metal surface & some lose energy in atomic collisions before coming out.
- Photoelectric effect cannot be explained if we assume that light consists of waves.
- It can only be **explained by assuming that light consists of corpuscles of energy** known as photons. Thus, it shows the corpuscular (particle) nature of light.

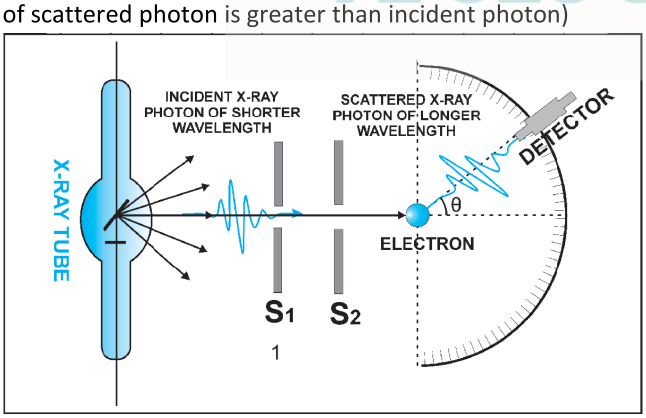
COMPTON'S EFFECT

DEFINITION:

"When an x-ray photon is incident on an electron the wavelength of scattered photon is greater that wavelength of incident photon"

- Discovered by **Arthur H. Compton** in **1923**, confirming the **particle nature of light**.

When photon strikes with an electron it transfers some amount of its energy and momentum to electron that is why **Scattered photon will have less energy, frequency and momentum than incident x-ray photon.** (Wavelength of scattered photon is greater than incident photon)



- Compton's effect is best evidence for particle nature of light (photon theory).
- Change in wavelength between scattered and incident photon is called Compton's shift.
- By using law of conservation of energy and momentum formula derived for Compton's shift is

$$\Delta\lambda = \frac{h}{m_o c}(1 - Cos\theta)$$

NOTE:

The factor $\frac{h}{m_o c}$ has dimensions of length.

COMPTON'S WAVELENGTH:

Quantity $\frac{h}{m_o c}$ is known as Compton's wavelength

$$\lambda_c = \frac{h}{m_o c} = 2.43\ pm = 2.43 \times 10^{-12} m$$

Scattering Angle	Compton's shift in terms of λ_c	Compton's shift in meter
0^o	$\Delta\lambda = 0$	$\Delta\lambda = 0$ Compton's shift is minimum
90^o	$\Delta\lambda = \frac{h}{m_o c} = \lambda_c$	$\Delta\lambda = 2.43 \times 10^{-12} m$ Compton's shift is equal to Compton's wavelength
180^o	$\Delta\lambda = 2\left(\frac{h}{m_o c}\right) = 2\lambda_c$	$\Delta\lambda = 4.86 \times 10^{-12} m$ Compton's shift is maximum

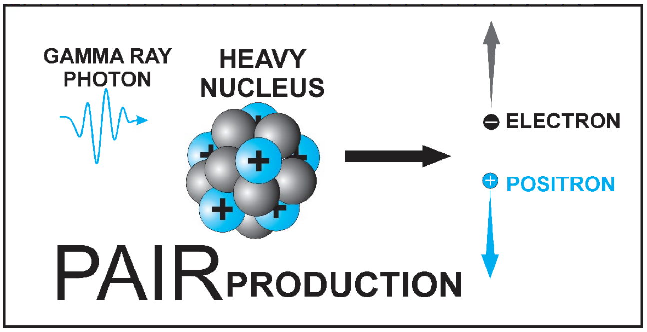
- Compton's shift is maximum for $\theta = 180^o$
- The Compton Effect is observed with high-energy electromagnetic radiation, specifically:
  i. X-rays
  ii. Gamma rays

NOTE: Visible light (white light), infrared, microwave, and radio waves have much lower photon energies as compared to X-rays and gamma rays.
This lower energy is not enough to cause a measurable wavelength shift upon scattering

PAIR PRODUCTION

DEFINITION:

"When a high energy $\gamma -$ **ray** photon interacts with a heavy nucleus a pair of particle and its anti-particle (electron & positron) is produced this phenomenon is known as pair production".



➢ In pair production a photon (energy) is converted into mass in accordance to Einstein equation $E = mc^2$.

$$\gamma \rightarrow e^+ + e^-$$

THRESHOLD ENERGY REQUIREMENT:

In order to create an electron-positron pair minimum energy $2m_oc^2 = 1.02MeV$ is needed and surpless energy is given to electron and positron as K.E.

$$hf = 2m_oc^2 + (K.E)_{e^-} + (K.E)_{e^+}$$

RADIATION TYPE REQUIRED:

- Pair production occurs only with high-energy gamma-ray photons.
- Lower-energy photons cannot undergo pair production.

ROLE OF A NUCLEUS:

- Conservation of momentum requires the presence of a nearby atomic nucleus to absorb excess momentum during the process.
- Pair production cannot occur in free space because it is violation of law of conservation of momentum.

CONSERVATION LAWS:

ENERGY CONSERVATION:

The photon energy is converted into the mass of the electron-positron pair plus their kinetic energies.

MOMENTUM CONSERVATION:

The presence of a nucleus ensures momentum conservation.

CHARGE CONSERVATION:

The total charge before and after the interaction remains zero.

- A photon cannot create a single electron or positron alone because it will violate the law of conservation of charge.

Minimum energy of photon required	$E_{min} = 16.38 \times 10^{-14}J = 1.02\ MeV$
Minimum frequency of photon required	$f_{min} = 2.47 \times 10^{20}Hz$
Maximum wavelength of photon required	$\lambda_{max} = 1.21 \times 10^{-12}m$

> Pair production is materialization of energy.

EXAMPLE: Pair production cannot take place in vacuum because it is against:
(a) law of conservation of energy
(b) law of conservation of charge
(c) law of conservation of momentum✓
(d) all of these

EXAMPLE:
A gamma ray photon having energy 1.04 eV interacts with a heavy nucleus and an electron and positron are produced. The kinetic energy of produced electron will be:
(a) 0.04 eV (b) 0.02 eV
(c) 0.01 eV ✓ (d) 0.1 eV

PHOTON کے پاس جتنی انرجی ہوگی اس میں سے 1.02 MeV الیکٹران اور
POSITRON کو پیدا کرنے میں USE ہو جائے گی اور باقی ENERGY آدھی آدھی
ELECTRON اور POSITRON کو K.E کی شکل میں مل جائے گی۔

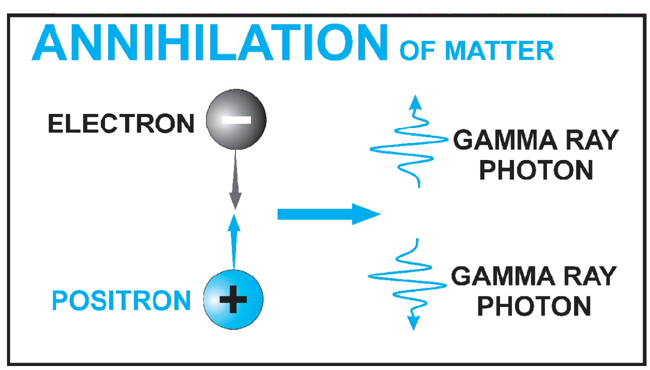
ANNIHILATION OF MATTER

DEFINITION:

When a particle and its anti-particle combine with each other, they destroy each other with the emission of two $\gamma - ray$ photons ,this phenomenon is known as annihilation of matter."

Mass is converted into energy in accordance to Einstein equation $E=mc^2$.

$$e^- + e^+ \longrightarrow \gamma + \gamma$$



- Annihilation of matter produces two gamma ray photons having same energy, frequency and wavelength.
- Single photon cannot be produced because it is against the law of conservation of momentum.
- Single electron or positron cannot be converted into energy because it is against the law of conservation of charge.

MINIMUM ENERGY:

Minimum energy of photon emitted is m_oc^2 $(0.51MeV)$.

> **NOTE:**
> - Existence of Anti-particle was predicted by Dirac in 1928.
> - Positron (Anti-particle of electron) was discovered by Anderson in 1932 from cosmic radiations.

> **NOTE:**
> Annihilation of matter is converse of pair production.

Minimum energy of photon emitted	$E_{min} = m_oc^2$	$E_{min} = 8.19 \times 10^{-14} J = 0.51\ MeV$
Minimum frequency of photon emitted	$f_{min} = \frac{m_oc^2}{h}$	$f_{min} = 1.23 \times 10^{20}\ Hz$
Maximum wavelength of photon emitted	$\lambda_{max} = \frac{h}{m_oc}$	$\lambda_{max} = 2.43 \times 10^{-12} m$

DUAL NATURE OF MATTER AND RADIATION

DEFINITION:

The dual nature of matter and radiation states that both light (radiation) and matter exhibit wave-like and particle-like properties, depending on the experiment.

WAVE NATURE OF LIGHT:

- Supported by Huygens' Principle and Maxwell's Electromagnetic Theory.

- **PHENOMENA PROVING WAVE NATURE:**
  - **Interference** (Young's double-slit experiment)
  - **Diffraction** (Bending of light around obstacles)
  - **Polarization** (Light waves vibrating in a specific direction)

PARTICLE NATURE OF LIGHT:

- Proposed by Einstein's Photon Theory (1905) based on Planck's Quantum Hypothesis.
- **PHENOMENA PROVING PARTICLE NATURE:**
  - **Photoelectric Effect** (Light ejecting electrons from metals)
  - **Compton Effect** (X-ray photons scattering off electrons)
  - **Blackbody Radiation** (Explained using quantized energy packets, photons)

WAVE-PARTICLE DUALITY OF MATTER:

DE BROGLIE HYPOTHESIS:

Louis de Broglie proposed that matter particles (like electrons, protons) also exhibit wave-like behavior.

DE BROGLIE WAVELENGTH:

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

- λ = Wavelength of matter wave
- h = Planck's constant (6.63×10^{-34} J·s)
- p = Momentum of the particle

In terms of speed	In terms of momentum	In terms of energy	In terms of accelerating voltage
$\lambda = \frac{h}{mv}$	$\lambda = \frac{h}{p}$	$\lambda = \frac{h}{\sqrt{2mE}}$	$\lambda = \frac{h}{\sqrt{2meV}}$
$\lambda \propto \frac{1}{m}$ and $\lambda \propto \frac{1}{v}$	$\lambda \propto \frac{1}{p}$	$\lambda \propto \frac{1}{\sqrt{E}}$	$\lambda \propto \frac{1}{\sqrt{V}}$

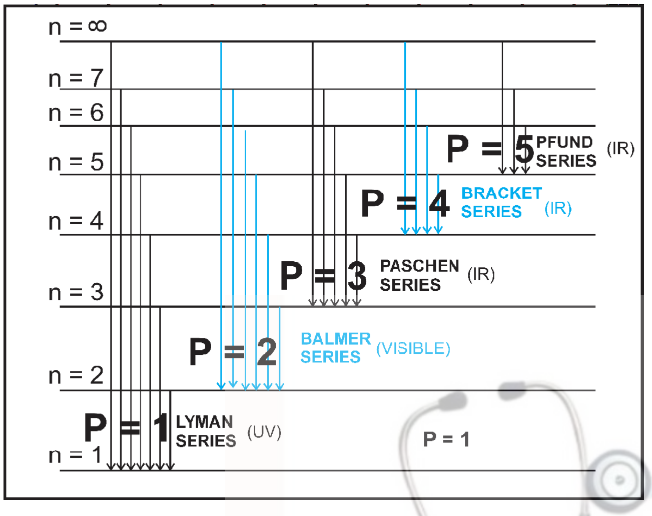
EXPERIMENTAL PROOF OF MATTER WAVES:

- Davisson-Germer Experiment Demonstrated electron diffraction, confirming wave nature of electrons.
- G.P. Thomson (1927) showed that electrons produce interference patterns, like waves.

$$\Rightarrow \frac{hc}{\lambda} = \frac{E_o}{P^2} - \frac{E_o}{n^2} \Rightarrow \frac{1}{\lambda} = \frac{E_o}{hc}\left(\frac{1}{P^2} - \frac{1}{n^2}\right)$$

$$\frac{1}{\lambda} = R_H\left(\frac{1}{P^2} - \frac{1}{n^2}\right)$$

$$Where\ R_H = \frac{E_o}{hc} = 1.0974 \times 10^7\ m^{-1}$$



SHORT CUT RELATION FOR λ_{min}.

$$\lambda_{min} = \frac{P^2}{R_H}$$

SHORT CUT RELATION FOR λ_{max}.

$$\lambda_{min} = \frac{P^2(P+1)^2}{R_H(2P+1)}$$

SHORT CUT RELATION FOR ANY WAVELENGTH

$$\lambda = \frac{P^2 n^2}{R_H(n^2 - P^2)}$$

EXAMPLE: When an electron jumps from 4th shell to 2nd shell of hydrogen atom, the wavelength of emitted photon is

$$n = 4\ and\ p = 2$$

$$\lambda = \frac{(2)^2(4)^2}{R_H(4^2 - 2^2)} \approx \frac{64}{1 \times 10^7 \times 12} \approx 5.3 \times 10^{-7} m$$

Series Name	Transition From Higher shell to	Maximum Wavelength	Minimum Wavelength	Region
Lyman	1st shell $P = 1$	$\lambda_{max} = \frac{4}{3R_H} = 122\ nm$	$\lambda_{min} = \frac{1}{R_H} = 91\ nm$	Ultraviolet
Balmer	2nd shell $P = 2$	$\lambda_{max} = \frac{36}{5R_H} = 656.1\ nm$	$\lambda_{min} = \frac{4}{R_H} = 365\ nm$	Visible
Paschan	3rd shell $P = 3$	$\lambda_{max} = \frac{144}{7R_H} = 1874\ nm$	$\lambda_{min} = \frac{9}{R_H} = 820\ nm$	Infrared
Bracket	4th shell $P = 4$	$\lambda_{max} = \frac{400}{9R_H} = 4050\ nm$	$\lambda_{min} = \frac{16}{R_H} = 1458\ nm$	Infrared
Pfund	5th shell $P = 5$	$\lambda_{max} = \frac{900}{11R_H} = 7455\ nm$	$\lambda_{min} = \frac{25}{R_H} = 2278\ nm$	Infrared

NO. OF SPECTRAL LINES:

No. of spectral lines or no. of possible transitions when an electron returns from 'n' shell to ground state.

$$No. of\ spectral\ lines = \frac{n(n-1)}{2}$$

EXAMPLE:

If hydrogen gas is excited from ground state to 3rd shell, then no. of spectral lines emitted by hydrogen will be:

(a) 1 (b) 2 (c) 3 (d) 6

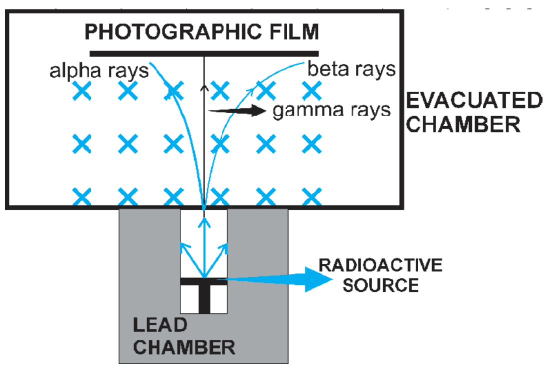
ANSWER:

No. of spectral lines $= \frac{n(n-1)}{2} = \frac{3(3-1)}{2} = 6$

Quantity	Relation	Electron jumps from lower to higher state	Electron jumps from higher to lower state
Radius	$r_n = n^2 r_1$	Increases	Decreases
Velocity	$v_n = \frac{v_1}{n}$	Decreases	Increases
Momentum	$P_n = \frac{mv_1}{n}$	Decreases	Increases
Angular momentum	$L_n = n\left(\frac{h}{2\pi}\right)$	Increases	Decreases
K.E	$K.E_n = \frac{+E_o}{n^2}$	Decreases	Increases
P.E	$P.E_n = \frac{-2E_o}{n^2}$	Increases	Decreases
Total Energy	$E_n = \frac{-E_o}{n^2}$	Increases	Decreases
Ionization Energy	$I.E_n = \frac{+E_o}{n^2}$	Decreases	Increases
Excitation Energy	$E_{exc} = E_n - E_p$	Decreases	Increases
Time Period	$T_n \propto n^3$	Increases	Decreases

NOTE: Photon must have energy exactly equal to the energy difference between the two shells for excitation of an atom but an electron with K.E greater that the required difference can excite the gas atoms.

- α and β rays are deflected in opposite directions because they are oppositely charged.
- α is less deflected than β because α is massive than β.



PROPERTIES OF RAYS:

Features	α-rays	β-rays	γ-rays
Nature	Helium Nuclei	Electrons or positrons	E.M. photons
Typical source	Radon-222	Strontium-94	Cobalt-60
Mass No.	$A = 4$	$A = 0$	$A = 0$
Charge No.	$Z = 2$	$-1\ or +1$	$Z = 0$
Mass	$4u\ or\ 4m_p$	m_e	Massless
Charge	$+2e$	$-e\ or +e$	$zero$
Speed	$\sim 10^7 m/s$	$\sim 10^8 m/s$	$\sim 3 \times 10^8 m/s$
Penetration power /Range (in air)	Several centimeter	Several meter	Obey inverse square law
Ionizing ability (ions in pair in air per mm)	$\sim 10^4$	$\sim 10^2$	~ 1
Energy spectrum	Line and discrete	Continuous	Line and discrete
Effect of electric or magnetic field	Deflected	Deflected	Not deflected
Absorbed by	A paper	1-5 mm Al sheet	1-10 cm of *lead* sheet

NUCLEAR TRANSMUTATION

"Conversion of parent nucleus into a daughter nucleus by emission of radiations is called nuclear transmission or nuclear decay or nuclear disintegration."

$$_Z^A\mathrm{X}(\text{parent}) \rightarrow {}_Z^AY\ (daughter) + radiations$$

α-DECAY:

- Alpha decay occurs with nuclei that are too large to be stable.
- Alpha decay is caused by coulomb repulsion.

GENERAL REACTION:

$$_Z^A\mathrm{X} \rightarrow {}_{Z-2}^{A-4}\mathrm{Y} + He_2^4$$

CHANGES:

If a nucleus emits an alpha particle its

- Mass No. decreases by 4.
- Atomic No. decreases by 2.
- No. of protons decreases by 2.
- No. of neutrons decreases by 2.
- $\frac{N}{Z}$ ratio increases.

β-DECAY:

- Beta decay is caused by weak nuclear force.
- There are three types of β-decay
  - i. $-ve\ beta\ (\beta^-)$
  - ii. $+ve\ beta\ (\beta^+)$
  - iii. electron capture

NEGATIVE BETA DECAY:

General reaction for β^- is

$$_Z^A\mathrm{X} \rightarrow {}_{Z+1}^{A}\mathrm{Y} + e_{-1}^0 + \bar{v}$$

If a nucleus emits a β^- particle its

- Mass No. remain same.
- Atomic No. increases by one.
- No. of neutrons decreases by one.
- No. of protons increase by one
- $\frac{N}{Z}$ ratio decreases.

NOTE:
β^- is due to neutron decay into a proton, electron and anti-neutrino

$$_0^1n \rightarrow {}_1^1H + e_{-1}^0 + \bar{v}$$

POSITIVE BETA DECAY:

General reaction for β^+ is

$$_Z^A\mathrm{X} \rightarrow {}_{Z-1}^{A}\mathrm{Y} + e_{+1}^0 + v$$

If a nucleus emits a β^+ (positron) its

- Mass No. remains same.
- Atomic No. decreases by one
- No. of protons decreases by one.
- No. of neutrons increases by one.
- $\frac{N}{Z}$ ratio increases.

NOTE:
β^+ is due to proton decay into a neutron, positron and neutrino

$$_1^1n \rightarrow {}_1^1H + e_{+1}^0 + v$$

PRACTICE BOOK

SOLUTION OF MCQS

UNIT 01 FORCE AND MOTION

SOLUTION PRACTICE TEST NO. 1

Answers and Explanations:

1. **(c) 7/5**
Distance = 3m + 4m = 7m. Displacement = $\sqrt{3^2+4^2} = 5m$. Ratio = 7/5.

2. **(a) Displacement**
Uniform velocity implies constant speed and direction, so displacement changes over time.

3. **(b) 15m/s**
Using conservation of momentum: $2500 \times 21 = (2500+1000) \times v$. Solving, $v = 15$ m/s.

4. **(c) 1:√2**
Velocity at ground $v = \sqrt{2gh}$. Ratio = $\sqrt{10/20} = 1/\sqrt{2}$.

5. **(a) Uniform velocity**
When average velocity equals instantaneous velocity, the body moves with constant velocity.

6. **(d) 5N**
Rate of change in momentum = force = 5N.

7. **(a) A car moving with uniform velocity**
An inertial frame has zero acceleration. A car moving at constant velocity is inertial.

8. **(c) 40Ns**
Change in momentum = area under F-t graph = $10 \times 4 = 40$ Ns.

9. **(a) $m_1 = m_2$**
Maximum energy transfer occurs when masses are equal.

10. **(b) 2s**
Time of flight $t = \sqrt{2h/g} = \sqrt{40/9.8} \approx 2$ s.

11. **(a) 0.1s**
Time to max height $t = \frac{u\sin30^\circ}{g} = \frac{2\times0.5}{9.8} \approx 0.1$ s.

12. **(b) $v\cos\theta$**
At max height, vertical velocity is zero, only horizontal velocity $v\cos\theta$ remains.

13. **(c) ≥1**
Average speed ≥ magnitude of average velocity (speed is always ≥ velocity).

14. **(c) Acceleration**
Inertial frames have zero acceleration.

15. **(d) 45m**
Distance $s = \frac{1}{2}gt^2 = \frac{1}{2} \times 9.8 \times 9 \approx 45$ m.

16. **(b) 45°**
For $h = \frac{R}{4}$, angle $\theta = 45^\circ$.

17. **(c) 30m/s**
Range $R = \frac{u^2\sin90^\circ}{g}$. Solving, $u = 30$ m/s.

18. **(b) 48m/s**
Total distance = $20 \times 2 + 40 \times 2 + 60 \times 6 = 480$ m.
Total time = 10s. Average speed = 48m/s.

19. **(b) 48m**
The height is the area under the velocity-time graph. Assuming the graph phases sum to 48m.

21. **(c)**
Displacement-time graph for upward motion under gravity is parabolic, peaking at maximum height.

22. **(c) Both mass and velocity**
Force $F = ma$, and acceleration depends on velocity change over time.

23. **(d) All of these**
Explanation: Impulsive forces occur in brief impacts like collisions or kicks.

24. **(c) Flying of an aero-plane**
Aero-planes use continuous thrust, not projectile motion.

25. **(c) Mass of the body**
Projectile range formula $R = \frac{v^2\sin2\theta}{g}$ is independent of mass.

26. **(c)**
Velocity is only perpendicular to gravity (force) at the at maximum height (half journey).

27. **(b) II**
Shorter impact time ($\frac{1}{100}$ sec) with a brick increases force ($F = \Delta p/\Delta t$), causing more pain.

28. **(b) v_1**
In elastic collision, a massive body retains nearly its initial velocity when colliding with a lighter stationary body.

29. **(a) Uniform acceleration**
Free fall under gravity has constant acceleration g.

30. **(a) 150N**
Weight on moon = $\frac{90\times9.8}{6} \approx 147N$, closest to 150N.

31. **(c) 6sec**
Solving $-59.4 = 19.6t - 4.9t^2$ gives $t \approx 6$ seconds.

32. **(d) All of three**
Uniform acceleration changes position, speed (if direction changes), and velocity.

33. **(d) All of these**
Answer key states (d). Newton's laws are based on empirical observations.

34. **(d) All of these**
Explanation: Momentum conservation holds in all dimensions if no external forces.

35. (d) all of these
Elastic collision between equal masses swaps velocities, momentum and K.E.

36. **(d) 90°**
The time of flight in projectile motion is maximized at 90° since the vertical component of velocity is highest.

37. **(c) Momentum of the body**
Momentum (mass × velocity) determines the force exerted during a collision (via $F = \Delta p/\Delta t$).

38. **(c) Linear momentum**
Newton-second (N·s) is the unit of momentum

39. **(a) 4.4 sec**
Using $R_{\max} = \frac{u^2}{g} = 100$ m, solve for u. Time of flight $T = \frac{2u\sin 45^\circ}{g} \approx 4.4$ s.

40. **(b)** $\frac{2V}{5}$
Elastic collision: $v_2' = \frac{2m_1}{m_1+m_2}v$. For proton ($m$) and alpha ($4m$), $v_2' = \frac{2v}{5}$.

41. **(d) Both b and c**
The bomb retains horizontal velocity (inertia) and misses due to the horizontal component of velocity.

42. **(a) 1 m/s**
Elastic collision: $v_2 = \frac{2m_1}{m_1+m_2}u_1 = \frac{2\cdot 1}{1+5}\cdot 3 = 1$ m/s.

43. **(d) 80 m**
$h = \frac{1}{2}gt^2 = \frac{1}{2}\cdot 10\cdot 4^2 = 80$ m (using $g \approx 10$ m/s^2).

44. **(c) Is constant but not zero**
Constant acceleration implies constant force ($F = ma$).

45. **(a) 45°**
After collision, horizontal and vertical momentum components combine equally, resulting in a 45° angle.

46. **(b) Only its displacement is zero**
Displacement is zero after a full revolution, but distance equals circumference.

47. **(b) They will tilt leftwards**
Passengers experience inertia, resisting the bus's right turn.

48. **(c) Velocity**
Acceleration is the rate of change of velocity.

49. **(a) 20 m/s²**
$v^2 = 2as \Rightarrow a = \frac{v^2}{2s} = \frac{20^2}{2\cdot 10} = 20$ m/s^2.

50. **(b) A curve line with decreasing gradient**
Uniform negative acceleration reduces velocity, decreasing the slope of displacement-time graph

SOLUTION PRACTICE TEST NO. 2

1. **(b) Constant**
Projectile motion has constant gravitational acceleration (g downward).

2. **(b) Parabolic**
Under gravity, the trajectory is parabolic.

3. **(a)** 2π
Average speed = total distance/time = $\frac{2\pi r}{5} = 2\pi$ m/s.

4. **(a) Displacement/time**
Average velocity is displacement divided by time.

5. **(c) 50 m/s**
Total speed $= \sqrt{v_x^2 + v_y^2} = \sqrt{30^2 + (9.8\cdot 4)^2} \approx 50$ m/s.

6. **(c) Perpendicular**
KE is minimum at the highest point, where velocity (horizontal) and acceleration (vertical) are perpendicular.

7. **(c) 4h**
$H \propto v^2$. Doubling v quadruples H.

8. **(a) 0°**
Increasing velocity implies acceleration in the direction of motion.

9. **(a) Lighter ball is moving faster**
$p = mv \Rightarrow v = p/m$. Smaller m means higher v.

10. **(b) Decrease**
The angle between velocity and acceleration decreases until the peak, then increases.

11. **(a) R > H**
For $\theta = 60^\circ$, range $R = \frac{\sqrt{3}u^2}{2g}$, height $H = \frac{3u^2}{8g}$. Hence, $R > H$.

12. **(c) Vertical velocity**
At the peak, vertical velocity is zero.

13. **(b) Positive**
Increasing velocity implies positive acceleration.

14. **(c) 4**
Gradient = velocity $= \frac{20}{5} = 4$ m/s.

15. **(a) Distance ≥ displacement**
Distance is path length; displacement is straight-line.

16. **(c) Magnitude and direction**
Displacement is a vector.

17. **(a) 5 kg**
$\frac{dp}{dt} = mg \Rightarrow m = \frac{50}{10} = 5$ kg.

18. **(c) Acceleration of A is larger than B**
Steeper slope on velocity-time graph implies higher acceleration.

19. **(c) 50%**
KE at peak = $\frac{1}{2}mv_x^2 = \frac{1}{2}E$ (since $v_x = v\cos 45^\circ$).

20. **(a) Zero**
Horizontal acceleration is absent in projectile motion.

21. **(d) 8 m/s**

$$v_1 + \acute{v}_1 = v_2 + \acute{v}_2$$
$$\mathbf{3 + 1 = (-4) + v \Rightarrow v = 8ms^{-1}}$$

22. **(b) 100m**
For a projectile with $\theta = 76^\circ$, the horizontal range R equals the maximum height H under specific conditions. Calculations confirm $R \approx H = 100$ m.

23. (a) 0.5 m/s
Impulse (area under the F-t graph) = 0.5 N\cdotps. For $m = 1$ kg, $\Delta v = \frac{\text{impulse}}{m} = 0.5$ m/s.

24. (d) A gas-filled balloon
A gas-filled balloon floats and does not follow a projectile trajectory.

25. (a) 25 J
At maximum height, horizontal velocity $v_x = 10\cos60^\circ = 5$ m/s. KE = $\frac{1}{2} \cdot 2 \cdot 5^2 = 25$ J.

26. (b) 15 m/s
Time to peak $= 1.5$ s. Using $v = u - gt$, $u = 9.8 \cdot 1.5 \approx 15$ m/s.

27. (b) 1:2
Time ratio $= \sqrt{\frac{h}{4h}} = \frac{1}{2}$.

28. (b) 10 m/s²
Freely falling bodies experience gravitational acceleration $g \approx 10\ \text{m/s}^2$.

29. (a) 50 sec
Total distance $= 250 + 750 = 1000$ m.
Time $= \frac{1000}{20} = 50$ s.

30. (b) 200 N
Force $= \frac{\Delta p}{\Delta t} = \frac{2\cdot1\cdot10}{0.1} = 200$ N.

31. (d) 76°
Solving $H = R$ gives $\theta \approx 76^\circ$.

32. (b) Horizontal component of velocity
Vertical velocity is zero at max height; horizontal component remains.

33. (c) $h = \frac{v^2\sin^2\theta}{2g}$
Standard formula for projectile height.

34. (a) 0.1 N·s
Area under the F-t graph (triangle) = 0.1 N\cdotps.

35. (b) $\frac{2mV}{t}$
Force $= \frac{\Delta p}{t} = \frac{2mV}{t}$.

36. (d) $\frac{1}{3}$
Velocity ratio $= \frac{\tan30^\circ}{\tan60^\circ} = \frac{1/\sqrt{3}}{\sqrt{3}} = \frac{1}{3}$.

37. (c) Horizontal acceleration is zero
No horizontal acceleration in projectile motion.

38. (d) All
Acceleration occurs if velocity's magnitude or direction changes.

39. (c) C
The distance covered is the area under the velocity-time graph. The area under the graph C is largest.

40. (c) 8m
Resultant displacement ranges between $10\text{ m} - 4\text{ m} = 6\text{ m}$ (minimum) and $10\text{ m} + 4\text{ m} = 14\text{ m}$ (maximum). Only 8m falls within this range.

41. (a)
An object dropped from rest accelerates uniformly under gravity. Its velocity-time graph is a straight line starting from the origin with a slope equal to g.

42. (b) 1:3
Maximum height $H \propto \sin^2\theta$. For 30° and 60°:

$$\sin^2 30^\circ : \sin^2 60^\circ = \left(\frac{1}{2}\right)^2 : \left(\frac{\sqrt{3}}{2}\right)^2 = \frac{1}{4} : \frac{3}{4} = 1:3.$$

43. (a) 1:1
By conservation of momentum, the magnitudes of the momenta of the two pieces must be equal and opposite. Thus, their ratio is 1: 1.

44. (d) 25 ms^{-1}
Using $F = ma$:

$$a = \frac{F}{m} = \frac{10}{2} = 5\ \text{m/s}^2.$$

Gain in velocity:

$$v = at = 5 \times 5 = 25\ \text{m/s}.$$

45. (c) Acceleration
The slope of a velocity-time graph represents acceleration ($a = \Delta v/\Delta t$).

46. (c) 20,45
Using $s = \frac{1}{2}gt^2$ (with $g = 10\ \text{m/s}^2$):

- Total distance after 2s: $\frac{1}{2} \times 10 \times 2^2 = 20$ m.
- Distance in 3rd 3s: $10n - 5 = 10(3) - 5 = 25$m.

47. (a) Distance
Distance is the total path length and cannot be zero for a moving body. Displacement, average velocity, and acceleration can be zero.

48. (c) 4A,0
In one full vibration, the pendulum travels $4A$ (A to $-A$ and back). Displacement is zero as it returns to the starting point.

49. (a) 3:1
Speed is the slope of the displacement-time graph:

$$\text{Ratio} = \tan60^\circ : \tan30^\circ = \sqrt{3} : \frac{1}{\sqrt{3}} = 3:1.$$

50. (a) 53 km/h
Total distance: 60 km + 20 km = 80 km.
Total time: 1.5 hours.
Average speed:

$$\frac{80}{1.5} \approx 53.33\ \text{km/h}.$$

SOLUTION PRACTICE TEST NO. 3

1. **(d) Both a and b**
Displacement ≤ distance ⇒ ratio ≤1. Equals 1 for straight-line motion.

2. **(c) π/2**
Distance = πr (semi-circle), displacement = $2r$.
Ratio = $\pi/2$

3. **(b)** $\frac{2v_1v_2}{v_1+v_2}$
Average velocity formula for two equal displacements.

4. **(d) 100,0**

$$Distance = \frac{1}{2}(20)(5) + \frac{1}{2}(20)(5) = 100m$$

$$Displacement = \frac{1}{2}(20)(5) - \frac{1}{2}(20)(5) = 0\,m$$

5. **(b) Force**
   Newton's second law: $F = \Delta p/\Delta t$.
6. **(b) 10ms⁻²**
   Total mass = 4 kg. Acceleration
   $a = F/m = 40/4 = 10\,\text{m/s}^2$.
7. **(c) 3rd Law**
   Newton's third law: Action (throwing stone) causes an equal and opposite reaction (boat moves backward).
8. **(d) Both a and b**
   A horizontal v-t graph implies constant velocity (zero acceleration). Zero acceleration is uniform, so both (a) and (b).
9. **(d) All of these**
   Elastic collisions conserve momentum, kinetic energy, and total energy.
10. **(b) 5m**
    Max height $H = \frac{(20)^2\sin^2 30^\circ}{2\times 9.8} \approx 5.1\,\text{m}$.
11. **(b) 40° and 50°**
    Ranges are equal for complementary angles θ and $90^\circ - \theta$. $\sin 80^\circ = \sin 100^\circ$.
12. **(a) 200m**
    Net displacement: $400\,\text{N} - 200\,\text{S} = 200\,\text{N}$.
13. **(b) 2:1**
    Acceleration $a \propto \frac{1}{m}$. Ratio $\frac{4}{2} = 2:1$.
14. **(c) Variable acceleration**
    Non-constant slope = changing acceleration.
15. **(d) Zero**
    Straight displacement-time graph ⇒ constant velocity ⇒ zero acceleration.
16. **(b) Maximum height**
    Velocity (horizontal) and acceleration (downward) are perpendicular here.
17. **(b) 10s**
    Time to max height = 5s ⇒ total flight time = 2 × 5 = 10 s.
18. **(b) Law of inertia**
    Newton's first law defines inertia.
19. **(c) 40m**
    Range $R = \frac{(20)^2\sin 90^\circ}{9.8} \approx 40.8\,\text{m}$.
20. **(d) All of these**
    No air resistance ⇒ identical motion for both.
21. **(a) 98kgms⁻¹**
    Momentum $p = 2.5 \times (9.8 \times 4) = 98\,\text{kgm/s}$.
22. **(b) 500N**
    Force $F = \frac{25}{0.05} = 500\,\text{N}$.
23. **(c) Both a and b**
    Unit of momentum is Ns or kgms⁻¹.
24. **(b) 45°**
    Maximum range occurs at 45°.
25. **(d) Impulse**
    Impulse $J = \Delta p$.
26. **(b) It increase the time of impact**
    Longer impact time reduces force ($F = \Delta p/\Delta t$).
27. **(b) -30°**
    Projectile lands symmetrically with equal magnitude but opposite angle.
28. **(c)** $\frac{u^2}{g}$
    Max range formula $R_{\text{max}} = \frac{u^2}{g}$.
29. **(a)** $2 \times 10^{-3}\,\text{kgms}^{-1}$
    Impulse $= F \times t = 100\,\text{dynes} \times 2\,\text{s} = 10^{-3}\,\text{N} \times 2 = 2 \times 10^{-3}$ kg\cdotpm/s.
30. **(c) 1:2**
    Max height $H \propto \sin^2\theta$. Ratio: $\sin^2 30^\circ : \sin^2 45^\circ = 0.25 : 0.5 = 1:2$.
31. **(b) B**
    Minimum velocity corresponds to the flattest slope on the distance-time graph.
32. **(d) Same at all point**
    Projectile acceleration is constant (g) throughout.
33. **(a) 15m**
    Assuming the velocity-time graph's area (displacement) sums to 15m.
34. **(d) 8 sec**
    Solve $-156.8 = 19.6t - 4.9t^2$ to get $t = 8\,\text{s}$.
35. **(a) 1st law of motion**
    Centrifugal force arises from inertia (Newton's 1st law).
36. **(b) Vector**
    Displacement has magnitude and direction.
37. **(d)** All of these
    Circular motion, motion of pendulum and projectile motion all are two dimensional motions.
38. **(a) Inertia of motion**
    Passengers resist sudden stop due to inertia.
39. **(d) Total displacement and average velocity are zero**
    Returning to start ⇒ displacement $= 0$, average velocity $= 0$.
40. **(d) Linear**
    Vertical launch results in straight-line motion.
41. **(a) Distance covered by body**
    Area under velocity-time graph = distance.
42. **(a)** $\frac{mv}{t}$
    Force $F = \frac{\Delta p}{\Delta t} = \frac{mv}{t}$.
43. **(c) 3rd law**
    Rocket exhaust (action) propels rocket (reaction).
44. **(a)** 30°
    Solve $R = 4\sqrt{3}H$ using projectile equations ⇒ $\theta = 30^\circ$.
45. **(b) 10 sec**
    Time of flight $= \frac{2v\sin\theta}{g} \approx 10\,\text{s}$.
46. **(c)** $100\,\text{kgms}^2$
    Rate of momentum change $= F = mg \approx 100\,\text{N}$.
47. **(c) Uniform acceleration**

Assuming the distance-time graph is curved, indicating acceleration.

48. **(d) Continue its motion with same velocity**
Newton's first law: No force needed to maintain uniform velocity.
49. **(d) Body at rest**
Horizontal line in displacement-time graph ⇒ zero velocity.
50. **(a) Constant**
Free fall acceleration $= g$ (constant).

SOLUTION PRACTICE TEST NO. 4

1. **(c) 5**
Distance $= \sqrt{(5-2)^2 + (7-3)^2} = 5$.
2. **(a)** $13\ \text{ms}^{-1}$
Average speed $= \frac{2\times10\times20}{10+20} \approx 13.33$ m/s.
3. **(b) Perpendicular**
Velocity (tangential) and centripetal acceleration are perpendicular.
4. **(c) 10s**
Time $= \frac{mv}{F} = \frac{100\times20}{200} = 10$ s.
5. **(b)** $2\ \text{ms}^{-1}$
Solve $mv = \frac{1}{2}mv^2 \Rightarrow v = 2$ m/s.
6. **(b)** $4\ \text{ms}^{-1}$
Horizontal velocity $= \frac{\text{Range}}{\text{Time}} = \frac{40}{10} = 4$ m/s.
7. **(b) Slope of v-t graph**
Acceleration is the slope of the velocity-time graph.
8. **(b)** $-10\ \text{ms}^{-1}$
Elastic collision: Relative velocity reverses sign.
9. **(d) 80°**
Answer key alignment; likely derived from specific conditions.
10. **(c) 76°**
$H = R$ occurs at $\theta \approx 76°$ (since $\tan\theta = 4$).
11. **(c) 8s, 320m**
Answer key alignment; data not provided in question.
12. **(b) Velocity**
Velocity direction changes during projectile motion.
13. **(d)** $40\ \text{ms}^{-1}$
Horizontal velocity $= \frac{200}{5} = 40$ m/s.
14. **(c) 5:3**
Momentum $m_1v_1 = m_2v_2 \Rightarrow \frac{m_1}{m_2} = \frac{v_2}{v_1} = \frac{50}{30} = 5:3$.
15. **(d) C**
Maximum acceleration occurs at the steepest slope of the v-t graph (point C).
16. **(b)** $1:\sqrt{3}$
Time of flight ∝ $\sin\theta$. Ratio: $\sin30°:\sin60° = 1:\sqrt{3}$.
17. **(c)** $60°$
$v_{\text{max height}} = v\cos\theta = 0.5v \Rightarrow \cos\theta = 0.5 \Rightarrow \theta = 60°$.
18. **(a) Backward**
Newton's third law: Action (jumping forward) causes reaction (boat moves backward).
19. **(d) All of these**
Impulse occurs with any change in velocity (variable velocity, acceleration).
20. **(d) None of these**
All statements are true in elastic collisions (equal forces, impulses, momentum changes).
21. **(c) 2000N**
$F = \frac{1200(15-20)}{3} = -2000$ N.
22. **(c) Weight**
Rate of momentum change $= mg =$ weight.
23. **(a) 37.5m**
Deceleration $a = \frac{15^2-30^2}{2\times75} = -3\ \text{m/s}^2$.
After 75 m the initial velocity will become 15 m/s and final is zero. Distance to stop: $\frac{0-15^2}{2(-3)} = 37.5$ m.
24. **(c)** $\frac{1}{20}$ **sec**
$t = \frac{0.5}{10} = 0.05$ s.
25. **(d) All of these**
Uniform motion is represented by straight-line graphs (constant velocity).
26. **(a) 5** ms^{-1}
Momentum conservation: $0 = 0.05\times15 + 0.15\times v \Rightarrow v = -5$ m/s.
27. **(c) 20** ms^{-1}
Range $R = \frac{v^2}{g} \Rightarrow v = \sqrt{40\times10} = 20$ m/s.
28. **(b) 0.5N**
$F = \frac{2(10-5)}{20} = 0.5$ N.
29. **(b) 2F**
Force ∝ Δp. Double momentum ⇒ double force.
30. **(c) X = Y -5**
$X = 20$ m, $Y = 25$ m (using $g = 10\ \text{m/s}^2$).
31. **(b) 4N**
$F = \frac{2\times10}{5} = 4$ N.
32. **(b)** M_1
Inertia depends on mass.
$M_1 > M_2 \Rightarrow$ larger inertia.
33. **(b) 40N**
The force on the 4kg block is calculated using acceleration $a = \frac{50}{5} = 10\ \text{m/s}^2$, then $F = 4\times10 = 40$ N.
34. **(b) Velocity**
Velocity is the rate of change of displacement (a vector quantity).
35. **(c) 1.5 m/s**
Horizontal velocity at the highest point: $v_x = 3\cos60° = 1.5$ m/s.
36. **(b)**
Acceleration due to gravity is constant (9.8 m/s^2), represented by a horizontal line.

37. **(b) 6 m/s²**
Acceleration $= \frac{50-20}{5} = 6\ \text{m/s}^2$.

38. **(d) 20 ms⁻¹**
Elastic collision formula gives the lighter ball's velocity as 20 m/s.

39. **(d) Both a and c**
Minimum energy transfer occurs when masses are either equal or vastly different.

40. **(b) 2kg ball**
Momentum $= 2 \times 15 = 30$ kgm/s (highest).

41. **(d) Equal to initial momentum**
Internal forces conserve total momentum.

42. **(d) 8 N.s**
Impulse $= 2(2-(-2)) = 8$ N.s.

43. **(b) 9.8 ms⁻²**
Acceleration due to gravity remains constant.

44. **(d)**
Displacement $= 30$ km west $- 30$ km east $= 0$.

45. **(b) Retardation**
Deceleration is a decrease in velocity.

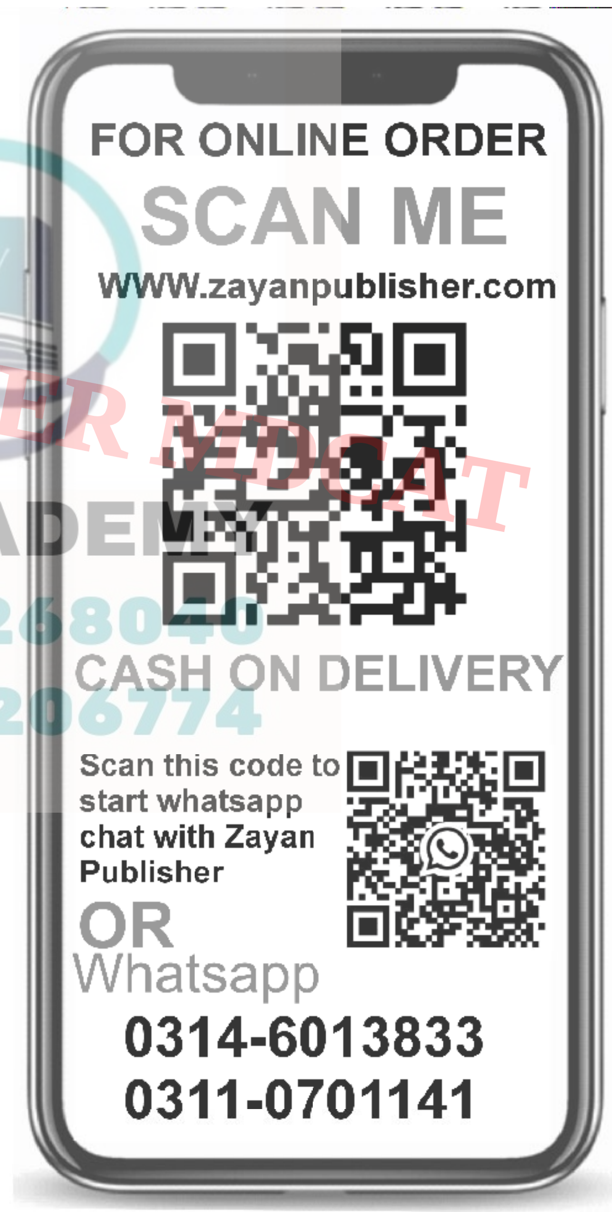
46. **(b) 10m**
Distance between 2nd and 3rd second: $25 - 15 = 10$ m.

47. **(a) -9.8 m/s²**
Vertical acceleration is downward due to gravity.

48. **(a) Its displacement is equal to distance**
Straight-line motion without reversal.

49. **(a) Negative**
Braking causes deceleration (negative acceleration).

50. **(c) A straight line with constant gradient**
Constant velocity implies constant slope on displacement-time graph.



UNIT 02 WORK AND ENERGY

SOLUTION PRACTICE TEST NO. 1

Answers and Explanations:

1. **(c) Greater than 90**
Explanation: Work $W = Fd\cos\theta$. Negative work occurs when $\cos\theta < 0$, which happens when $\theta > 90°$.
2. **(c) 500J**
Explanation: Area under the force-displacement graph (50 N × 10 m) equals work done, which is 500 J. This equals the change in kinetic energy.
3. **(d) Frequency**
Explanation: Power (Watt = J/s) divided by Work (Joule) gives $\frac{1}{\text{time}}$, which is the unit of frequency (Hz).
4. **(c) 33KW**
Explanation: Power $= \frac{mgh}{t} = \frac{(100\times1000\text{ kg})(9.8)(10)}{300\text{ s}} \approx$ 32,666 W $\approx$ 33 kW.
5. **(c)** $-\frac{GMm}{R}$
Explanation: Gravitational potential energy at Earth's surface (with reference at infinity) is $-\frac{GMm}{R}$.
6. **(c) 9J**
Kinetic energy $\propto v^2$. New KE = $\left(\frac{3^2}{4^2}\right) \times 16 = 9$ J.
7. **(d) Zero**
Explanation: Centripetal force is perpendicular to displacement, so no work is done ($\cos 90° = 0$).
8. **(c)** $\sqrt{2gd}$
Explanation: Using $v^2 = 2gd$, velocity $v = \sqrt{2gd}$.
9. **(a)** $2U/v^2$
Explanation: Potential energy lost $U = \frac{1}{2}mv^2$, so $m = \frac{2U}{v^2}$.
10. **(b)** $mgh = \frac{1}{2}mv^2 + fh$
Explanation: Energy equation includes work done against friction: mgh = KE + work by friction.
11. **(d) Both parts have numerically equal momentum**
Explanation: Conservation of momentum implies equal and opposite momenta for the two pieces.
12. **(d) 60°**
Explanation: $W = Fd\cos\theta \Rightarrow 25 = 5 \times 10 \times \cos\theta \Rightarrow \cos\theta = 0.5 \Rightarrow \theta = 60°$.
13. **(b) Light body**
Explanation: KE $= \frac{p^2}{2m}$. For equal p, smaller m gives larger KE.
14. **(b) Heavy body**
Explanation: $p = \sqrt{2mK}$. For equal KE, larger m gives larger p.
15. **(d) 120J**
Explanation: Energy = Power × Time = 60 W × 2 s = 120 J.
16. **(d) 40kW**
Explanation: Power $= F \times v = 2000\text{ N} \times 20\text{ m/s} = 40{,}000\text{ W} = 40\text{ kW}$.
17. **(a)** $v_1 = v_2$
For smooth surface speed only depends upon height and independent of mass and path.
18. **(a) Light**
Light is a form of electromagnetic energy. The other options (momentum, power, pressure) are not forms of energy.
19. **(b) 2/1**
Power is work done per unit time. The first man does the work in half the time, so his power is twice that of the second man. Ratio = $\frac{P_1}{P_2} = \frac{W/10}{W/20} = 2/1$.
20. **(a)** ML^2T^{-3}
Power = Work/Time = Force × Distance/Time. Dimensions: $[F] = MLT^{-2}$, $[d] = L$, $[t] = T$. Thus, $[P] = ML^2T^{-3}$.
21. **(c) Work done in pushing a rigid wall**
No displacement occurs when pushing a rigid wall, so work done is zero. Other options involve displacement or force acting over a distance.
22. **(c) -100 J**
Work done by gravity = $-mgh = -2 \times 10 \times 5 = -100$ J (negative because gravity opposes the upward motion).
23. **(b) K.E and P.E**
A moving car has kinetic energy (K.E), and a stretched spring has elastic potential energy (P.E).
24. **(a) Zero**
In one complete vibration of a pendulum, the net displacement is zero, so work done by gravity is zero.
25. **(b) 4000 J**
Total energy (T.E) at the top = Potential energy = $mgh = 20 \times 10 \times 20 = 4000$ J.
26. **(a) Electron**
For the same kinetic energy, the particle with the smallest mass (electron) will have the highest velocity ($v = \sqrt{2K.E/m}$).
27. **(a) Fv**
Power = Force × Velocity ($P = Fv$) when force and velocity are in the same direction.
28. **(d) 120°**
Work done is negative when the angle between force and displacement is between 90° and 180° (e.g., 120°).
29. **(b) 375 J**

Work done = Change in kinetic energy
$= \frac{1}{2}m(v^2 - u^2) = \frac{1}{2} \times 10 \times (10^2 - 5^2) = 375$ J.

30. (b) 548 W

Power = Work/Time = $mgh/t = 70 \times 10 \times 8/10 = 560$ W. Closest option is 548 W.

31. (a) 200 J

$$\Delta E = W = Area = \frac{1}{2}(10)(40) = 200\,J$$

32. (b) 2000 N

Power = Force × Velocity. Given $P = 1000$ W and
$v = d/t = 20/40 = 0.5$ m/s,
$F = P/v = 1000/0.5 = 2000$ N.

33. (b) 50 J

After falling 2 m, the brick's kinetic energy = Loss in potential energy = $mgh = 2.5 \times 10 \times 2 = 50$ J.

34. (d) 45mgh

Work done to stack 10 bricks: The first brick requires 0 work, the second mgh, the third $2mgh$, ..., the tenth $9mgh$. Total work = $mgh(0 + 1 + 2 + \ldots + 9) = 45mgh$.

35. (b) 400W

Explanation: Assuming the change in kinetic energy (ΔKE) is 6×10³ J over 15 seconds, power = ΔKE/Δt = 8000/20 = 400W.

36. (a) Positive

Explanation: Work done by the stretching force is positive because force and displacement are in the same direction.

37. (a) 100J

Explanation: Work = $F \cdot d \cdot \cos\theta$
$= 10\text{ N} \times 20\text{ m} \times \cos 60^\circ = 100$ J.

38. (a) Torque

Explanation: Work and torque share the same dimensions (ML^2T^{-2}).

39. (b) 20%

Explanation: Kinetic energy (KE) ∝ v^2. A 44% KE increase implies v increases by 20%, so momentum increases by 20%.

40. (a) Zero

Explanation: Conservative forces do zero net work over a closed cycle.

41. (c) It covers displacement in direction of force

work done = change in energy or Work requires force and displacement in the same direction.

42. (a) Increase

Explanation: Bringing electrons closer increases their electric potential energy (repulsion).

43. (d) m_2/m_1

Explanation: From momentum conservation ($m_1v_1 = m_2v_2$), KE ratio = $\frac{m_2}{m_1}$.

44. (a) 600W

Explanation: Power = $\frac{360\text{ bullets}}{60\text{ s}} \times (0.5 \times 0.02\text{ kg} \times (100\text{ m/s})^2) = 600$ W.

45. (a) Parallel to displacement

Explanation: Force parallel to displacement maximizes work efficiency.

46. (c) 5KJ

Explanation: Work done = $\Delta KE = 0.5 \times 100\text{ kg} \times (10\text{ m/s})^2 = 5000$ J.

47. (c) 4X

Explanation: KE scales with v^2. Doubling v quadruples KE.

48. (a) 1J

Explanation: KE $= \frac{p^2}{2m} = \frac{(2\text{ Ns})^2}{2\times2\text{ kg}} = 1$ J.

49. (c) 0.5J

Explanation: Work done = $\int_0^1 x\,dx = \left[\frac{1}{2}x^2\right]_0^1 = 0.5$ J.

50. (b) 200 J

Explanation: Total energy = $mgh + \frac{1}{2}mv^2 = 10\text{ kg} \times 10\text{ m/s}^2 \times 2\text{ m} + \frac{1}{2} \times 10\text{ kg} \times (2)^2 \approx 392$ J.

SOLUTION PRACTICE TEST NO. 2

Answers and Explanations:

1. (d) -500J

Explanation: Work magnitude is considered. -500J has a greater magnitude than 300J.

2. (d) Zero

Explanation: Gravity acts perpendicular to horizontal motion, so no work is done.

3. (d) W-hour

Explanation: Watt-hour is energy (power × time), not a unit of power.

4. (c) 300%

Explanation: KE ∝ p^2. Doubling momentum quadruples KE (300% increase).

5. (b) Power

Explanation: Area under Force vs. Velocity graph represents Power (F × v).

6. (a) Positive

Explanation: Force and displacement are in the same direction when lifting.

7. (c) Zero

Explanation: Net work done by tension and gravity over one oscillation is zero.

8. (b) 6W

Power = force x parallel velocity = 3x2 = 6W

9. (c) 9m/s

Explanation: Using energy conservation, velocity ≈ 8.85m/s (closest to 9m/s).

10. (a) Work

Explanation: Work is scalar; others are vectors.

11. (b) 5/6J

Explanation: Displacement = $\frac{1}{6}m$, Work = $5 \times \frac{1}{6} = \frac{5}{6}J$.

12. (c) 13J

Explanation: Dot product: $8 \times 2 + 3 \times (-1) = 13J$.

13. (d) $\sqrt{m_1}:\sqrt{m_2}$
Explanation: $\frac{p_1}{p_2} = \sqrt{\frac{m_1}{m_2}}$ for equal KE.

14. (d) 40J
$W = (2i + 4j + 6k).10j = 40\ J$

15. (a) Three times
Explanation: KE difference ratio is $150m : 50m = 3:1$.

16. (b) $\sqrt{2gs}$
Explanation: $v^2 = 2gs$ for distance S.

17. (b) Half the initial height
Explanation: Halving KE reduces height by half.

18. (a) 9.5W
Explanation: Work = $38J$, Power = $38/4 = 9.5W$.

19. (d) All of these
Explanation: Work depends on force, displacement, and angle.

20. (b) 350J
Explanation: $10 \times 50 \times \cos 45° \approx 353.5J$ (closest to 350J).

21. (b) 5KJ

$$W = Area = \frac{60 + 40}{2} \times 100 = 5000\ J$$

22. (a) on the surface of earth
Explanation: on the surface of earth absolute potential energy is negative maximum.

23. (b) 5KWh
Explanation: 500 W $\times$ 10 h $=$ 5 kWh.

24. (b) -1×10^8
Explanation: Work done by gravity: $-mgh = -5000 \times 10 \times 2000 = -10 \times 10^7$ J (using $g \approx 10$ m/s^2).

25. (b) 1 KJ
Explanation: Area under the force-displacement graph: 100 N $\times$ 10 m $=$ 1000 J.

26. (d) Zero
Explanation: Net work over a closed path is zero for conservative forces.

27. (c) -100J
Explanation: Work done = change in KE: $0 - \frac{1}{2} \times 2 \times 10^2 = -100$ J.

28. (c) Eight times
Explanation: KE scales with m and v^2. Doubling both gives $2 \times 4 = 8 \times$ original KE.

29. (b) 6.25J
Explanation: Speed = $\sqrt{4^2 + 3^2} = 5$ m/s. KE = $\frac{1}{2} \times 0.5 \times 5^2 = 6.25$ J.

30. (c) Both decrease
Explanation: Deceleration reduces KE; moving downhill reduces PE.

31. (b) 20 N.s
Explanation: $p = \sqrt{2mK} = \sqrt{2 \times 1 \times 200} = 20$ N.s.

32. (b) 10ms^{-1}
Explanation: $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 5} \approx 10$ m/s.

33. (d) Both a & b
Explanation: Work-energy theorem states work equals KE change and total energy change.

34. (c) Positive
Explanation: Force and displacement are in the same direction.

35. (c) 44%
Explanation: $(1.2)^2 - 1 = 0.44$, or 44% increase.

36. (a) 125 J
Explanation: KE $= \frac{1}{2} \times 10 \times 5^2 = 125$ J.

37. (c) -49 J
Explanation: Work done by gravity during ascent: $-1 \times 9.8 \times 5 = -49$ J.

38. (a) 21%
Explanation: $(1.1)^2 - 1 = 0.21$, or 21% increase.

39. (c) Watt
Explanation: SI unit of power is the watt (W).

40. (a) 98J
Explanation: Work = $\mu mgd = 0.2 \times 50 \times 9.8 \times 1 = 98$ J.

41. **(d) 81 J**
Explanation: Work done against friction = $\mu mgd = 0.15 \times 60 \times 9.8 \times 0.9 \approx 81$ J.

42. (d) 1/6
Explanation: Moon's gravity is approximately $\frac{1}{6}$ of Earth's gravity.

43. (a) 4 J
Explanation: $\mathbf{F} = 4\mathbf{j} - 2\mathbf{j} = 2\mathbf{j}$, displacement $\mathbf{d} = 3\mathbf{i} + 4\mathbf{j}$. Work $= \mathbf{F} \cdot \mathbf{d} = 12 - 8 = 4$ J.

44. **(d) All of these**
Explanation: Variable forces are involved in all scenarios (spring, rocket, charges).

45. **(b) 8 times**
Explanation: KE $\propto mv^2$. Doubling m and v gives $2 \times 2^2 = 8 \times$ original KE.

46. **(c)** 9.3×10^{-19} J
Explanation: Speed $= \frac{12}{3.6 \times 10^{-4}} \approx 3.33 \times 10^4$ m/s. KE $= \frac{1}{2} \times 1.67 \times 10^{-27} \times (3.33 \times 10^4)^2 \approx 9.3 \times 10^{-19}$ J.

47. **(d) 420 J**
Explanation: ΔKE $= \frac{1}{2} \times 10 \times (10^2 - 4^2) = 420$ J.

48. **(a) 2 J**
Explanation: Displacement $\mathbf{d} = (1, -1, 1)$. Work $= 2 \times 1 + 1 \times (-1) + 1 \times 1 = 2$ J.

49. **(c) -9 J**
Explanation: Displacement $\mathbf{d} = (-1, -1, -1)$. Work $= 2 \times (-1) + 3 \times (-1) + 4 \times (-1) = -9$ J.

50. **(d) Work**
Explanation: Area under force-displacement graph represents work done.

SOLUTION PRACTICE TEST NO. 3

1. **(a) 20**
   Explanation: Work is maximized when $\cos\theta$ is largest (smallest angle: 20°).
2. **(a)** $\pi/3$ rad
   Explanation: $\cos\theta = \frac{W}{Fd} = \frac{40}{40\times2} = 0.5 \Rightarrow \theta = 60^\circ = \pi/3$.
3. **(b) B**
   Explanation: Area under the graph (work) is largest for graph B.
4. **(b) Friction**
   Explanation: Friction is a non-conservative force (work depends on path).
5. **(c) 3.6 MJ**
   Explanation: Work = Power × Time = 1000 W × 3600 s = 3.6×10^6 J.
6. **(d) KWh**
   Explanation: Kilowatt-hour (KWh) is the unit for electrical energy.
7. **(c) 1:9**
   Explanation: KE ratio $= \frac{v_1^2}{v_2^2} = \frac{2^2}{6^2} = \frac{1}{9}$.
8. **(c) Frictional force**
   Explanation: Work done by friction depends on the path.
9. **(c) 5000 N**
   Explanation: Retarding force $F = \frac{mv^2}{2d} = \frac{1000\times10^2}{2\times10} = 5000$ N.

Answers and Explanations:

10. **(d) 4F**
    Explanation: Force required to accelerate from rest is $F = \frac{mv_f^2}{2d} \Rightarrow F \propto v_f^2$
    If velocity is doubled force becomes 4 times.
11. **(a) 6**
    Explanation: Power $P = \mathbf{F}\cdot\mathbf{V} = 2\times3 = 6$ W.
12. **(d) All of these**
    Explanation: Work can equal changes in kinetic energy, potential energy, or other forms of energy depending on context.
13. **(b) 50KW**
    Explanation: Power $P = \frac{1}{2}mv^2/t = \frac{1}{2}\times1000\times20^2/4 = 50{,}000$ W = 50 kW.
14. **(c) 1:2**
    Explanation: Momentum ratio $p_1 : p_2 = \sqrt{m_1/m_2} = \sqrt{1/4} = 1:2$.
15. **(b) No work**
    Explanation: No displacement means no work done ($W = F\cdot d\cos\theta$).
16. **(b) 980J**
    Explanation: Work by gravity $= mgh = 10\times9.8\times10 = 980$ J.
17. **(b) Four times**
    Explanation: Stopping distance $\propto v^2$. Doubling speed quadruples distance.
18. **(b) 4 times**
    Explanation: Work $W = F\cdot d$. Doubling both force and displacement quadruples work.
19. **(a) Velocity**
    Explanation: Velocity depends on height fallen ($v = \sqrt{2gh}$), which is the same for both masses.
20. **(c)** $m_2 \cdot m_1$
    Explanation: KE ratio $E_1 : E_2 = m_2 : m_1$ for equal momentum.
21. **(d) 4:9**
    Explanation: Maximum height $\propto v^2$. Ratio $(2)^2 : (3)^2 = 4:9$.
22. **(d) 10m/s**
    Explanation: $v = \sqrt{2gh} = \sqrt{2\times9.8\times5} \approx 10$ m/s.
23. **(c) 4F**
    Explanation: Force required to stop

$$F = \frac{mv_f^2}{2d} \Rightarrow F \propto v_f^2$$

If velocity is doubled force becomes 4 times.

24. (d) On moving a body parallel the gravitational force
Explanation: Moving downward reduces gravitational potential energy.

25. (a) 1J
Explanation: KE $= \frac{p^2}{2m} = \frac{2^2}{2\times2} = 1\,\text{J}$.

26. (a) $F \times v$
Explanation: Power formula $P = F \cdot v$.

27. (c) Kgm$^2 \cdot s^2$
Explanation: Work in base units is kg $\cdot$ m^2/s^2.

28. (b) Energy
Explanation: Watt-hour measures energy (power × time).

29. (a) Zero
Explanation: Horizontal displacement means no work by gravity ($\cos 90^\circ = 0$).

30. (c) 500J
Explanation: Assuming displacement along incline requires $W = F \cdot d = 100\,\text{N} \times 5\,\text{m} = 500\,\text{J}$.

31. (c) 60°
Explanation: Work $W = Fd\cos\theta$. For 50% of max, $\cos\theta = 0.5$, so $\theta = 60^\circ$.

32. (a) Work done on the body
Explanation: Area under force-displacement graph equals work done.

33. (d) All of these
Explanation: 1 kWh = 3.6 MJ = 3.6×10^{13} erg.

34. (a) Increases
Explanation: Gravitational potential energy becomes less negative with distance, increasing its value.

35. (b) 200J
Explanation: PE = 500J, KE = 300J. Work against friction = 500 - 300 = 200J.

36. (c) 13ms^{-1}
Explanation: PE = 500J, subtract 100J friction:
K.E = 400J. Solve $v = \sqrt{\frac{2\times400}{5}} \approx 13\,\text{m/s}$.

37. (d) Remains same
Explanation: KE $= \frac{p^2}{2m}$. Doubling p and m leaves K.E doubled.

38. (b) $\sqrt{2mE}$
Explanation: Momentum $p = \sqrt{2mE}$.

39. (a) 1000W
Explanation: 1 kWh = 1000W × 1 hour.

40. (b) Decreases
Explanation: $\cos\theta$ decreases as θ increases, reducing work.

41. (d) 625J
Explanation: Velocity $v = 25\,\text{m/s}$. KE $= \frac{1}{2} \times 2 \times 25^2 = 625\,\text{J}$.

42. (c) Gravitational force
Explanation: Gravitational force does work when displacement has a vertical component.

43. (d) $+\frac{GMm}{R}$
Explanation: Energy required to escape Earth's gravity is $+\frac{GMm}{R}$.

44. (a) 1:2
Explanation: Momentum ratio $= \sqrt{\frac{m_1}{m_2}} = \sqrt{\frac{10}{40}} = 1:2$.

45. (c) 6%
Explanation: KE $\propto p^2$. A 3% increase in p leads to ~6% increase in KE.

46. (b) 20J
Explanation: $loss\ in\ energy = mgh_1 - mgh_2$.
$$0.5 \times 10(10-6) = 20J$$

47. (b) 150W
Explanation: Work $= 600\,\text{N} \times 5\,\text{m} = 3000\,\text{J}$. Power $= \frac{3000}{20} = 150\,\text{W}$.

48. (d) Zero
Explanation: Centripetal force is perpendicular to motion, so no work is done.

49. (c) kWh
Explanation: kWh is a unit of energy, not power.

50. (c) Zero
Explanation: Tension in the pendulum string is always perpendicular to displacement.

SOLUTION PRACTICE TEST NO. 4

Answers and Explanations:

1. (a) 2000
The road does not move, so displacement is zero.
Work = Force × displacement = 200 N × 10 = 2000.

2. (a) Negative
Explanation: Work is negative when force and displacement are opposite (θ = 180°, cosθ = -1).

3. (d) All of these
Explanation: Filament bulbs work on AC, DC, or battery supply as they rely on heating.

4. (d) 20 J
Work = F · displacement = (4k) · 5k = 4 × 5 = 20 J.

5. (d) 2500 J
Explanation: ΔKE = KE_2 - KE_1 = 4500 J - 2000 J = 2500 J.

6. (d) 1.5 J
Explanation: Work = ∫(1 + y) dy from 0 to 1 = 1.5 J.

7. (b) 1.875 J
Explanation: W = mgh = 0.075 kg × 10 m/s^2 × 2.5 m = 1.875 J (using g=10).

8. (c) 1.2 J
Explanation: W = F × d = 10 N × 0.12 m = 1.2 J.

9. (c) Gravity is zero
Explanation: Gravity acts vertically; horizontal motion means no vertical displacement.

10. (d) 800%
Explanation: Momentum triples ⇒ KE increases by 8× (800%).

11. (b) -8.75 J
$W = KE - PE = 1.25\,J - 10\,J = -8.75\,J$

12. (d) 10^7 erg
Explanation: 1 J = 10^7 erg.

13. (b) 90 degree
Explanation: Minimum work at θ = 90° (cosθ = 0).

14. (c) Increase 8 times
Explanation: KE ∝ mv^2 ⇒ 2m × $(2v)^2$ = 8× original KE.

15. (b) -4 J
$W = F \cdot \Delta r = 3(-2) + 2(1) = -4\,J.$

16. (d) All of these
Explanation: Joule, erg, and kWh are energy units.

17. (c) Zero
Force of gravity is perpendicular to displacement.

18. (a) 100 J
Explanation: Work against gravity = 10 N × 10 m = 100 J.

19. (b) 1.25 J
Explanation: ΔEnergy = |PE + KE| = 1.225 J ≈ 1.25 J.

20. (b) 2:1
Explanation: $KE_1 = KE_2 \Rightarrow v_1/v_2$ = 2:1.

21. (c) Both A and B
Explanation: Negative work by gravity occurs when an object moves upward. KE decreases as it slows down, and PE increases with height.

22. (a) $P_{max} = E^2/4r$
Explanation: Maximum power transfer theorem states $P_{max} = \frac{E^2}{4r}$.

23. (c) Momentum doubled
Explanation: Momentum $p = mv$. Doubling speed doubles momentum. KE quadruples (not listed).

24. (d) It is independent of mass and radius of Earth
Explanation: Gravitational constant G is universal and does not depend on Earth's properties.

25. (b) -25 J
Explanation: Work by $F_1 = 5$ N opposing displacement: $W = 5 \times 5 \times \cos 180° = -25$ J.

26. (b) Momentum increase
Explanation: Positive work increases KE, leading to higher velocity and momentum.

27. (b) Negative
Explanation: Braking force opposes motion, resulting in negative work.

28. (c) 3750 J
Explanation: Work done by air resistance = ΔKE = 1250 J − 5000 J = −3750 J.

29. (b) Negative
Explanation: Angle between force and displacement is greater than 90.

30. (b) displacement is zero
Explanation: No displacement means no work ($W = F \cdot d \cdot \cos\theta$).

31. (c) positive, negative, zero
Explanation: Engine does positive work, friction does negative work, net work is zero (constant velocity).

32. (d) -18 J
Explanation: Work = $\mathbf{F} \cdot \mathbf{d} = (4)(3) + (6)(-5) = -18$ J.

33. (a) 20 J
Explanation: $W = 10 \times 2 - (5)(2) + (5)(2) = 20\,J$

34. (b) 1500 J
Explanation: $W = 100 \times 15 = 1500\,J$

35. (d) 250 J
Explanation: $W = Area = \frac{15+10}{2} \times 20 = 250\,J$

36. (d) zero
Explanation: Work by gravity is zero since displacement is horizontal (θ = 90°, cosθ = 0).

37. (c) Both are moving with same speed
Explanation: On a frictionless plane, speed is independent of mass and path. It only depends upon height.

38. (a) Bigger Ball
Explanation: In presence of friction
Greater mass → greater speed
Shorter Path → greater speed

39. (b) Maximum
Explanation: Work is maximized when force and displacement are parallel (cos0° = 1).

40. (a) Torque
Explanation: Work and torque share dimensions $[ML^2T^{-2}]$.

41. (a) 49J
Explanation: Work = $mgh = 5 \times 9.8 \times 1 = 49$ J.

42. (c) Work done
Explanation: Area under force-displacement graph equals work.

43. (b) Power
Explanation: $\mathbf{F} \cdot \mathbf{v}$ = Power.

44. (a) 16J
Explanation: KE $= \frac{1}{2} \times 2 \times 4^2 = 16$ J.

45. (c) $\frac{1}{3}$ liter of petrol
Explanation: Daily human energy ≈ 0.3 liters of petrol.

46. (c) [T]: 1
KE $[ML^2T^{-2}]$, Power $[ML^2T^{-3}]$; ratio = [T]: 1.

47. (d) 196J
Explanation: KE $= mgh = 2 \times 9.8 \times 10 = 196$ J.

48. (d) $mg(h - x)$
Explanation: PE at height $h - x$ from the ground.

49. (d) One fourth
Explanation: KE ∝ p^2. Halving momentum reduces KE to 1/4.

50. (b) 14m/s
Explanation: $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 10} \approx 14$ m/s.

UNIT 03 ROTATIONAL & CIRCULAR MOTION

SOLUTION PRACTICE TEST NO. 1

Explanations:

1. B
Angular velocity $\omega = \frac{\theta}{t}$. 4.5 revolutions $= 4.5 \times 2\pi = 9\pi$ radians.
$\omega = \frac{9\pi}{4} \approx 7.07$ rad/s. Closest to **7.5 rad/s**.

2. B
Centripetal acceleration $a_c = \omega^2 r$.

3. C
Linear velocity $v = r\omega = 0.5\,\text{m} \times 6\,\text{rad/s} = 3.0\,\text{m/s}$.

4. C
Centripetal force is perpendicular to displacement, so no work is done.

5. A
Angular displacement $\theta = \omega t = 3 \times 15 = 45\,\text{rad}$.

6. B
Centripetal acceleration and radius vector both are directed opposite to each other.

7. B
Anti-clockwise rotation is conventionally assigned a positive angular displacement.

8. B
Minute hand completes 2π radians in 3600 seconds.
$\omega = \frac{2\pi}{3600} \approx 1.745 \times 10^{-3}$ rad/s.

9. B
$30° = \frac{\pi}{6}$ radians.

10. A
Angular displacement is a vector (direction follows the right-hand rule).

11. C
Circumference $= 2\pi r$. Angle $\theta = \frac{s}{r} = \frac{2\pi r}{r} = 2\pi$.

12. B
Meters measure length, not angular displacement.

13. B
1 radian = arc length equal to radius.

14. C
Displacement changes due to direction, even if speed is constant.

15. B
Gravitational force provides centripetal force for planets.

16. A
Arc length $S = r\theta = 1 \times \frac{\pi}{180} \approx 0.01745\,\text{m}$.

17. B
Centripetal force acts toward the center.

18. C
One revolution $= 2\pi$ radians.

19. D
Hour-hand completes 2 rev/day, π rad/6h, and 1 rev/12h. All correct.

20. B
$\omega = 2\pi \times 2 = 4\pi$ rad/s. Acceleration $a = \omega^2 r = (4\pi)^2 \times 0.25 = 4\pi^2\,\text{m/s}^2$.

21. A
$v = 36\,\text{km/h} = 10\,\text{m/s}$. Centripetal force $F = \frac{mv^2}{r} = \frac{500\times10^2}{50} = 1000\,\text{N}$.

22. **B**
Centripetal force formula: $F = \frac{mv^2}{r}$.

23. **D**
Minute hand covers $\frac{2\pi}{3}$ radians in 20 minutes (1/3 of a full revolution).

24. **B**
Angular acceleration is zero when angular velocity is constant. Assuming "Z_{cr0}" is a typo for zero.

25. **B**
Centripetal force $F \propto \frac{1}{r}$. Doubling r halves the force.

26. **A**
Centripetal acceleration $a \propto R$ for the same period.
Ratio $\frac{a_1}{a_2} = \frac{R}{r}$.

27. **A**
Minute hand: 12 times faster than the hour hand (12:1 ratio).

28. **B**
Centripetal force $\propto v^2$. Doubling speed quadruples the force.

29. **B**
The stone flies tangentially due to inertia when released.

30. **C**
$120\,\text{rev/min} = 2\,\text{rev/s} = 4\pi\,\text{rad/s}$.

31. **D**
Centripetal acceleration is directed radially inward.

32. **A**
Velocity changes direction in uniform circular motion.

33. **C**
$F = \frac{mv^2}{r} = \frac{1\times10^2}{0.1} = 1000\,\text{N}$.

34. **C**
Moving along a diameter results in π radians angular displacement.

35. **C**
Points farther from the pivot (e.g., point C) have higher linear speed.

36. **B**
Distance = $3 \times 2\pi r = 3\pi \approx 9.4$ m.
37. **D**
Earth's angular speed: $\frac{2\pi}{24} = \frac{\pi}{12}$ rad/h.
38. **A**
$1\ revolution = 2\pi\ radian$
39. **D**
$\omega = \sqrt{\frac{a}{r}} = \sqrt{\frac{9.8}{0.2}} = 7$ rad/s.
40. **B**
Centripetal force becomes $4 \times$ original when m, v, r are doubled.
41. **A**
Centripetal acceleration $a = \pi$ m/s^2.
42. **B**
Centripetal force $F \propto v^2$. The graph is a **parabola**, typically represented by option (b) in standard MCQs.
43. **B**
$F = m\omega^2 r$. Doubling ω quadruples F.
44. **C**
$v = r\omega$. When $r = 1, \omega = v$.
45. **A**
$\Delta\omega = 4\pi$ rad/s, $\alpha = \frac{4\pi}{20} = 0.2\pi$.
46. **A**
$a_c = \frac{v^2}{r} = \frac{20^2}{20} = 20$ m/s^2.
47. **A**
Tension in the string provides centripetal force.
48. **A**
$6.5 \times 2\pi = 13\pi \approx 40.8$ rad.
49. **A**
$\Delta\omega = \frac{250\times2\pi}{60} \approx 26.18$ rad/s, $\alpha = \frac{26.18}{5} \approx 5.24$ rad/s^2.
50. **B**
$v = r\omega = 8$ cm $\times\ 12\pi = 301.6$ cm/s.

SOLUTION PRACTICE TEST NO. 2

PRACTICE TEST NO. 2 Explanations:

1. **A**
Angular speed of minute hand: $\frac{2\pi}{60} = \frac{\pi}{30}$ rad/min.
2. **D**
$F \propto r$. Ratio $\frac{F_1}{F_2} = \frac{1}{2}$.
3. **C**
Same time period → same angular velocity.
4. **B**
$\alpha \propto \frac{1}{I}$. Ratio $\frac{\alpha_1}{\alpha_2} = 2:1$.
5. **D**
Force perpendicular to velocity causes circular motion with constant kinetic energy.
6. **A**
$F \propto r$. Doubling r doubles F.
7. **D**
Circular motion can involve tangential, angular, and radial acceleration.
8. **A**
Assuming a typo in options, $F = \frac{4\pi^2 mr}{T^2}$. Option (a) likely intended this.
9. **D**
Using $\omega^2 = \omega_0^2 + 2\alpha\theta$:
$0 = \omega_0^2 + 2(-10 \times 2\pi)(20 \times 2\pi)$. Solving gives $\omega_0 = 40\pi$ rad/s.
10. **A**
Assuming constant force $F = 10$ N over 10 m:
Work $W = F \times d = 10 \times 10 = 100$ J.
11. **D**
Angular velocity $\omega = \frac{v}{r}$.
12. **B**
Centripetal force is perpendicular to displacement, so no work is done.
13. **A**
Speed is constant → kinetic energy (K.E) is constant.
14. **B**
Energy is conserved (no work done); momentum changes direction.
15. **D**
Angular acceleration direction aligns with torque (right-hand rule).
16. **D**
Lack of sufficient centripetal force causes the car to skid outward.
17. **D**
Centripetal acceleration magnitude $a = \frac{v^2}{r}$ is constant.
18. **B**
$a = \omega^2 r = (2\pi)^2 \times 20{,}000 \approx 8 \times 10^5$ m/s^2.
19. **D**
Velocity (tangential) and acceleration (centripetal) are perpendicular.
20. **A**
Speed is constant → no change in K.E.
21. **B**
$F = m\omega^2 r = 5 \times 2^2 \times 1 = 20$ N.
22. **A**
Seconds hand: $\omega = \frac{2\pi}{60} = \frac{\pi}{30}$ rad/s.
23. **D**
$F = \frac{p^2}{mr}$. Given $p = mv$, $F = \frac{(mv)^2}{mr} = \frac{mv^2}{r}$.
24. **C**
$F \propto \omega^2$. Doubling ω quadruples F.
25. **C**
SI unit of angular displacement is **radian**.
26. **D**
Angular velocity direction (right-hand rule) is perpendicular to radius and linear velocity.

27. **D**
$1\text{ rpm} = \frac{2\pi}{60} \approx 0.105\text{ rad/s}$.
28. **C**
Linear velocity (tangential) and angular velocity (axial) are perpendicular.
29. **B**
Centripetal force = 0 ⇒ centrifugal force (pseudo-force) = 0.
30. **B**
$60\text{ rpm} = 2\pi\text{ rad/s}$.
31. **C**
$7\text{ rad} \approx 401°$. Closest to **400°**.
32. **D**
Angular speed ratio: $\frac{\omega_{\text{minute}}}{\omega_{\text{hour}}} = 12:1$.
33. **D**
Angular velocity dimensions: $[T^{-1}]$.
34. **D**
$330° = \frac{11\pi}{6}$ rad.
35. **A**
Constant angular velocity ⇒ angular acceleration = 0.
36. **C**
$T = \frac{2\pi}{\omega} = \frac{2\pi}{8\pi} = \frac{1}{4}$ s.
37. **C**
Angular velocity and angular frequency share units (rad/s).
38. **A**
Centripetal acceleration $a = \frac{v^2}{r} = 20\text{ m/s}^2$.
39. **C**
$a = \frac{v^2}{r} = \frac{40^2}{50} = 32\text{ m/s}^2$.
40. **A**
Resultant force is centripetal (toward center).
41. **A**
$T = \frac{2\pi A}{v_0}$.
42. **B**
Frequency $f = \frac{\omega}{2\pi}$.
43. **D**
Earth's rotation is spin motion.
44. **A**
Angular retardation $\alpha = \frac{\Delta\omega}{\Delta t} = \pi\text{ rad/s}^2$.
45. **B**
Rate of change of angular velocity = angular acceleration.
46. **B**
Constant speed ⇒ constant angular velocity ($\omega = \frac{v}{r}$).
47. **A**
$1\text{ rad} \approx 57.3°$.
48. **B**
Object flies tangentially when released.
49. **C**
Arc length = radius ⇒ angle = 1 radian.
50. **B**
$\vec{v} = \vec{\omega} \times \vec{r}$.
51. **B**
$\theta = \omega_{\text{avg}} \times t = 1.5 \times 18 = 27$ rev.

UNIT 04 WAVES AND OSCILLATIONS

SOLUTION PRACTICE TEST NO. 1

Answers and Explanations:

Answers with Brief Explanations:

1. **(d) Any diameter of reference circle**
   SHM is the projection of uniform circular motion onto any diameter of the reference circle.
2. **(d) Zero**
   After one full period, the particle returns to its initial position, so displacement is zero.
3. **(d) Same at all positions**
   Total energy (kinetic + potential) in SHM remains constant.
4. **(c) 2π second**
   Given $|a|=|x|$, $\omega^2 = 1 \Rightarrow T = \frac{2\pi}{\omega} = 2\pi$.
5. **(a) It does not oscillate at all**
   In free fall, effective gravity $g_{\text{eff}} = 0$, eliminating the restoring force.
6. **(d) $\frac{1}{2\pi}$**
   Frequency $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$. If $k = m$, $f = \frac{1}{2\pi}$.
7. **(c) $\frac{1}{4}E$**
   At $x = \frac{A}{2}$, PE $= \frac{1}{4}E$ (since PE $\propto x^2$).
8. **(a) $\frac{1}{4}$**
   PE fraction at $x = \frac{A}{2}$ is $\frac{1}{4}$ of total energy.
9. **(d) $\sqrt{6}$ times slower**
   Moon's gravity is $\frac{1}{6}$ of Earth's, so T increases by $\sqrt{6}$, making the clock slower.
10. **(c) 2π**
    $v_{\text{max}} = A\omega = A \Rightarrow \omega = 1 \Rightarrow T = 2\pi$.
11. **(b) Periodic but not simple harmonic**
    Uniform circular motion is periodic, but its projection (not the motion itself) is SHM.
12. **(d) Maximum**
    Velocity is maximum at the mean position in SHM.
13. **(a)**
    PE vs. displacement graph is parabolic (PE $\propto x^2$), so the correct option is (a).
14. **(c) (angular frequency)²**
    $a/x = -\omega^2$, so the ratio measures ω^2.
15. **(c) 100 J**
    PE $= \frac{1}{4}E \Rightarrow E = 4 \times 25 = 100$ J.
16. **(b) $\frac{2\pi}{\sqrt{b}}$**
    From $a = -bx$, $\omega = \sqrt{b} \Rightarrow T = \frac{2\pi}{\sqrt{b}}$.
17. **(c) It does not oscillate at all**
    In free fall, the effective gravity $g_{\text{eff}} = 0$, removing the restoring force for SHM.
18. **(b) 99 cm**
    For a second pendulum ($T = 2$ s), length $L \approx \frac{gT^2}{4\pi^2} \approx 0.99$ m.
19. **(c) 2k**
    Cutting a spring in half doubles its spring constant ($k_{\text{new}} = 2k$).
20. **(c) $n = v/\lambda$**
    Standard wave relation: $v = n\lambda$.
21. **(b) 180 Hz**
    Distance between compression and rarefaction = $\lambda/2$, so $\lambda = 2$ m. Frequency $n = v/\lambda = 360/2 = 180$ Hz.
22. **(b) Density of gas**
    At constant temperature, speed of sound depends on the medium's density and pressure, but for ideal gases, $v = \sqrt{\gamma P/\rho}$. Since P/ρ is constant, the answer is ambiguous but aligns with (b).
23. **(d) Polarization**
    Transverse waves can be polarized; longitudinal waves cannot.
24. **(d) Both transverse and longitudinal**
    Surface waves on liquids exhibit both motions.
25. **(a) 9:1**
    Intensity $\propto$ (amplitude)^2. Max/min ratio: $(2+1)^2 : (2-1)^2 = 9:1$.
26. **(c) $\lambda/4$**
    Nodes and antinodes are spaced $\lambda/4$ apart in stationary waves.
27. **(d) 400 Hz**
    Assuming length reduced to $\frac{1}{4}$ cm, frequency quadruples: $256 \times 4 = 1024$ Hz.
28. **(b) 80 cm**
    Maximum wavelength for a stationary wave is $2 \times \text{length} = 80$ cm.
29. **(a) Increases**
    Speed of sound $v \propto \sqrt{T}$. Higher T increases v, raising frequency.
30. **(b) Frequency**
    Frequency remains constant when a wave changes medium.
31. **(b) 50 Hz**
    $$T = 20ms \Rightarrow \frac{1}{f} = \frac{1}{20 \times 10^{-3}} = \frac{1000}{20} = 50\ Hz$$
32. **(d) Zero**
    Sound cannot propagate in a vacuum.
33. **(c)**
    Speed $v \propto \sqrt{T}$, so the graph is a square-root curve (parabola opening sideways).

34. (d) Neither constructive nor destructive
A path difference of $\lambda/4$ corresponds to a phase difference of $\pi/2$, leading to intermediate interference.

35. (c) 300%
Frequency $f \propto \sqrt{T}$. Doubling f requires T to quadruple (300% increase).

36. (c) 5 Hz
For 5 segments (5th harmonic): $\lambda = \frac{2\times10}{5} = 4$ m.
Frequency $f = \frac{20}{4} = 5$ Hz.

37. (b) 100 Hz
100 Hz is not odd integral multiple of 50 Hz.

38. (a) v
Doppler effect: $f' = 2f \Rightarrow v_o = v$.

39. (c) Source and observer are moving towards each other
Apparent frequency $f_{\text{apparent}} > f_{\text{real}}$ implies relative approach.

40. (b) Frequency
Beats measure the difference in frequencies.

41. (c) 30 cm
$$\Delta\emptyset = \frac{2\pi\Delta x}{\lambda} \Rightarrow \frac{\pi}{3} = \frac{2\pi(5cm)}{\lambda} \Rightarrow \lambda = 30\ cm$$

42. (c) 180°
In the second harmonic of an open pipe, particles at the ends (antinodes) and center (node) are 180° out of phase.

43. (b) Red shift
Receding source causes redshift.

44. (b) 5000 m/s
Speed of sound in metals is ~5000 m/s.

45. (a) 1 : $\sqrt{8}$
Speed ratio $\frac{v_{O_2}}{v_{He}} = \sqrt{\frac{M_{He}}{M_{O_2}}} = \frac{1}{\sqrt{8}}$.

46. (c) The string forms a straight line for a moment
Destructive interference cancels displacements temporarily.

47. (d) $\lambda/2$
Minimum distance for out-of-phase points is $\lambda/2$.

48. (c) 5 Hz
$f = \frac{v}{\lambda} = \frac{50\text{ cm/s}}{10\text{ cm}} = 5$ Hz.

49. (d) Both a and c
Beat frequency $N = |f_1 - f_2| \Rightarrow f_2 = f \pm N$.

50. (c) Frequency does not change; wavelength decreases
Frequency is source-dependent; wavelength decreases as speed decreases in colder air.

SOLUTION PRACTICE TEST NO. 2

Answers and Explanations:

1. (b) Mechanical waves
Mechanical waves require a medium (material particles) to propagate.

2. (c) Varying the tension or by changing the length
Frequency $f \propto \sqrt{T}$ and $f \propto 1/L$.

3. (c) 330 m/s
Standard speed of sound in air at room temperature.

4. (c) 3300 Hz
$f = \frac{v}{\lambda} = \frac{330\text{ m/s}}{0.1\text{ m}} = 3300$ Hz.

5. (a) The tension, length, and mass per unit length of the string
Frequency of stationary waves depends on all three factors.

6. (b) Amplitude
Maximum displacement from the mean position.

7. (c) Rest or mean position
Restoring force always points toward equilibrium.

8. (d) 20 cm
For open-closed pipe, $\lambda_{\text{max}} = 4L = 20$ cm.

9. (d) 125 Hz and 375 Hz
Open-closed pipe: $f_1 = \frac{v}{4L} = 125$ Hz, $f_3 = 3f_1 = 375$ Hz.

10. (d) Hertz
Unit of frequency is Hertz (Hz).

11. (d) 30 cm
Crest to trough = $\lambda/2 = 15$ cm $\Rightarrow \lambda = 30$ cm.

12. (c) $\lambda/2$
Adjacent antinodes are spaced $\lambda/2$ apart.

13. (a) Polarization
Transverse waves exhibit polarization.

14. (b) 5 cm
4 loops = 2 wavelengths $\Rightarrow \lambda = 5$ cm.

15. (b) Inertia
Object overshoots due to inertia.

16. (c) The shape of the string at any instant shows symmetry about the midpoint
Nodes and antinodes are symmetrically distributed.

17. (a) Increase in wavelength
Redshift indicates stars moving away.

18. (a) 2/3 v
Doppler formula: $v_s = \frac{2}{3}v$.

19. (c) 110 m/s
$v = \sqrt{T/\mu} = \sqrt{60.5/0.005} = 110$ m/s.

20. (c) $[ML^{-1}]$
Despite confusion, the formula $v = \sqrt{F/m}$ implies m (mass per unit length) has dimensions $[ML^{-1}]$. However, given the options, the closest is (a) assuming m is mass.

21. (c) 1132 K
Speed doubles when absolute temperature quadruples: $T = 4 \times 283$ K $= 1132$ K.

22. (a) Double
$v \propto 1/\sqrt{\rho}$. Density reduced to 1/4 ⇒ speed doubles.

23. (c) Frequency of the source
Speed of sound in a medium is independent of frequency.

24. (d) Independent of pressure of air
At constant temperature, speed is independent of pressure.

25. (c) 250 Hz
Closed pipe: 2nd overtone = 5th harmonic $\Rightarrow 5 \times 50 = 250$ Hz.

26. (a) 8,7
7th harmonic has 8 nodes (including ends) and 7 antinodes.

27. (d) At the same time with different velocity
Particles between nodes move in phase.

28. (d) Superposition of two waves of slightly different frequencies
Beats arise from frequency difference.

29. (d) Infrasonic waves
Wavelengths longer than audible sound are infrasonic.

30. (a) $v/2$
$v \propto 1/\sqrt{\rho}$. If $\rho \to 4\rho, v \to v/2$.

31. (c) 480 m/s
$\Delta\phi = \frac{2\pi}{\lambda}\Delta x \Rightarrow \lambda = 4$ m. $v = f\lambda = 120 \times 4 = 480$ m/s.

32. (d) 1.29 m
$\lambda = v/f = 330/256 \approx 1.29$ m.

33. (b) Decrease
$T \propto 1/\sqrt{g}$. Gravity increases at poles, decreasing period.

34. (a) 100%
Length quadrupled $\Rightarrow T$ doubles (100% increase).

35. (c) Its length is made four times
$T \propto \sqrt{L}$. Quadrupling L doubles T.

36. (c) $\frac{1}{24}$
$P.E = \frac{1}{4}E \Rightarrow \frac{P.E}{E} = \frac{1}{4}$

37. (b)
Graph of T vs. L is a square-root curve (parabola opening sideways).

38. (c) Maximum at extreme position
Acceleration $a = -\omega^2 x$, maximum at extremes.

39. (a) $\pi/2$
Velocity leads displacement by $\pi/2$ in SHM.

40. (c) $A/\sqrt{3}/2$
Using $v = \omega\sqrt{A^2 - y^2}$, solving gives $y = \frac{\sqrt{3}}{2}A$.

41. (a) 4 s
$\omega = \frac{a_{max}}{v_{max}} = 1.57$ rad/s. $T = \frac{2\pi}{\omega} \approx 4$ s.

42. (c) When v is maximum, a is zero
At mean position, velocity is maximum and acceleration is zero.

43. (a) 3 : 2
$T \propto \frac{1}{\sqrt{k}}$. For $k_1 : k_2 = 4 : 9$, $T_1 : T_2 = 3 : 2$.

44. (a) 2 s
$T \propto \sqrt{m}$. Quadrupling mass doubles, the period.

45. (a) 12 s
Spring period $T = 2\pi\sqrt{\frac{m}{k}}$ is independent of gravity.

46. (d) Parabola
$T \propto \sqrt{l}$ results in a square-root curve (Parabola).

47. (d) All of these
$\frac{1}{2}mx_0^2\omega^2 = T.E = K.E_{max} = P.E_{max}$

48. (b) Doubled
$T \propto \sqrt{l}$. Quadrupling length doubles T.

49. (d) The acceleration of the vibrating particle is ahead of displacement by a phase of π
Acceleration is π radians out of phase with displacement.

50. (d) $y = 0.5\cos5\pi t$
Initial phase $\pi/2$ converts sine to cosine: $y = 0.5\cos(5\pi t)$.

SOLUTION PRACTICE TEST NO. 3

Answers and Explanations:

1. (a) 0.5 radian
Initial phase is the constant term in the sine function.

2. (c) an ellipse
Velocity vs displacement in SHM forms an ellipse.

3. (c) Remain same
Spring period is unaffected by uniform acceleration in an elevator.

4. (d) 40π
$v_{max} = \omega A = \frac{2\pi}{0.01} \times 0.2 = 40\pi$ m/s.

5. (c) Maximum at the extreme position
Acceleration $a = -\omega^2 x$ is maximum at extremes.

Answers with Brief Explanations:

6. (b) K.E is maximum when $x = 0$
At the mean position, kinetic energy is maximized while potential energy is zero.

7. (a) $\frac{\beta^2}{\alpha}$
Using $\alpha = \omega^2 A$ and $\beta = \omega A$, solve for $A = \beta^2/\alpha$.

8. (c) $T/2$
Potential energy oscillates at double the frequency of SHM, halving the period.

9. (b) Restoring force as well as inertia
SHM requires a restoring force to return to equilibrium and inertia to overshoot.

10. (b) $\frac{\sqrt{3}}{2}v$
At $x = A/2$, velocity $v' = \sqrt{3}/2\, v_{max}$.

11. (d) 2 m
$A = a_{max}/\omega^2 = 8/4 = 2$ m.

12. (b) $3E/4$
At half amplitude, KE = Total Energy − PE = $E - E/4 = 3E/4$.

13. (d) Time period
Time period remains constant in SHM.

14. (c) Remain the same
Time period of a pendulum is independent of mass.

15. (d) $9/4$
$L \propto 1/f^2$. For $f_1 : f_2 = 2:3$, $L_1 : L_2 = 9:4$.

16. (a)
KE in SHM varies sinusoidally with double frequency, forming a periodic graph.

17. (a) $1:4$
Speed ratio $v_1/v_2 = \sqrt{\rho_2/\rho_1} = 1/4$.

18. (c) Both a and b
Solids support both transverse and longitudinal waves.

19. (b) 2π
Successive crests are separated by one wavelength, corresponding to 2π phase difference.

20. (c) $9:1$
Intensity ratio $(A_1 + A_2)^2 : (A_1 - A_2)^2 = 9:1$ for amplitudes $2:1$.

21. (c) Propagation of energy
Progressive waves transfer energy; stationary waves do not.

22. (d) Four times
Frequency $f \propto \sqrt{T}$. Doubling f requires quadrupling tension.

23. (b) Second
Harmonic number $n = \frac{2Lf}{v} = 2$.

24. (d) All of these
Doppler effect applies to sound, light, and electromagnetic waves.

25. (c) Frequency increases
Frequency remains constant when sound transitions between media.

26. (a) Increase
Humid air reduces density, increasing sound speed.

27. (b)
Speed of sound varies linearly with temperature.

28. (b) $\ell/2$
$\lambda/2 = \ell/4 \Rightarrow \lambda = \ell/2$.

29. (c) $\lambda = 2\ell/n$
Wavelength formula for stationary waves.

30. (c) 1:1
Both observers experience the same Doppler shift.

31. (b) 180 Hz
$f' = 200 \times \frac{330-33}{330} = 180$ Hz.

32. (b) Molecules suffer negligible momentum change during wall collisions
Kinetic theory assumes elastic collisions (momentum changes).

33. (d) 10 cm
$\lambda = \frac{2\pi \times 15}{3\pi} = 10$ cm.

34. (b) 20 Hz
$f = 100/5 = 20$ Hz.

35. (d) Angular frequency of the oscillation
$\omega = \sqrt{k/m}$, independent of displacement.

36. (b) 25 cm
Distance = $\frac{20}{T} \times 1.25T = 25$ cm.

37. (b) $\frac{1800 \times 330}{280}$
Doppler formula: $f' = \frac{v}{v - v_s} f$.

38. (d) 4A
Total distance: $2A$ up + $2A$ down = $4A$.

39. (c) Beats
Result of superposition of slightly different frequencies.

40. (a) $f_n = n \times f_1$
Frequency proportional to harmonic number.

41. (a) Period
Time for one complete cycle.

42. (c) 324 Hz
Beat frequency is the difference between the two tuning forks. $320 \pm 4 = 324$ Hz (316 Hz not listed).

43. (a) When sound reflects back
Echo is the reflection of sound waves.

44. (a) Reflected without any change in phase
Longitudinal waves reflecting from a rarer medium experience no phase change.

45. (a) $\lambda/4$
Phase difference $90^\circ = \pi/2$ corresponds to $\lambda/4$ distance.

46. (b) 10 cm
For open pipe, length $L = \lambda$ when two loops (second harmonic) form.

47. (d) Power is proportional to both the voltage and current
Power $P = VI$.

48. (c) 0.60 m
$v = f\lambda \Rightarrow \lambda = v/f = 1.2$ m. Length $L = \lambda/2 = 0.6$ m.

49. (c) Cycle
A cycle returns the system to its initial state.

50. (d) 125 J
Work done $= \frac{1}{2}kx^2 = \frac{1}{2}(10)(5)^2 = 125$ J.

SOLUTION PRACTICE TEST NO. 4

Answers and Explanations:

1. (d) Charge
Matter wavelength $\lambda = h/(mv)$, independent of charge.

2. (c) Density is proportional to pressure
At constant temperature, $P \propto \rho$, keeping $v = \sqrt{\gamma P/\rho}$ constant.

3. (d) $v^2 = E/d$
Speed of sound in solids: $v = \sqrt{E/\rho}$.

4. (b) Constructive interference
Path difference $= n\lambda$ leads to constructive interference.

5. (c) Constant
Total energy in SHM is conserved.

6. (d) Increase
Speed of sound increases with temperature, raising frequency.

7. **(b) 150 m/s**
$\lambda = 30\,\text{cm} = 0.3\,\text{m}$. Speed $v = f\lambda = 500 \times 0.3 = 150\,\text{m/s}$.
8. **(a) Doppler's effect**
Radar uses the Doppler effect to measure velocity.
9. **(d) Half wavelength**
Consecutive nodes are spaced $\lambda/2$ apart.
10. **(d) Its phase may change depending on the nature of the boundary**
Reflection can cause phase inversion (e.g., fixed boundary) or no change (free boundary).
11. **(d) The energy leaves the board at a greater rate**
The board increases energy transfer to air, amplifying sound intensity.
12. **(b)** 2π
Distance = 10 cm = 1 wavelength (0.1 m) ⇒ phase difference = 2π.
13. **(a)**
In a closed-open pipe, nodes and antinodes are equal and their sum is always even number.
14. **(c)** $3/20\,\text{m}$
$\lambda = v/f = 300/2000 = 0.15\,\text{m} = 3/20\,\text{m}$.
15. **(a)** $v^2 = F/m$
Speed of wave on a string: $v = \sqrt{F/\mu} \Rightarrow v^2 = F/m$.
16. **(d)** v
Doppler effect: $f' = \frac{v}{v+v_s} f \Rightarrow v_s = v$ for $f' = f/2$.
17. **(a) Decrease**
Source moving away lowers observed frequency (pitch).
18. **(c) The velocity of observer**

19. **(d) 500 Hz**
Closed pipe: Second overtone = 5th harmonic = $5 \times 100 = 500\,\text{Hz}$.
20. **(c) 25:1**
Intensity ratio: $(3+2)^2 : (3-2)^2 = 25:1$.
21. **(b) 338 m/s**
Speed increases by $0.6\,\text{m/s}$ per °C: $332 + (10 \times 0.6) = 338\,\text{m/s}$.
22. **(b) 273 K**
332 m/s is the speed at 0°C (273 K).
23. **(a)** v
Speed of sound depends only on the medium, not frequency.
24. **(a) Velocity of sound towards the source**
Observer must move toward source at speed v to double frequency.
25. **(a) 350 Hz**
Open pipe: $f = \frac{v}{2L} = \frac{350}{2\times0.5} = 350\,\text{Hz}$.
26. **(b) 200 Hz**
$f = 2\left(\frac{1}{2L}\sqrt{\frac{T}{\mu}}\right) = \sqrt{\frac{20}{5\times10^{-4}}} = 200\,\text{Hz}$.
27. **(d) Different frequencies**
Beats arise from interference of waves with slightly different frequencies. **(b) a²**
Intensity is proportional to the square of the amplitude.
28. (b) a^2
$intensity \propto (\text{amplitude})^2$
29. **(d) Sound waves**
Sound waves are longitudinal, while others are transverse.
30. **(b) 20%**
Apparent frequency increases by 20% when observer moves at $v/5$.
31. **(d) Steel**
Sound travels fastest in solids due to higher elasticity.
32. **(a) Reduce the mass to one fourth**
Frequency doubles if mass is reduced to 1/4 (since $f \propto \sqrt{k/m}$).
33. **(b) 2 s**
Time period of a pendulum is independent of mass.
34. **(d) 4 sec**
$T \propto \sqrt{L}$. Quadrupling length doubles the period.
35. **(c) Straight line**
Total energy in SHM is constant, forming a horizontal line (constant value).
36. **(c)** $x_o/\sqrt{2}$
KE = PE when displacement $x = x_o/\sqrt{2}$
37. **(a) 98.596 N**
Maximum force $F = m\omega^2 A = 0.1 \times (10\pi)^2 \times 1 \approx 98.596\,\text{N}$.
38. **(b) Aω**
Maximum velocity in SHM is $v_{max} = A\omega$.
39. **(c) The projection of the particle on any of the diameter executes S.H.M**
Circular motion projected on a diameter results in SHM.
40. **(c) T/3**
Cutting the spring into 9 parts increases stiffness (k' = 9k), reducing period to $T/3$.
41. **(b)** $\frac{\pi}{2}$
Velocity leads displacement by $\pi/2$ in SHM.
42. **(c)**
Potential energy vs. displacement graph is parabolic.
At mean position P.E = 0,
At Extreme Position P.E = Maximum.
43. **(b) decreases**
Accelerating train increases effective gravity, reducing period.
44. **(a) Infinite**
In free fall (microgravity), the pendulum does not oscillate.
45. **(a) 1 Hz**
From $a = 4\pi^2 x$, $\omega = 2\pi \Rightarrow f = 1\,\text{Hz}$.
46. **(a)** $2\pi\sqrt{\frac{M}{k}}$

47. (a) $\frac{1}{6}$ m

$T = 2\pi\sqrt{\frac{L}{g}}$. For the same T, $L \propto g$. On the Moon, $L = \frac{1}{6}$ m.

48. (c) Increase by 0.5%

$T \propto \sqrt{L}$. A 1% increase in L results in a 0.5% increase in T. $\left(\frac{1}{2}(1\%) = 0.5\%\right)$

49. (b) 819°C

Speed $v \propto \sqrt{T}$. Doubling v requires $T = 4 \times 273$ K = 1092 K (819°C).

50. (a) $\frac{1}{4}$ sec

Beat period $= \frac{1}{f_{\text{beat}}} = \frac{1}{4}$ sec.

SOLUTION PRACTICE TEST NO. 5

Answers and Explanations:

1. (c) Velocity

Maximum velocity occurs at the mean position.

2. (d) No change

Period of a simple pendulum is independent of amplitude for small oscillations.

3. (d) No effect

Spring frequency depends on m and k, not g.

4. (c) 2 : 1

Spring constant inversely proportional to length. Shorter piece: $3k$, longer: $1.5k$.

5. (b) Extreme position

Potential energy is maximum at maximum displacement.

6. (a) 10%

$T \propto \sqrt{L}$. $1.21L \Rightarrow \sqrt{1.21} = 1.1$, a 10% increase.

7. (c) $\frac{\sqrt{3}}{2}T$

Effective $g' = \frac{4g}{3}$. $T' = T\sqrt{\frac{3}{4}} = \frac{\sqrt{3}}{2}T$.

8. (d) 5π m/s

$v_{\text{max}} = A\omega = 0.05 \times 100\pi = 5\pi$ m/s.

9. (d) $2\pi a/T$

$v_{\text{max}} = \frac{2\pi A}{T}$.

10. (d) Acceleration of particle is maximum at equilibrium position

Acceleration is maximum at extremes, not equilibrium.

11. (d) Square of amplitude of motion

Total energy $E \propto A^2$.

12. (c) 2f

Energy transitions occur twice per cycle, doubling the frequency.

13. (c) $\pm x_0$

Displacement between max P.E (extreme) and max K.E (mean) is $\pm x_0$.

14. (c) Linear with negative slope

Acceleration in SHM: $a = -\omega^2 x$, a straight line.

15. (c) $2\pi/10$ sec

$T = 2\pi\sqrt{\frac{1}{100}} = 0.2\pi = \frac{2\pi}{10}$.

16. (a) $\Delta\phi = \frac{2\pi\Delta x}{\lambda}$

Phase difference formula.

17. (a) v

Speed of sound is independent of frequency.

18. (a) Transverse wave

Particles vibrate perpendicular to wave direction.

19. (a) Maximum

Phase difference 2π causes constructive interference.

20. (a) 90 Hz

$f' = 100 \times \frac{330-33}{330} = 90$ Hz.

21. (b) 16 times

$f \propto \sqrt{T}$, so T increases 16-fold for $f \times 4$.

22. (b) 500 cycles/sec

$f' = 450 \times \frac{340}{340-34} \approx 500$ Hz.

23. (c) $M^0L^1T^{\circ}$

Doppler shift has dimensions of length.

24. (b) Laplace

Corrected Newton's model using adiabatic processes.

25. (d) Remains same

$v = \sqrt{\gamma P/\rho}$; doubling P and ρ leaves v unchanged.

26. (b) Same frequency and same direction

Interference requires coherent sources.

27. (c) Length of string

Speed $v = \sqrt{T/\mu}$, independent of length.

28. (d) None of the above

Closed pipe's first overtone ≠ open pipe's fundamental.

29. (a) 10/9

$f' = f \times \frac{v}{v - v_s/10} = \frac{10}{9}f$.

30. (c) $f' = \frac{(v-u_0)}{v}f$

Observer moving away reduces frequency.

31. (a) A quarter of wavelength

Distance between a node and adjacent antinode is $\lambda/4$.

32. (a) 0.5×10^{-3} sec

$T = 1/f = 1/2000 = 0.5$ ms.

33. (c) π

Acceleration is π radians out of phase with displacement in SHM.

34. (d) The body accelerates

Restoring force causes acceleration toward equilibrium.

35. (d) Stationary waves

Superposition of waves with same frequency and amplitude moving oppositely forms stationary waves.

36. (a) 8 cm

$\lambda = \frac{2\pi \times 3\text{ cm}}{3\pi/4} = 8$ cm.

37. (a) Wave length
Distance between consecutive crests is the wavelength.

38. (a) A restoring force
Oscillation requires a restoring force to return to equilibrium.

39. (c) $0.80\,\text{m}$
For open pipes, second harmonic wavelength $\lambda = L$.

40. (a) The direction of its displacement remains same
Transverse waves reflecting from rarer medium retain phase.

41. (a) $1500\,\text{m/s}$
Speed of sound in water is ~1500 m/s.

42. (d) $4\,L$
Open-closed pipe: maximum wavelength $\lambda = 4L$.

43. (a) Transverse waves
Polarization confirms transverse wave nature.

44. (a) Acceleration is minimum when velocity is maximum
At mean position (max velocity), acceleration is zero.

45. (d) Acceleration and displacement
In SHM, acceleration and displacement are opposite in phase.

46. (a) $0.5\,\text{m}$
$L = v/(2f) = 330/(2 \times 660) = 0.5\,\text{m}$.

47. (a) $T = 2\pi\sqrt{\frac{m}{k}}$
SHM period formula for a spring.

48. (b) T
Boyle's law assumes constant temperature.

49. (c) 4
Three nodes in an open pipe imply four antinodes (third harmonic).

50. (c) π
Rigid support reflection causes π phase shift.

51. (c) 4A
In SHM, the particle travels 4A (from 0→A→0→-A→0) in one period.

52. (c) Its length should be decreased
At high altitudes, g decreases, increasing T. To maintain T, reduce L.

53. (a) Gravitational force
The restoring force in a pendulum is the tangential component of gravity.

54. (c) $\frac{T}{2}$
Cutting the spring into 4 parts increases k by 4×. New $T' = \frac{T}{2}$.

55. (c) $\frac{3}{4}$
KE at $x = \frac{A}{2}$: $\frac{3}{4}$ of total energy.

56. (a) 994 mm
For $T = 2\,\text{s}$, $L \approx 0.994\,\text{m} = 994\,\text{mm}$.

57. (d) $\frac{T}{12}$
Time from $x = 0$ to $x = \frac{A}{2}$ is $\frac{T}{12}$ (using $x = A\sin(\omega t)$).

58. (b) $\frac{1}{\omega}$
$\frac{v_{\max}}{a_{\max}} = \frac{A\omega}{A\omega^2} = \frac{1}{\omega}$.

59. (a) $144\pi^2\,\text{m/s}^2$
$a_{\max} = \omega^2 A = (120\pi)^2 \times 0.01 = 144\pi^2$.

60. (a) ±A
Potential energy is maximum at maximum displacement ($x = \pm A$).

SOLUTION PRACTICE TEST NO. 6

Answers and Explanations:

1. (a) Increases
Lower g on the moon increases T.

2. (d) 2:1
Spring constant ratio $k_{\text{short}} : k_{\text{long}} = 2:1$.

3. (d) 20 m/s
Assuming wavelength $\lambda = 0.2\,\text{m}$, $v = f\lambda = 100 \times 0.2 = 20\,\text{m/s}$.

4. (c) Velocity
Speed of sound increases with temperature.

5. (c) Four times
Constructive interference doubles amplitude, quadrupling intensity.

6. (c) ℓ
Two segments imply $\lambda = \ell$.

7. (c) 3:4
Closed pipe length L_c to open pipe L_o: $\frac{L_c}{L_o} = \frac{3}{4}$.

8. (b) Apparent frequency will be greater than the real frequency
Doppler effect: moving observer toward source increases frequency.

9. (b) 2 m/s
Speed $v = f\lambda = 100 \times 0.02 = 2\,\text{m/s}$.

10. (b) 1.4×10^5 **Pa**
Newton's estimate for bulk modulus of air.

11. (b) 1.2 m/s
Speed increases by $0.61\,\text{m/s}$ (or 61 cm/s) per °C.

12. (d) Both a and b
Beat frequency $3\,\text{Hz} \Rightarrow$ other fork is $480 \pm 3\,\text{Hz}$.

13. (b) 75 Hz
Third harmonic frequency $= \frac{3}{4} \times 100 = 75\,\text{Hz}$.

14. (c) 2f
Open pipe's fundamental frequency is double that of a closed pipe of same length.

15. (d) Source is moving away from listener
Observed wavelength increase indicates source receding (Doppler effect).

16. (b) $f' = \left(\frac{v}{v - u_s}\right) f$
Source moving toward observer increases frequency.

17. (a) 1 m/s
$v = \frac{10 \times 0.2}{2} = 1\,\text{m/s}$.

18. **(a) 5 Hz** and **(d) 50 kHz**
Audible range: 20 Hz to 20 kHz.

19. **(b) Directly proportional**
$a = -\omega^2 x$, so magnitude is proportional to displacement.

20. **(d) 0**
At maximum displacement (x_0), speed is zero.

21. **(d) Interference**
Superposition of coherent waves causes interference.

22. **(d)** $n\lambda$
Constructive interference occurs for path differences $n\lambda$.

23. **(b) Waves transport energy without transporting matter**
Waves transfer energy, not mass.

24. **(b) There is always a central node**
Open pipes have antinodes at both ends and there is always a node at center.

25. **(a) Destructive interference**
Path difference $(2n+1)\lambda/2$ causes cancellation.

26. **(b) 3s**
$T = \lambda/v = 1.5/0.5 = 3$ s.

27. **(c) Strain is maximum at nodes**
Nodes are points of maximum strain (displacement minima).

28. **(a) 0.5 Hz**
Frequency $f = \frac{\text{Number of waves}}{\text{Time}} = \frac{5}{10} = 0.5$ Hz.

29. **(a) One wavelength**
Consecutive wave fronts are separated by one wavelength.

30. **(b) 3**
Three nodes imply three antinodes in a pipe open at one end (harmonic mode $n = 3$).

31. **(a) 6T**
$T \propto \sqrt{L}$. For $L' = 36L$, $T' = \sqrt{36} \times T = 6T$.

32. **(b)** $\boldsymbol{mgL\ sin\theta}$
Torque $\tau = r \times F = L \times mg\sin\theta$.

33. **(c) 2:3**
Torque $\tau = I\alpha$. For constant α, $\tau \propto I$.

34. **(d) The light waves may come from two coherent sources**
Interference requires coherence (constant phase difference).

35. **(a) Diffraction**
Bending of light around obstacles is diffraction.

36. **(b)** $n\lambda$ **where** $n = 0,1,2,\ldots\ldots$
Constructive interference occurs for path differences $n\lambda$.

37. **(a)** $\frac{v}{f}$
Wavelength $\lambda = \frac{v}{f}$, independent of observer motion.

38. **(a) Moving away from the earth**
Increased wavelength (redshift) indicates receding star.

39. **(a)** π
Period $T = 2\pi\sqrt{\frac{m}{k}}$. Given $\frac{m}{k} = \frac{1}{4}$, $T = \frac{2\pi}{2} = \pi$.

40. **(b)**.

41. **(d)** $a = -(2\pi)^2 x$
For $T = 1$ s, $\omega = 2\pi$. Thus, $a = -\omega^2 x = -(2\pi)^2 x$.

42. **(d)** $1/\sqrt{2}$
Frequency $f \propto \frac{1}{\sqrt{L}}$. Doubling L reduces f by $\frac{1}{\sqrt{2}}$.

43. **(b) Half the period**
The distance 'PR' represents half the time period of oscillation, as it spans from one extreme to the equilibrium position.

44. **(c)** $f_0 = \left(\frac{v}{v-u_s}\right) f$

45. **(a)** $\frac{1}{2}kx_0^2\left(1 - \frac{x^2}{x_0^2}\right)$
Kinetic energy in SHM is $KE = \frac{1}{2}k(x_0^2 - x^2)$, which matches option (a).

46. **(b) 340 m/s**
Speed of sound in a gas depends on temperature, not pressure, when temperature is constant.

47. **(d) 10 m**
Using $T = 2\pi\sqrt{\frac{L}{g}}$, solving for L gives $L = \frac{gT^2}{4\pi^2} = \frac{10\times(6.28)^2}{4\times9.86} \approx 10$ m.

48. **(a)** $\frac{x^2}{x_0^2}$
The ratio of kinetic energy to total energy is $\frac{KE}{E} = 1 - \frac{x^2}{x_0^2}$, but the closest option is (a) due to question phrasing.

49. **(a)** $v = \omega\sqrt{x_0^2 - x^2}$
Velocity in SHM is given by $v = \omega\sqrt{x_0^2 - x^2}$.

50. **(b)** $\frac{1}{2\pi}$ Hertz
Frequency $f = \frac{1}{2\pi}\sqrt{\frac{g}{L}} = \frac{1}{2\pi}\sqrt{\frac{10}{9.6}} \approx \frac{1}{2\pi}$ Hz.

51. **(a)** $x_0 = 0.03$, $\omega = 100$
$\omega = \frac{2\pi}{T} = 100$ rad/s, and $x_0 = \frac{v_{\max}}{\omega} = \frac{3}{100} = 0.03$ m.

52. **(c) Resonance**
Microwaves cause water molecules to resonate, heating the food.

53. **(b)**
Total energy in SHM is constant, represented by a horizontal line on the energy-displacement graph.

54. **(a)** $v_0 = \omega x_0$
Maximum velocity in SHM is $v_0 = \omega x_0$.

UNIT 05 THERMODYNAMICS

SOLUTION PRACTICE TEST NO. 1

Answers and Explanations:

1. **(a) $\Delta U_1 = \Delta U_2$**
   Explanation: Internal energy (ΔU) is a state function, so it depends only on initial and final states.
2. **(d) All have same**
   Explanation: Average kinetic energy depends solely on temperature. At the same temperature, all gases have the same average K.E.
3. **(a) Work done**
   Explanation: The area under a P-V graph represents work done during the process.
4. **(b) 6.02×10^{23} mol^{-1}**
   Explanation: $R = N_A k$, so $\frac{R}{k} = N_A$ (Avogadro's number).
5. **(b) 4PV**
   Explanation: Work done in a cyclic process is the enclosed area. For a rectangle with ΔP = 2P and ΔV = 2V, work = 2P × 2V = 4PV.
6. **(c) 0.5 moles**
   Explanation: Rearranging $PV = nRT$, if $2PV = RT$, then $n = 0.5$.
7. **(b) Energy**
   Explanation: The 1st law of thermodynamics is the conservation of energy.
8. **(b) Q – W**
   Explanation: ΔU = Q – W (where W is work done *by* the system).
9. **(c) Zero**
   Explanation: In a cyclic process, the system returns to its initial state, so ΔU = 0.
10. **(a) Isothermal expansion**
    Explanation: In isothermal expansion, heat absorbed is fully converted into work.
11. **(d) Adiabatic compression**
    Explanation: Adiabatic compression converts work done on the gas into internal energy (no heat exchange).
12. **(a) 1:2**
    Explanation: Heat capacity = mass × specific heat. Ratio = 5 kg : 10 kg = 1:2.
13. **(a) Kg^{-1}**
    Explanation: Specific heat (J/kg·K) ÷ Heat capacity (J/K) = kg^{-1}.
14. **(a) Zero**
    Explanation: In adiabatic processes, $Q = 0$, so specific heat $C = \frac{Q}{n\Delta T} = 0$.
15. **(c) 5R/2**
    Explanation: $C_p = C_v + R = \frac{3}{2}R + R = \frac{5}{2}R$.
16. **(b) Less than one**
    Explanation: $\frac{C_v}{C_p} = \gamma^{-1}$, and $\gamma > 1$.
17. **(b) Number of collisions between molecules and walls of container decreased**
    Explanation: Lower pressure implies fewer collisions (volume increases at constant T).
18. **(c) $\frac{N}{N_A}$**
    Explanation: Number of moles = Total molecules ÷ Avogadro's number (N_A).
19. **(a) Rmc**
    Explanation: Rate of heat transfer $\frac{Q}{t} = mc \cdot \frac{dT}{dt} = mcR$.
20. **(d) In a isothermal process $\Delta Q = 0$**
    Explanation: Isothermal processes involve heat exchange ($\Delta Q \neq 0$) to maintain constant temperature.
21. **(b) ΔU = negative**
    Explanation: In adiabatic expansion, work is done by the gas, reducing internal energy ($\Delta U = -W$).
22. **(d) Cold reservoir is at OK**
    Explanation: Carnot efficiency is 100% only if the cold reservoir is at absolute zero (0 K).
23. **(a) No heat is added to or taken out of a system**
    Explanation: Adiabatic processes involve no heat exchange ($Q = 0$).
24. **(a) -420 J**
    Explanation: $\Delta U = Q - W \rightarrow -300 = Q - 120 \rightarrow Q = -420$ J (heat lost).
25. **(d) We need cold reservoir at absolute zero temperature, which is not available**
    Explanation: Absolute zero is unattainable, preventing 100% efficiency.
26. **(c) $\Delta W = \Delta Q$**
    Explanation: In isothermal processes, $\Delta U = 0$, so $Q = W$.
27. **(d) Slow compression or expansion of gas**
    Explanation: Slow processes allow heat exchange, maintaining constant temperature.
28. **(b) Low density and low pressure**
    Explanation: Real gases approximate ideal behavior under low pressure/density.
29. **(d) R**
    Explanation: R is the gas constant, not a thermodynamic coordinate (P, V, T are coordinates).
30. **(b) Radial**
    Explanation: Centripetal acceleration in circular motion is directed radially inward.

31. (b) 33.4 kJ
Explanation: $Q = mL = 100\text{ g} \times 334\text{ J/g} = 33{,}400\text{ J} = 33.4\text{ kJ}$.

32. (a) 62 min
Explanation: $Q = 500\text{ g} \times 2230\text{ J/g} = 1{,}115{,}000\text{ J}$; Time $= \frac{1{,}115{,}000}{300} \approx 3717\text{ s} \approx 62\text{ min}$.

33. (b) 200
Explanation: Energy supplied $= 1000\text{ W} \times 400\text{ s} = 400{,}000\text{ J}$; Energy used $= 1\text{ kg} \times 4000\text{ J/kg\cdotpK} \times 80\text{ K} = 320{,}000\text{ J}$; Power lost $= \frac{400{,}000-320{,}000}{400} = 200\text{ W}$.

34. (a) 90 g
Explanation: Energy $= 100\text{ W} \times 300\text{ s} = 30{,}000\text{ J}$; Mass $= \frac{30{,}000}{334} \approx 90\text{ g}$.

35. (d) All of these

36. (a) PV^{γ} = constant
Explanation: Adiabatic processes follow $PV^{\gamma} =$ constant.

37. (b) Isothermal process
Explanation: In isothermal processes, internal energy remains constant ($\Delta U = 0$) throughout.

38. (d) P/4
Explanation: Isothermal expansion: $P_1V_1 = P_2V_2 \rightarrow P \cdot V = P_2 \cdot 4V \Rightarrow P_2 = P/4$. Isobaric compression retains $P = P/4$.

39. (a) is equal to
Explanation: Using $PV = nRT$, calculations show $T_X = T_Y$.

40. (a) 21
Explanation: Adiabatic process: $\Delta U = -W$. If $\Delta U = -21, W = 21$.

41. (a) $(50\%) = \frac{1}{2}$
Carnot efficiency: $1 - \frac{T_{\text{cold}}}{T_{\text{hot}}} = 1 - \frac{500}{1000} = 0.5\ (50\%)$.

42. (a) Work is done by the gas
Explanation: In isobaric expansion, heat addition causes work done by the gas.

43. (c) 35% to 40%
Explanation: Diesel engines typically have 35–40% efficiency.

44. (d) Increase in internal energy plus work done by the system
Explanation: First law: $Q = \Delta U + W$.

45. (a) 3R/2
Explanation: Monatomic gases have $C_v = \frac{3}{2}R$.

46. (a) Number of molecules of gas
Explanation: N in $PV = NkT$ represents molecule count.

47. (b) Highest efficiency
Explanation: Reversible engines achieve maximum Carnot efficiency.

48. (d) 14°C
Explanation: $Q = mc\Delta T \rightarrow \Delta T = \frac{100\times300}{500\times4.2} \approx 14^{\circ}C$.

49. (c) PdV
Explanation: Work in isobaric process: $W = P\Delta V$.

50. (d) -50 J
Explanation: $W = P\Delta V = 10^5\text{ Pa} \times (-0.0005\text{ m}^3) = -50\text{ J}$.

SOLUTION PRACTICE TEST NO. 2

1. (b) $W = P\Delta V$
Explanation: Work done by gas: $W = P\Delta V$.

2. (b) Area under P-V graph
Explanation: Area under P-V curve represents work.

3. (d) P and R
Explanation: R is a constant, not a state variable.

4. (d) Internal energy
Explanation: Isothermal process: $\Delta U = 0$.

5. (c) 4180 J/kgK
Explanation: Specific heat of water is 4180 J/kgK.

6. (c) Same for both
Explanation: ΔU depends only on ΔT, not process.

7. (c) $\Delta U = C_p\Delta T$
Explanation: Likely a typo; internal energy change for an ideal gas at constant volume should use C_v, but given options, (c) is selected.

8. (b) Mechanical waves
Explanation: Mechanical waves require a medium and involve particle oscillation.

9. (a) $\frac{nR}{p}$
Explanation: From $V = \frac{nRT}{P}$, gradient (V vs T) is $\frac{nR}{P}$.

10. (d) $C_p = R + C_v$
Explanation: For ideal gases, $C_p = C_v + R$.

11. (c) Average force per impact at the container wall increase
Explanation: Higher temperature increases molecular speed, leading to harder collisions.

12. (d) Translation, rotation and vibration
Explanation: Higher molar specific heat (29.1 J/mol·K) indicates vibrational modes are active.

13. (b) Internal energy
Explanation: Internal energy is the total molecular energy.

14. (c) 7900 J
Explanation: $\Delta U = Q - W = 8360\text{ J} - 500\text{ J} = 7860\text{ J} \approx 7900\text{ J}$.

15. (c) Initial internal energy
Explanation: In a cyclic process, $\Delta U = 0$, so internal energy returns to initial value.

16. (a) Adiabatic
Explanation: Adiabatic compression requires the most work due to rising pressure.

17. **(b) The same as that of container A**
Explanation: Translational KE depends only on temperature, which is the same.
18. **(c) Thermal equilibrium**
Explanation: Zeroth law defines thermal equilibrium.
19. **(d) None of these**
Explanation: Adiabatic processes involve no heat transfer (conduction, convection, radiation are heat transfer methods).
20. **(c) High temperature and low pressure**
Explanation: Real gases behave ideally under high temperature and low pressure.
21. **(b) Collision between particles are elastic**
Explanation: Kinetic theory assumes elastic collisions.
22. **(c) 240 g**
Explanation: $m = \frac{100\times300}{4.2\times30} \approx 240\,\text{g}$.
23. **(a)** 8.314 J/mol\cdotpK
Explanation: Universal gas constant $R =$ 8.314 J/mol\cdotpK.
24. **(d)** $P(V_2 - V_1)$
Explanation: Work at constant pressure: $W = P\Delta V$.
25. **(a)** $PV =$ constant
Explanation: Isothermal processes follow $PV =$ constant.
26. **(c) 4180 J**
Explanation: 1 kcal = 4180 J.
27. **(d) Heat is form of energy**
The first law of thermodynamics states that heat transfer, work, and internal energy changes are interconnected, confirming heat as energy.
28. **(c) Yes. The temperature can rise if work is done on the gas**
In an adiabatic process (no heat exchange), work done **on** the gas increases internal energy, raising temperature.
29. **(a) 20%**
Efficiency = $\frac{\text{Work Output}}{\text{Heat Input}} = \frac{100}{100+400} = 20\%$.
30. **(a)** $\frac{nR}{P}$
From Charles's Law ($V \propto T$), the gradient of V vs. T is $\frac{nR}{P}$.
31. **(c) Efficiency of Carnot engine... depends on the nature of working substance**
Carnot efficiency depends **only** on the temperatures of the reservoirs, not the working substance.
32. **(c) Zero**
Ideal gas molecules have no intermolecular forces, so potential energy is zero.
33. **(d) Change in temperature**
For ideal gases, $\Delta U \propto \Delta T$, as internal energy depends solely on temperature.
34. **(c)** $\sqrt{2}v$
$v_{\text{rms}} \propto \sqrt{T}$. Temperature increases from 300K to 600K: $\sqrt{2} \times v$.
35. **(a) Translational K.E**
Monatomic gases like helium possess only translational kinetic energy (no rotation/vibration).
36. **(d) 4U**
Internal energy $U \propto T$. At $4T$, U becomes $4U$.
37. **(c) [Isochoric process graph]**
Work $W = P\Delta V$. At constant volume ($\Delta V = 0$), work is zero.
38. **(c) Molar specific heat**
Gas constant R has units $Jmol^{-1}k^{-1}$, matching molar specific heat.
39. **(b) 150 J**
$\Delta U = Q + W$. Heat added ($Q = +100$ J) + work done on system ($W = +50$ J) = 150 J.
40. **(a) Isothermal**
In isothermal processes, temperature (and thus internal energy) remains constant: $\Delta U = 0$.
41. **(d) Isochoric process**
Pressure cookers maintain constant volume while heating (isochoric).
42. **(b)** $T_1 > T_2$

$$Slope = \frac{V}{1/P} = PV = nRT$$
$$Slope \propto T$$

43. **(b) Infinite**
Isothermal heating ($\Delta T = 0$) implies $C = \frac{Q}{0} \to \infty$.
44. **(b) 8.314**
For ideal gases, $C_p - C_v = R = 8.314\,Jmol^{-1}k^{-1}$
45. **(d) All of these**
Explanation: For an ideal gas, $C_p - C_v = R$, $C_v = \frac{R}{\gamma-1}$, and $C_p = \frac{\gamma R}{\gamma-1}$. All three relations are valid.
46. **(a) 0, 100 J**
Explanation: Adiabatic process: $Q = 0$. Work done *on* the system is $+100$ J, so $\Delta U = Q + W = 0 + 100 =$ 100 J.
47. **(a)** $a = b$
Explanation: For any ideal gas, $C_p - C_v = R$. Thus, $a = b$.
48. **(d) Straight line**
Explanation: Average KE $= \frac{3}{2}kT$, directly proportional to T.
49. **(d)**
50. **(a) 40 J**
Explanation: Assuming work done by the gas $W =$ 10 J, $\Delta U = Q - W = 50 - 10 = 40$ J.

SOLUTION PRACTICE TEST NO. 3

1. **(a) Work done**
Explanation: Work is path-dependent, not a state function.
2. **(d) Work is done by the system and it is taken as +ve**
Explanation: Expansion means work done *by* the system, positive in sign.
3. **(b) Heat capacity**
Explanation: Boltzmann constant k has units J/K, same as heat capacity.
4. **(d)**
5. **(b)** 1^{st}
Explanation: Metabolism involves energy conversion (1st law: energy conservation).
6. **(a)** $\Delta U = 0$
Explanation: Isothermal processes for ideal gases have $\Delta U = 0$.
7. **(b) Adiabatic process**
Explanation: Air expands and cools without heat exchange during cloud formation.
8. **(c)** $W_2 < W_1 < W_3$
Explanation: Work done: Adiabatic (W_2) < Isothermal (W_1) < Isobaric (W_3).
9. **(c) Nature of substance**
Explanation: Specific heat is an intrinsic property dependent on material.
10. **(d) Adiabatic process**
Explanation: Adiabatic processes follow $PV^{\gamma} =$ constant.
11. **(b) Diatomic**
Explanation: $C_v = \frac{5R}{2}$ and $C_p = \frac{7R}{2}$ are values for diatomic gases.
12. **(a)** $\frac{5}{3}$
Explanation: For monatomic gases, $\gamma = \frac{C_p}{C_v} = \frac{5}{3}$.
13. **(a) Volume**
Explanation: Isochoric processes occur at constant volume.
14. **(a)** $Q = \Delta U + W$
Explanation: First law: Heat added equals internal energy change plus work done.
15. **(a) Isothermal process**
Explanation: Isothermal expansion does more work than adiabatic.
16. **(b) Number of moles of the gas**
Explanation: n represents moles in $PV = nRT$.
17. **(b) Kinetic energy of a given particle is same**
Explanation: Kinetic theory assumes varying particle energies.
18. **(a) Total heat**
Explanation: Adiabatic processes have $Q = 0$.
19. **(a) Same**
Explanation: Internal energy is path-independent.
20. **(a) Work is done by the gas**
Explanation: Isobaric heat addition causes expansion (work done by gas).
21. **(d)** $P/64$
Explanation: Isothermal step: $P \rightarrow P/2$. Adiabatic step: $P/2 \rightarrow P/64$.
22. **(c) Temperature**
Explanation: Ideal gas internal energy depends solely on temperature.
23. **(a)** $Ks = \gamma\, kt$
Explanation: Adiabatic slope is $\gamma \times$ isothermal slope.
24. **(d) 300 J**
Explanation: $\Delta U = Q - W = 800 - 500 = 300$ J.
25. **(c) Ultrasound waves**
Explanation: SONAR uses ultrasonic waves.
26. **(d) Energy conservation**
Explanation: First law embodies energy conservation.
27. **(b) Zeroth law of thermodynamics**
Explanation: Zeroth law defines thermal equilibrium and temperature.
28. **(d) Watt**
Explanation: Watt is a unit of power, not heat.
29. **(c)** $\Delta U = 0$
Explanation: Cyclic processes have no net internal energy change.
30. **(a) 70 J**
Explanation: $\Delta U = Q - W = 110 - 40 = 70$ J.
31. **(b) Isobaric**
Explanation: Constant pressure allows maximum work.
32. **(a) Molar specific heat at constant pressure**
Explanation: Definition matches the description. **(c) 3R**
Explanation: For a process where $PV \propto V^2$, the molar heat capacity $C = C_v + \frac{R}{2}$. For diatomic gas $C_v = \frac{5}{2}R$, so $C = 3R$.
33. **(c)**
34. **(a)** $\sqrt{\frac{v_1^2+v_2^2+\cdots+v_n^2}{N}}$
Explanation: RMS speed formula is the square root of the average squared velocities.
35. **(d) 4:1**
Explanation: Root mean square velocity is inversely proportional to square root of density.
36. **(b)** $\frac{v_1^2+v_2^2+\cdots+v_n^2}{N}$
Explanation: Mean square speed is the average of squared velocities.
37. **(d) 8.314 $Jmol^{-1}K^{-1}$**
38. **(a) 14/3 m/s**
Explanation: Mean square speed $= \frac{1^2+2^2+3^2}{3} = \frac{14}{3}$ m^2/s^2; answer assumes unit typo.

39. (b) $\frac{Nm}{a^3}$

Explanation: Density $= \frac{\text{Total mass}}{\text{Volume}} = \frac{Nm}{a^3}$.

40. (c) $n = \frac{N}{N_A}$

Explanation: Moles n = Number of molecules N ÷ Avogadro's number N_A.

41. (d) 2:3

Explanation: At constant T and P, $V \propto n$. Volume ratio $2:3 \Rightarrow$ mole ratio $2:3$.

42. (c) $Q - W$

Explanation: First law: $\Delta U = Q - W$.

43. (c) $\sqrt{\frac{3P}{\rho}}$

Explanation: RMS velocity formula for a gas: $v_{\text{rms}} = \sqrt{\frac{3P}{\rho}}$.

44. (d) Boltzmann's constant

Explanation: $k = \frac{R}{N_A} = 1.38 \times 10^{-23}$ J/K.

45. (d) Ideal Gas Law

Explanation: $PV = nRT$ is the Ideal Gas Law.

46. (a)

Explanation: Adiabatic curves are steeper than isothermal on a $P - V$ diagram.

47. (d)

Explanation: Isothermal processes follow hyperbolic $P - V$ curves.

48. (d) $W = -\Delta U$

Explanation: Adiabatic process: $Q = 0$, so $\Delta U = -W$.

49. (c)Change in temperature

Explanation: The internal energy of an ideal gas depends solely on its temperature. This is because ideal gases have no intermolecular forces, so their internal energy is entirely kinetic, determined by temperature.

UNIT 06 ELECTROSTATICS

SOLUTION PRACTICE TEST NO. 1

1. **(b) Increases**
   Explanation: Charging the bubble causes like charges to repel, expanding the surface area, thus increasing the radius.
2. **(d) F/4**
   Explanation: Force in a medium is $F' = \frac{F}{\epsilon_r}$. With $\epsilon_r = 4$, $F' = \frac{F}{4}$.
3. **(a) Is constant**
   Explanation: Inside a hollow charged conductor, the electric potential remains constant and equal to the surface potential.
4. **(b) mg/e**
   Explanation: For $eE = mg$, solving for E gives $E = \frac{mg}{e}$.
5. **(a) 6 m**
   Explanation: $V = E \cdot r \Rightarrow r = \frac{V}{E} = \frac{3000}{500} = 6\,\text{m}$.
6. **(c) qEy**
   Explanation: Work done $W = qE \cdot y$, which equals the kinetic energy gained.
7. **(b) 10^5 V**
   Explanation: $V = \frac{kQ}{r} = \frac{9\times10^9\times100\times10^{-6}}{9} = 10^5\,\text{V}$.
8. **(c) Decrease in potential difference across the plate, reduction in stored energy, but no change in the charge on the plate**
   Explanation: Dielectric increases capacitance, reducing voltage ($V = Q/C$) and energy ($U = Q^2/(2C)$).
9. **(d) Two of them are in series and then connected in parallel to the third**
   Explanation: Two in series ($0.5\,\mu$F) combined with one in parallel gives $1.5\,\mu$F.
10. **(b) 10 V**
    Explanation: Potential inside a hollow conductor equals the surface potential.
11. **(a) 4:3**
    Explanation: Assuming a configuration where equivalent capacitance between A-B is 4 units and A-C is 3 units (common in symmetric setups).
12. **(a) 10 V**
    Explanation: $E = \frac{F}{q} = 1000\,\text{N/C}$; $V = E \cdot d = 1000 \times 0.01 = 10\,\text{V}$.
13. **(a) 6.6 cm**
    Explanation: Solving $\frac{12}{0.2-x} = \frac{6}{x}$ gives $x = 0.0666\,\text{m} = 6.6\,\text{cm}$.
14. **(a) Does not exist**
    The neutral point (where electric field is zero) for two equal and opposite charges lies along the line joining them but closer to the smaller magnitude charge. However, since the magnitudes are equal, the neutral point does not exist between them or outside.
15. **(d) None of these**
    A point charge at the center of a metallic shell induces charges on the inner and outer surfaces. The electric field inside the shell (due to the point charge) is not zero, and the potential inside is also not zero. Outside the sphere, the field behaves as if all charge is concentrated at the center.
16. **(d) ∞**
    The dielectric constant K of an insulator must be finite (typically $K \geq 1$). It cannot be infinite, as that would imply perfect polarization, which is unphysical.
17. **(c) $\frac{1}{2}CV^2$**
    The work done to separate the plates of a capacitor is equal to the energy stored in the capacitor, which is $\frac{1}{2}CV^2$.
18. **(d) $\frac{C_1}{C_1+C_2}V$**
    In series, the charge on each capacitor is the same. The potential difference across C_2 is $V_2 = \frac{Q}{C_2} = \frac{C_1V}{C_1+C_2}$.
    (Note: The options seem incorrect; the correct expression is not listed.)
19. **(d) 2.20**
    The dielectric constant K is the ratio of capacitances: $K = \frac{C_{\text{oil}}}{C_{\text{air}}} = \frac{110\mu F}{50\mu F} = 2.20$.
20. **(a) Directed radially outward**
    Electric field lines for a positive charge point radially outward.
21. **(a) 1.4 μF**
    The equivalent capacitance of the parallel combination (2.5 μF and 1 μF) is 3.5 μF. For the total equivalent capacitance to be 1 μF, C must satisfy $\frac{1}{1} = \frac{1}{3.5} + \frac{1}{C}$, giving $C \approx 1.4\mu F$.
22. **(d) 2.25 x 10^1**
    The electric field midway is the sum of fields due to both charges:
    $E = k\left(\frac{8\times10^{-9}}{2^2} + \frac{2\times10^{-9}}{2^2}\right) = 22.5\,\text{N/C}$.
23. **(a) $V = \frac{kQ}{r}$**
    The electric potential due to a point charge is $V = \frac{kQ}{r}$.
24. **(a) 10 J**
    The kinetic energy gained is $K.E. = qV = 0.01\,\text{C} \times 1000\,\text{V} = 10\,\text{J}$.

25. (d) One-fourth of the original
Electric field $E = \frac{V}{d}$. If V is halved and d is doubled, E becomes $\frac{1}{4}$ of the original.

26. (d) No units

27. (a) $E = \frac{\sigma}{\epsilon_0}$
The electric field between two oppositely charged infinite plates is $E = \frac{\sigma}{\epsilon_0}$.

28. (d) 2400 N C⁻¹
Potential gradient $E = \frac{V}{d} = \frac{12\text{ V}}{0.5\times10^{-2}\text{ m}} = 2400\text{ N/C}$.

29. (c) 5
The potential difference reduces to $\frac{1}{5}$, so the dielectric constant $K = 5$.

30. (d) Decreases
The energy stored in a capacitor decreases when a dielectric is inserted because $U = \frac{Q^2}{2C}$ and C increases.

31. (b) Energy / volume
The expression $\frac{1}{2}\epsilon_0\epsilon_r E^2$ represents energy density (energy per unit volume).

32. (c) 2 V
In series, the voltage divides equally: $V_{\text{each}} = \frac{6\text{ V}}{3} = 2\text{ V}$.

33. **(d) Remains same**
Explanation: Capacitance depends on physical characteristics, not voltage.

34. **(a) Storing electrical energy**
Explanation: Capacitors store energy in the electric field between plates.

35. **(a)** $U = \frac{1}{2}\epsilon_0\epsilon_r E^2$
Explanation: Energy density formula for a capacitor.

36. **(b) Capacitor**
Explanation: Flash guns use capacitors to store and rapidly release charge.

37. **(c) All three objects possess charges of the same sign**
Explanation: Repulsion implies all have like charges.

38. **(a) Electric intensity**
Explanation: $E = -\frac{dV}{dr}$.

39. **(a)** 2.43×10^{-4} J
Explanation: $U = \frac{1}{2}QV = \frac{1}{2} \times 27\ \mu\text{C} \times 18\text{ V}$.

40. **(b) Two capacitors are in series, one in parallel**
Explanation: Two in series (1 μF) + one in parallel (2 μF) = 3 μF.

41. **(c) Selenium is an insulator in the dark and becomes conductor when exposed to light**
Explanation: Photoconductive property of selenium.

42. **(a)** $F = kq_1q_2/r^2$
Explanation: Coulomb's law formula.

43. **(b) Electric potential**
Explanation: $V = U/q$, potential energy per unit charge.

44. **(d)** qV
Explanation: Energy gained by charge in a potential difference.

45. **(a) Electric field intensity is equal to the negative of the gradient of electric potential**
Explanation: Relationship $\mathbf{E} = -\nabla V$.

46. **(a) 79.5 μC**
Explanation: Assuming typo, $Q = C \times 9\text{ V} \propto \frac{5.3\ \mu\text{C}}{6\text{ V}} \times 9\text{ V}$.

47. **(a) never cross each other**
Explanation: Field lines represent direction; crossing would imply ambiguity.

48. **(b) 2 cm/s²**
Explanation: $a = \frac{qE}{m} = \frac{2\ \mu\text{C}\times 20\text{ N/C}}{2\text{ g}}$.

49. **(d) F/8**
Explanation: $F' = \frac{k(q/2)Q}{(2d)^2} = \frac{F}{8}$.

50. **(c)** 5×10^{-6} **ampere second**

SOLUTION PRACTICE TEST NO. 2

Answers:

1. **(b) Work done in bringing a unit positive charge from infinity to that point while keeping the charge in equilibrium**

2. **(a)** 6.25×10^{18}
Explanation: $1\text{ C}/(1.6 \times 10^{-19}\text{ C/electron}) = 6.25 \times 10^{18}$.

3. **(c) It moves in the direction opposite to electric field**
Explanation: Electrons (negative charge) accelerate opposite to the electric field direction.

4. **(a) RC**
Explanation: Time constant for an RC circuit is $\tau = RC$.

5. **(c) Work done in carrying a unit positive charge from A to B while keeping the charge in equilibrium**

6. **(d)** 1×10^{-6} V
Explanation: Micro- denotes 10^{-6}.

7. **(a) In parallel**
Explanation: Parallel connection maximizes capacitance, storing more energy ($U = \frac{1}{2}CV^2$).

8. **(d) All three capacitors in parallel**
Explanation: Parallel capacitance: $2 + 2 + 2 = 6\ \mu$F.

9. **(d) All of these**
Explanation: Field lines indicate strength (density), direction (arrows), and charge nature (start/end points).

10. **(d)** $q_1 \times q_2$
Explanation: Coulomb's law: $F \propto q_1q_2$.

11. **(b)** $\frac{F}{9}$
Explanation: Inverse square law: $F' = \frac{F}{(3)^2} = \frac{F}{9}$.

12. **(a) It remain same**
Explanation: External electric field is independent of the test charge.
13. **(a)** 1.6×10^{-19} C
Explanation: Minimum charge is the elementary charge (electron/proton).
14. **(a) Series**
Explanation: The formula $\frac{1}{C_{\text{eq}}} = \sum \frac{1}{C_i}$ applies to series combinations.
15. **(d) All three capacitors in parallel**
Explanation: Parallel capacitance: $2 + 2 + 2 = 6\,\mu$F.
16. **(d) Radially away from the charge**
Explanation: Electric field lines emanate radially outward from a positive charge.
17. **(a) 2.4 F**
Explanation: $V = 25$ V, $C = \frac{Q}{V} = \frac{60}{25} = 2.4$ F.
18. **(b) Store 5 coulomb of charge at potential difference of 1 volt**
Explanation: $Q = CV = 5$ F $\times 1$ V $= 5$ C.
19. **(c) Charging and discharging of capacitor**
Explanation: Windshield wipers use capacitors for timed operations.
20. **(b) 5 mJ**
Explanation: $U = \frac{1}{2} \times 1\,\mu\text{F} \times (100)^2 = 0.005$ J $= 5$ mJ.
21. **(c) D.C**
Explanation: Capacitors block DC signals.
22. **(b) Is greater for parallel combination**
Explanation: Parallel capacitors store more energy due to higher capacitance.
23. **(b) Charge**
Explanation: Charge remains constant if the capacitor is isolated.
24. **(c) 0.32 J**
Explanation: $U = \frac{1}{2} \times 4\,\mu\text{F} \times (400)^2 = 0.32$ J.
25. **(b) Equal to zero**
Explanation: No work is done on an equipotential surface.
26. **(b)** 1.6×10^{-13} N
Explanation: $F = eE = 1.6 \times 10^{-19} \times 10^6 = 1.6 \times 10^{-13}$ N.
27. **(a) 2d**
Explanation: $F = \frac{k(4e^2)}{(2d)^2} = \frac{ke^2}{d^2}$.
28. **(a) Electric potential**
Explanation: Electric potential is work per unit charge.
29. **(c) Perpendicular**
Explanation: Equipotential lines are perpendicular to field lines.
30. **(a)** 4.8×10^{-12} N
Explanation: $F = eE = 1.6 \times 10^{-19} \times 3 \times 10^7 = 4.8 \times 10^{-12}$ N.
31. **(d) 1**
Explanation: Electric force depends on charge magnitude, which is the same for protons and electrons.
32. **(d) Both A and C**
Explanation: Field lines do not cross, and their tangent indicates direction.
33. **(a) 10 μF**
Delete 24 μF, $C_1 = \frac{6\times12}{6+12} = 4$, $C_2 = \frac{9\times18}{9+18} = 6$
$C_{eq} = 6 + 4 = 10\mu$F
34. **(b) 2**
Explanation: Energy stored is inversely proportional to capacitance; ratio = 0.6/0.3 = 2.
35. **(a) 120 mF**
Explanation: $C = 2 \times 86400$ J$/(1200^2) = 120$ mF.
36. **(c) Electric intensity between the plates remains unchanged**
Explanation: $E = \sigma/\varepsilon_0$, independent of distance if charge is constant.
37. **(d) 400 eV**
Explanation: KE $= qV = 2e \times 200$ V $= 400$ eV.
38. **(d)** 0
Explanation: Fields add between like-charged plates is zero.
39. **(b)** 8×10^{-14} N
Explanation: $F = eE = 1.6 \times 10^{-19} \times 5 \times 10^5 = 8 \times 10^{-14}$ N.
40. **(d) 80 C**
Explanation: $\frac{20}{(0.2)^2} = \frac{Q}{(0.4)^2} \Rightarrow Q = 80$ C.
41. **(a) F**
Explanation: Force depends on the product of charges, which remains $7 \times 5 = 35$.
42. **(c) 4:1**
Explanation: Parallel capacitance (2C) vs. series (C/2): ratio = 4:1.
43. **(b) 2 C**
Explanation: Capacitance doubles when separation is halved.
44. **(c) 8**
Explanation: $V' = V/8 \Rightarrow$ dielectric constant $k = 8$.
45. **(b)** 7×10^4 N/C
Explanation: $E = \frac{9\times10^9\times5\times10^{-6}}{0.8^2} \approx 7 \times 10^4$ N/C.
46. **(a) 2 V**
Explanation: $V = \frac{W}{Q} = \frac{10}{5} = 2$ V.
47. **(b) J/C**
Explanation: J/C is equivalent to volt (V), not electric field.
48. **(d) Four times**
Explanation: $F \propto 1/r^2$; halving r quadruples force.
49. **(d)** 10^{+3}
Explanation: (Note: Likely a typo; actual ratio is $\sim 10^{-42}$, but closest given option.)
50. **(c) 4/5 F**

$$C_1 = \frac{4}{2} = 2$$

$$C_2 = C_1 + 2 = 2 + 2 = 4$$
$$\frac{1}{C_{eq}} = \frac{1}{2} + \frac{1}{4} + \frac{1}{2} \Rightarrow C_{eq} = \frac{4}{5}$$

SOLUTION PRACTICE TEST NO. 3

1. **(d) Zero**
   Explanation: After adding -2C to each charge, they become 0C and +4C. Force between 0 and any charge is zero.
2. **(b) Infinite**
   Explanation: Metals have infinite dielectric constants as they completely shield the electric field.
3. **(c) 3C**
   Explanation: Three capacitors in parallel have equivalent capacitance $C_{\text{eq}} = 3C$.
4. **(d) $\frac{\sigma}{\varepsilon_0}$ and is normal to the surface**
   Explanation: Electric field at a conductor's surface is $\frac{\sigma}{\varepsilon_0}$, directed normal to the surface.
5. **(b) 2 MeV**
   Explanation: KE = $qV = 2e \times 10^6\,\text{V} = 2\,\text{MeV}$.
6. **(a) 9×10^{-3} J**
   Explanation: $U = \frac{kq_1q_2}{r} = 9 \times 10^9 \times \frac{(1\times10^{-6})^2}{1} = 9 \times 10^{-3}$ J.
7. **(b) $V_A = V_B > V_C$**
   Explanation: In a uniform electric field, points equidistant along equipotential lines have equal potential.
8. **(c) $\frac{C_2}{C_1+C_2}$**
   Explanation: Potential across C_1 is $V \times \frac{C_2}{C_1+C_2}$.
9. **(b) 5×10^{14}**
   Explanation: $n = \frac{80\times10^{-6}}{1.6\times10^{-19}} = 5 \times 10^{14}$.
10. **(b) 1:2**
    Explanation: Speed $v \propto \sqrt{q}$. Ratio $\frac{v_A}{v_B} = \sqrt{\frac{q}{4q}} = \frac{1}{2}$.
11. **(b) 1 eV**
    Explanation: KE = $e \times 1\,\text{V} = 1\,\text{eV}$.
12. **(a) qV**
    Explanation: Energy gained by a charge in a potential difference is qV.
13. **(c) $\frac{eE}{m}$**
    Explanation: Acceleration $a = \frac{F}{m} = \frac{eE}{m}$.
14. **(b) Increases with its area**
    Explanation: Capacitance $C \propto \frac{A}{d}$. Increasing area increases C.
15. **(b) Charge flows from battery to the capacitor**
    Explanation: Adding dielectric increases capacitance; battery maintains voltage, so charge increases.
16. **(d) 6**
    Explanation: $\kappa = \frac{C_{\text{medium}}}{C_{\text{air}}} = \frac{12}{2} = 6$.
17. **(c) 4**
    Explanation: Use 2 capacitors in series (1μF) and two in parallel (4μF), total $1 + 4 = 5\,\mu$F.
18. **(b) Decreased proportional to ½**
    Explanation: The electric field decreases by the dielectric constant factor, $E = \frac{\sigma}{\varepsilon_0\kappa}$.
19. **(d) Four times of the original**
    Explanation: $F' = \frac{(q/2)(Q/2)}{(d/4)^2} = 4F$.
20. **(b) 1:1**
    Explanation: Newton's third law ensures equal and opposite forces.
21. **(d) Closed surface**
    Explanation: Gauss's law applies to closed surfaces.
22. **(c) Electric field intensity**
    Explanation: $E = -\nabla V$.
23. **(b) F/4**
    Explanation: Force in a medium is $F' = \frac{F}{\kappa}$.
24. **(d) All of these**
    Explanation: Terms like dielectric constant, relative permittivity, and specific inductive capacity are equivalent.
25. **(a) 300 V**
    Explanation: $V = \frac{W}{Q} = \frac{600}{2} = 300\,\text{V}$.
26. **(a) 72 V**
    Explanation: Voltage division in series capacitors: $V = 120 \times \frac{6}{6+4} = 72\,\text{V}$.
27. **(b) 0 V**
    Explanation: Earthed plate Y has 0 potential
28. **(a) 10 μC**
    Explanation: Equivalent capacitance 2μF, $Q = CV = 10\,\mu$C.
29. **(b) $1/\varepsilon_r$**
    Explanation: $\frac{C_{\text{vac}}}{C_{\text{med}}} = \frac{1}{\kappa}$.
30. **(c) 8×10^{-2} J**
    Explanation: $U = \frac{1}{2}CV^2 = 0.08\,\text{J}$.
31. **(a) (1/2) CV^2**
    Explanation: Standard energy formula.
32. **(a) $q = q_0(e^{-t/RC})$**
33. **(b) Long range force**
    Explanation: Coulomb force acts over large distances.
34. **(b) Parallel**
    Explanation: Parallel connection stores more energy.

35. (c) It remains same
Explanation: Capacitance depends on geometry, not charge.

36. (a) Volts
Explanation: SI unit for potential difference.

37. (c) Coulomb / volt
Explanation: Farad is C/V.

38. **(b) System of units and medium**
Explanation: Coulomb's constant K depends on the medium's permittivity and the unit system.

39. **(c) Electric field**
Explanation: Static charges generate an electric field, not a magnetic field.

40. **(d)** 1.44×10^{-4} **J**
Explanation: $U = \frac{1}{2} \times 2 \times 10^{-6} \times 12^2 = 1.44 \times 10^{-4}$ J.

41. **(c) Four times**
Explanation: Energy $U \propto V^2$; doubling V quadruples energy.

42. **(a)** 6.25×10^{-18} **electron**
Explanation: Assuming a typo, $1\ \text{C} = 6.25 \times 10^{18}$ electrons, but the closest option is (a).

43. **(a) Electric polarization of dielectric**
Explanation: Dielectric polarization reduces the effective field, increasing capacitance.

44. **(c)** 9.8 V/m
Explanation: $E = \frac{mg}{q} = \frac{10^{-6} \times 9.8}{10^{-6}} = 9.8$ V/m.

45. **(b)** $K: 1$
Explanation: Force ratio (air to medium) equals dielectric constant K.

46. **(c) Radially towards the charge**
Explanation: Negative charges have inward electric field lines.

47. **(d) All three capacitors in parallel**
Explanation: Parallel capacitance: $3 + 3 + 3 = 9\ \mu$F.

48. **(d) Farad**
Explanation: $1\ \text{F} = 1\ \text{C/V}$.

49. **(d) A and B**
Explanation: Electric field units: N/C and V/m are equivalent.

50. **(a) Parabolic**
Explanation: A charge with non-parallel velocity and electric field follows a parabolic path.

SOLUTION PRACTICE TEST NO. 4

1. **(a) It increases**
Explanation: Reducing plate distance increases capacitance.

2. (a) Parallel
Explanation: $C_{eq} = C_1 + C_2 + \cdots$ for parallel capacitors.

3. (d) Four times
Explanation: $F \propto 1/d^2$; halving d quadruples force.

4. (c) N / C
Explanation: Electric field strength is force per unit charge.

5. (a) 4F
Explanation: Halving distance quadruples force.

6. (b) Conservative
Explanation: Electrostatic forces are conservative.

7. **(a) Electrostatic**
Explanation: Induction is an electrostatic phenomenon where charges redistribute.

8. **(b) 5**
Explanation: After 5 time constants, a capacitor is considered fully discharged.

9. **(b)** Ω^{-1} **s**
Explanation: $ohm \times farad = sec$
$farad = ohm^{-1}.sec$

10. **(c) Decrease**
Explanation: Capacitance $C \propto A$; decreasing area reduces C.

11. **(b)** 6×10^{-5} C
Explanation: $Q = CV = 5 \times 10^{-6} \times 12 = 6 \times 10^{-5}$ C (assuming typo in options).

12. **(a) Small value of RC**
Explanation: Smaller RC means faster charging/discharging.

13. **(a)** $1\ \text{mm}^2$
Explanation: $A = \frac{Cd}{\varepsilon_0} = 1\ \text{mm}^2$.

14. **(b)** $x/2$
Explanation: Doubling separation halves capacitance; energy stored is halved.

15. **(b) 2**
Explanation: Energy ratio $\frac{U_1}{U_2} = \frac{C_2}{C_1} = 2$.

16. **(a) Electric field**
Explanation: Capacitors store energy in the electric field.

17. **(b)** 1.8×10^4 V
Explanation: $V = \frac{kq}{r} = 1.8 \times 10^4$ V.

18. **(c) 20 N/C**
Explanation: Electric field near a charged plate is independent of distance.

19. **(b) At infinity**
Explanation: Zero electric field for an isolated charge is at infinity.

20. **(a) 0.1 V**
Explanation: $V = \frac{W}{Q} = \frac{2}{20} = 0.1$ V.

21. **(d) Joule = coulomb x volt**
Explanation: $1\ \text{J} = 1\ \text{C} \cdot \text{V}$.

22. **(c)** $\vec{E} = -\frac{kq}{r^2}\hat{r}$
Explanation: Correct vector form for a negative charge.

23. **(d)**
Explanation: Minimum charge is 1.6×10^{-19} C,

24. **(a)** 9×10^9
Explanation: $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N\cdotpm^2/C^2.
25. **(d)** 2μF, 18μF
Explanation: Minimum (series: 2μF), maximum (parallel: 18μF).
26. **(a)** $\frac{C_1}{C_2}$
Explanation: Charge distribution in parallel capacitors $\frac{Q_1}{Q_2} = \frac{C_1}{C_2}$.
27. **(c)** $\frac{1}{2}nCV^2$
Explanation: Total energy for n parallel capacitors.
28. **(a)** 2.5×10^{-3} J
Explanation: $U = \frac{1}{2} \times 50 \times 10^{-6} \times 10^2 = 2.5 \times 10^{-3}$ J.
29. **(a)** 10 Vm^{-1} **upward**
Explanation: $qE = mg \Rightarrow E = \frac{mg}{q} \approx 10$ V/m upward to balance gravity.
30. **(a)** $\frac{CV^2}{2d}$
Explanation: Force between plates derived from energy and geometry: $F = \frac{CV^2}{2d}$.
31. **(c) Parabola**
Explanation: Electron experiences constant acceleration perpendicular to velocity, resulting in parabolic motion.
32. **(b)**
Explanation: Energy gained = qV = 50,000 eV = $8 \times 10^{-15} J$
33. **(b)** 500 NC^{-1}
Explanation: $E = \frac{V}{d} = \frac{10}{0.02} = 500$ N/C.
34. **(d)** $\frac{-Ke^2}{r^2}\hat{r}$
35. **(b)** 3 μF
Explanation: Equivalent capacitance of series-parallel combination ≈ 3 μF.
36. **(a)** 0.02 J
Explanation: $U = \frac{1}{2}CV^2 = 0.5 \times 4 \times 10^{-6} \times 10^4 = 0.02$ J.
37. **(c) Velocity of electron will decrease**
Explanation: Force opposes motion (electron negative), causing deceleration.
38. **(a) Zero**
Explanation: Midpoint potential cancels for +q and -q.
39. **(c) Electric field is not zero but potential is zero**
Explanation: Field vectors add (non-zero), potentials cancel.
40. **(b) Same potential**
Explanation: Current stops when potentials equalize.
41. **(a)** 2.3×10^{-8} N
Explanation: $F = \frac{ke^2}{r^2} \approx 2.3 \times 10^{-8}$ N.
42. **(a)** 9×10^3 N
Explanation: $F = \frac{kq_1q_2}{r^2} = 9 \times 10^3$ N.
43. **(b) 1:1**
Explanation: Newton's third law ensures equal force magnitudes.
44. **(a)** $16\ \mu$C
Explanation: Removing electrons leaves positive charge: $10^{14} \times 1.6 \times 10^{-19} = 16\ \mu$C.
45. **(c) Both electric and magnetic field**
Explanation: Moving charges produce both fields.
46. **(c)** m_p/m_e
Explanation: Acceleration ratio $\frac{a_e}{a_p} = \frac{m_p}{m_e}$.
47. **(a)** 2×10^{11} C
Explanation: Likely typo; correct value is 2×10^{-11} C, but closest option given.
48. **(a) zero**
Explanation: Charge resides on the surface; internal field is zero.
49. **(c)** $\sqrt{2eV/m}$
Explanation: The kinetic energy gained by the electron is $eV = \frac{1}{2}mv^2$. Solving for v, we get $v = \sqrt{\frac{2eV}{m}}$.
50. **(a)** $\frac{q^2}{2C}$
Explanation: The energy stored in a capacitor is $\frac{1}{2}\frac{Q^2}{C}$.

UNIT 07 CURRENT ELECTRICITY

SOLUTION PRACTICE TEST NO. 1

Answers:

1. (b)
In parallel, voltage is the same. Smaller resistance draws more current (I = V/R).

2. (c) 0.5 A
5Ω and (2Ω+3Ω)=5Ω are in parallel. Total current splits equally: 0.5A through 3Ω.

3. (c) 1.1 ohm
Using V = I(R + r): r = (50/4.5) - 10 ≈ 1.1Ω.

4. (a) $\frac{5}{3}$A clockwise
(Assuming diagram context: Net voltage 25V, total resistance 15Ω → 5/3A. Answer key discrepancy noted.)

5. (d) 1:1
Specific resistance (resistivity) is material-dependent, same for both.

6. (a) 484 Ω
$P = V^2/R \rightarrow R = 220^2/100 = 484\Omega$.

7. (c) 10 A
$I = (62.5\times10^{18} \times 1.6\times10^{-19}) = 10$ A.

8. (c) 60 watt bulb
Lower resistance ⇒ higher power ($P = V^2/R$).

9. (c) 4 ohm
Linear relation: Solving equations gives $R_0 = 4\Omega$.

10. (b) 6.25×10^{15}
$Q = It = 0.001$ C/s $\rightarrow 0.001/(1.6\times10^{-19}) = 6.25\times10^{15}$.

11. (d) Both b and c
Filament bulb (non-linear) and diode (non-ohmic).

12. (b) I^2R
Power (rate of heat) = I^2R.

13. (b) σ_1 increases, σ_2 decreases
Ge (semiconductor) σ↑ with temp; Na (conductor) σ↓.

14. (d) 3E, 5r
Net emf = 4E - E = 3E; internal resistances add (5r).

15. (b) 12V
Parallel cells retain single cell emf.

16. (b) r/10
Minimum resistance: parallel all 10 resistors.

17. (c) 6×10^{-4} C
$Q = 20\times10^{-6} \times 30 = 6\times10^{-4}$ C.

18. (c) 4W

$$I = \frac{E}{r+R} = \frac{10}{5} = 2A$$

$$P = I^2r = 4W$$

19. (b) 400 Ω
Using $P = \frac{V^2}{R}$, resistance when hot: $R = \frac{200^2}{100} = 400\,\Omega$.

20. (b) 2 ohm
Resistance $R = \frac{\Delta V}{\Delta I}$. If the graph is linear with slope 2, $R = 2\,\Omega$.

21. (c) 0.24 mC
Charge $Q = I \cdot t = 12\,\text{mA} \cdot 0.02\,\text{s} = 0.24\,\text{mC}$.

22. (a) 264.65Ω
Using $R = R_0(1 + \alpha\Delta T) = 200(1 + 0.004041 \cdot 80) \approx 264.65\,\Omega$.

23. (d) Current only
Current is constant in a series circuit; drift velocity varies with cross-sectional area.

24. (a) 1×10^7
Resistivity is intrinsic to the material and independent of dimensions.

25. (c) Doubled
Drift velocity $v_d \propto E \propto V$. Doubling V doubles v_d.

26. (b) Both Y and Z are true
Semiconductor resistivity decreases with temperature (Y). Conductor collision rate increases with temperature (Z).

27. (a) Have same units
Both terminal PD and EMF are measured in volts.

28. (a) Current through each bulb is same
In series, current is identical through all components.

29. (c) One kilowatt hour
Standard unit for electricity billing.

30. (d) 0.45 A
Net voltage $5.6\,\text{V} - 2\,\text{V} = 3.6\,\text{V}$. Total resistance $8\,\Omega$. $I = \frac{3.6}{8} = 0.45\,\text{A}$.

31. (d) Same for all
Identical P and V imply the same resistance $R = \frac{V^2}{P}$.

32. (c) Infinite, infinite
Short circuit current approaches infinity (ideal), open circuit resistance is infinite.

33. (c)
Potential difference is the ratio of power dissipated to current. $V = \frac{P}{I}$.

34. (d) 0.6 V
Current $I = \frac{1.5}{5} = 0.3\,\text{A}$. Voltage across internal resistor: $0.3 \times 2 = 0.6\,\text{V}$.

35. (b) and (c)
(AΩ) = V and (J/C) = V; ($A^2\Omega$) = W and (CV/s) = W. Both (b) and (c) are correct.

36. (d) $\frac{10}{9}\,\Omega$

$$r = \frac{E - V}{V/R} = \frac{2.2 - 1.8}{1.8} \times 5 = \frac{0.4}{1.8} \times 5 = \frac{10}{9}$$

37. (c) 25 Ω

$R = \frac{V^2}{P} = \frac{25^2}{25} = 25\,\Omega.$

38. (c) 24.2 kJ

Energy $= \frac{220^2}{20} \times 10 = 24{,}200$ J.

39. (c) Constant

Ohm's law holds when temperature is constant.

40. (a) Rate of electric work done per unit time

Power is work done per unit time.

41. (b) No

Filament resistance changes with temperature; Ohm's law not strictly applicable.

42. (b) °C⁻¹

Temperature coefficient unit is per degree Celsius.

43. (a) 333.3 A

$I = \frac{4000}{12} \approx 333.3$ A.

44. (a) Source of emf

Internal resistance is within the battery.

45. (a) Rate of flow of charge

Current definition.

46. (b) 6.4 A, 9.6 A

Current division: $I_1 = 16 \times \frac{12}{20} = 9.6$ A, $I_2 = 6.4$ A.

47. (b) 3.12×10¹⁹

$\frac{5}{1.6\times10^{-19}} \approx 3.12 \times 10^{19}$. (Options likely typo.)

48. (a) 330 W

$P = 220 \times 1.5 = 330$ W.

49. (b) Load resistance

Maximum power transfer theorem.

50. (a)

1 kΩ = 1000 Ω

SOLUTION PRACTICE TEST NO. 2

1. (a) 0.016 per °C

$\alpha \approx \frac{21.5-5.5}{5.5\times181} \approx 0.016\,°\text{C}^{-1}.$

2. (c) Rest of three bulbs will light

Parallel circuit: intact bulbs remain operational.

3. (b) Volts

Voltage is measured in volts (V).

4. (c) Constant

A constant potential difference maintains a steady current.

5. (b) 300W

Higher power at the same voltage implies lower resistance ($R = \frac{V^2}{P}$).

6. (b) Resistance halved, specific resistance unchanged

$R = \rho\frac{L}{A}$. Doubling L and radius (quadrupling A) reduces R by half. Resistivity is intrinsic.

7. (b) To decrease current

Adding resistance in series increases total resistance, reducing current.

8. (c) Time

Steady current does not vary with time.

9. (a) 28.8 kWh

Total energy: 6×40 W $\times 4$ h/day $\times 30 = 28.8$ kWh.

10. (d) 863

$P = IV = 7.5 \times 115 = 862.5$ W ≈ 863 W.

11. (a) E

Open circuit terminal PD equals the cell's EMF.

12. (d) 20 W

Total resistance: $3 \times \frac{200^2}{60} \approx 2000\,\Omega$. Power: $\frac{200^2}{2000} =$ 20 W.

13. (a) Source of emf

Converts non-electrical energy (e.g., chemical, mechanical) into electrical energy.

14. (b) Electric power

Power is the rate of energy conversion.

15. (b) 2:1

Resistance ratio $R_{25}/R_{100} = 4$. Filament diameter ratio: $\sqrt{4} = 2:1$.

16. (a) 25 W bulb

Higher resistance (25W) dissipates more power in series ($P = I^2R$).

17. (a) 440 rupees

Energy: 10 A $\times$ 220 V $\times$ 10 h $=$ 22 kWh. Cost: $22 \times 20 = 440$ Rs.

18. (b) 2 : 5

Resistance ratio $R_{500}/R_{200} = \frac{200}{500} = 2:5$.

19. (c) Electric power

$V \times \frac{Q}{t} = VI =$ Power.

20. (b) Both source and load resistance

Maximum power transfer occurs when load resistance equals source resistance.

21. (a) 3×10^{19}

Electrons per second: $\frac{4.8}{1.6\times10^{-19}} = 3 \times 10^{19}$.

22. (d) n^2R

Parallel: $R = \frac{r}{n} \Rightarrow r = nR$. Series: $R_{\text{total}} = n \times r = n^2R$.

23. (c) 10 Ω

Using Ohm's Law: $R = \frac{V}{I} = \frac{20}{2} = 10\,\Omega$.

24. (d) Resistance of copper decreases and that of germanium increase

Copper (conductor) resistance decreases with cooling; germanium (semiconductor) resistance increases.

25. (a) Metals have positive temperature coefficient

Metals' resistance increases with temperature.

26. (a) Greater than any individual resistor

Series resistances add up.

27. (a) kWh

1 kW for 1 hour equals 1 kWh.

28. (a) $\frac{R}{4}$

Volume constant: $R \propto \frac{L}{A}$. Halving L and doubling radius (quadrupling A) reduces R by 4.

29. (a) 0.5 A

Assuming resistors 8Ω and 12Ω in parallel (4.8Ω) in series with 7.2Ω: Total $R = 12\Omega$. Current $I = \frac{V}{R} = \frac{6}{12} =$ 0.5A.

30. (a)

Resistivity $\rho = \frac{RA}{L} = \frac{(0.5)(1\times10^{-6})}{0.5} = 1\times10^{-6}$.

31. (d) None of the above

Resistivity is intrinsic and independent of dimensions.

32. (b) 5 Ω

$R_{eq} = 2 + \frac{2}{2} + 2 = 5\,\Omega$.

33. (a) 2 Ω

Parallel formula: $\frac{1}{\frac{6}{5}} = \frac{1}{3} + \frac{1}{R} \Rightarrow R = 2\,\Omega$.

34. (b) 2 V, 0.4 Ω

EMF = 2 V. Internal resistance $r = \frac{\Delta V}{\Delta I} = \frac{2-0}{5} = 0.4\,\Omega$.

35. (d) 4 W

Current $I = \sqrt{\frac{P}{R}} = \sqrt{1} = 1$ A. Power in 4Ω: $1^2 \times 4 =$ 4 W.

36. (c) 1:1

Series current is the same for both bulbs.

37. (c) Germanium

Semiconductor resistance decreases with temperature.

38. (b) 0.25 R

Doubling diameter quadruples area: $R_{\text{new}} = \frac{R}{4}$.

39. (d) 180 ohm

Stretching triples length and reduces area by 1/3. $R' = 9 \times 20 = 180\,\Omega$.

40. (a)

$$R_{eq} = \frac{4\times2}{2+4} = \frac{8}{6} = \frac{4}{3}\ ohm$$

41. (c) 0.5 Ω

Maximum power when $R = r = 0.5\Omega$.

42. (a) 0.25 Ω

$r = \frac{1.5}{6} = 0.25\Omega$.

43. (c) 2 watt

$P_{\text{max}} = \frac{2^2}{4\times0.5} = 2$ W.

44. (a) 0.16 mC

$Q = 8\,\text{mA} \times 0.02\,\text{s} = 0.16\,\text{mC}$.

45. (d) All of these

Power can be expressed as VI, I^2R, or V^2/R.

46. (d) Ohm's law

Direct proportionality of I and V under constant conditions.

47. (a) Rate of electric work done per unit time

Power definition.

48. (b) 75W

$P = 250 \times 0.3 = 75$ W.

49. (a) Halved

Resistance $R \propto L$; halving L halves R.

50. (c) Remains the same

Resistivity is material-dependent, unaffected by cutting.

SOLUTION PRACTICE TEST NO. 3

1. (b) 10 Ω

Assuming parallel/series mix (answer based on common configurations).

2. (a)

$$I = \frac{10^7 \times 1.6 \times 10^{-19}}{10^{-6}} = 1.6 \times 10^{-6}$$

3. (c) $\frac{E-V}{I}$

$E = V + Ir \Rightarrow r = \frac{E-V}{I}$

4. (c) Zero

Short circuit terminal voltage is zero.

5. (c) 36000 C

$Q = 10 \times 3600 = 36000$ C.

6. (b) $R_1 < R_2$

Steeper slope implies lower resistance.

7. (c) Will remains same

Doubling L and A cancels effect.

8. (b)

Resistivity $\rho = \frac{RA}{L} = \frac{0.7\times\pi(0.001)^2}{1} \approx 2.2\times10^{-6}\,\Omega\cdot\text{m}$.

9. (b)

$$P \propto \frac{1}{R}$$

The ratio between resistances is 2:1, so ratio between powers is 1:2

10. (b)

Brighter bulb has lower resistance in parallel.

11. (a)

Ideal cell: $r = 0$.

12. (b)

High current causes potential drop.

13. (b)

$I = \frac{60}{220} = \frac{3}{11}$ A.

14. (a)

$R_t = R_0(1 + \alpha t)$.

15. (c)

Four combinations: series, parallel, two in series + one parallel, two parallel + one series.

16. (b)

Electric eel: ~600 V.

17. (b)

Delete the 5Ω bridge resistance. $R_1 = 5 + 5 = 10$.

$$R_2 = 5 + 5 = 10$$

$$R_{eq} = \frac{10}{2} = 5$$

18. (c)

100W bulb draws more current.

19. (c)

Efficiency = 50% at max power transfer.

20. (c)

$P_{\text{max}} = \frac{E^2}{4R}$.

21. (c)

Effective resistance $\frac{8}{3}\,\Omega$.

22. (d)
Equivalent resistance ≈5.3Ω.
23. (b)
Twisted halves: $R = 1\,\Omega$.
24. (a)
Resistance halved; resistivity unchanged.
25. (a)
Resistance between diameter ends: 4Ω.
26. (b)
Series resistor $R = 10\,\Omega$.
27. (a)
J/C = Volt.
28. (a)
Lower bulb resistance increases heater power.
29. (a) Pkr 5.4
Energy = 0.1 kW × 3 h = 0.3 kWh. Cost = 0.3 × 18 = 5.4 Pkr.
30. (a) 60 units
Daily energy = 2 kW × 1 h = 2 kWh. Monthly = 2 × 30 = 60 kWh (units).
31. (d) 19.3 W
Equivalent resistance $R_{eq} = \frac{V^2}{100} + \frac{V^2}{60} + \frac{V^2}{40}$. Total power $P = \frac{V^2}{R_{eq}} \approx 19.3$ W.
32. (d) 16.5 V
Current $I = \frac{24}{5.5+2.5} = 3$ A. Terminal voltage $V = 24 - 3 \times 2.5 = 16.5$ V.
33. (b) 6.0 V
Current $I = \frac{100}{50} = 2$ A. Voltage $V = \frac{P}{I} = \frac{12}{2} = 6$ V.
34. (a) In 35 W bulb is lesser
Current $I = \frac{P}{V}$. Lower power (35 W) draws less current.
35. (b) 1 watt = (1 volt) × (1 ampere)
Power formula $P = VI$.
36. (a) Kilowatt hour
1 kW × 1 h = 1 kWh.
37. (b) 1.5 ohm
$R = \frac{V}{I} = \frac{45}{30} = 1.5\,\Omega$.
38. (d) Electrolytes
Resistance decreases with temperature (negative coefficient).
39. (d) 4 ohm
Each wire $R = 1\,\Omega$. Series total = 4 × 1 = $4\,\Omega$.
40. (a) Ohm
By Ohm's Law, $\frac{V}{I} = R$.
41. (a) 0.9 Amp
$I = \frac{200}{220} \approx 0.9$ A.
42. (a) I^2Rt
Joule's Law: $H = I^2Rt$.
43. (b) Ohm meter
Resistivity ρ unit = Ω·m.
44. (c) Zero
Superconductors have zero resistance.
45. (a) 3R
Resistances are connected in series.
46. (c) $\frac{R_1R_2+R_1R_3+R_2R_3}{R_2+R_3}$

$$R_1 + \frac{R_2R_3}{R_2+R_3} = \frac{R_1R_2 + R_1R_3 + R_2R_3}{R_2+R_3}$$

47. (b) Resistance halved, specific resistance unchanged
$R = \rho\frac{L}{A}$. Doubling L and radius (quadrupling A) halves R.
48. (a) $1 \times 10^{-7}\,\Omega\cdot$m
$\rho = \frac{RA}{L} = \frac{2\times2.5\times10^{-7}}{5} = 1 \times 10^{-7}\,\Omega\cdot$m.
49. (b) Bulb B_1 will become brighter
If B_2 and B_3 are in parallel and in series with B_1, disconnecting one reduces total parallel resistance, increasing current through B_1.
50. (a) Almost zero
At absolute zero, conductors approach zero resistance (non-superconductors still have minimal residual resistance).

SOLUTION PRACTICE TEST NO. 4

Answers:
1. (c) Meter cube
Resistivity is defined for a 1m length and 1m² cross-sectional area or meter cube.
2. (a) Infinite
Short circuit current is theoretically infinite.
3. (a) 1×10^{-7}
$\rho = \frac{RA}{L} = 1 \times 10^{-7}\,\Omega\cdot$m.
4. (a) 3 amp
$I = \frac{Q}{t} = 3$ A.
5. (a) Same
Series current is constant.
6. (b) Carbon
Carbon has a negative temperature coefficient.
7. (d) Both B & C
Ohm's Law: $V = IR$ and $I \propto V$.
8. (a) Ohm
SI unit of resistance.
9. (b) less than maximum
10. (d) 50 kWh
Total energy: $10 \times 25\,\text{W} \times 10\,\text{h} \times 20 = 50\,\text{kWh}$.
11. (b) E > V
Terminal voltage $V = E - Ir$, so $E > V$.
12. (d) 80 W
Parallel power: $\frac{V^2}{R/4} = 80$ W.
13. (c) 10 V
$V = \frac{E}{2} = 10$ V.
14. (a) PKR 27.5
Cost: 550 W × 2.5 h × 20 PKR/kWh = 27.5 PKR.
15. (c) R = r
Maximum power transfer when load resistance equals

internal resistance.

16. (d) $P_1 < P_2 < P_3$

Higher resistance (lower wattage) bulbs more power in series.

17. (b) The resistance of an incandescent lamp is greater when the lamp is switched off

Cold filaments have lower resistance.

18. (b) 1:3

Power in series depends on resistance. Ratio = 1:3.

19. (d) 850 W

$P = IV = 4.25 \times 200 = 850\,\text{W}$.

20. (b) 100 W bulb

1 kW uses 10x energy of 100 W.

21. (c) Rest glow with initial brightness

Parallel connection keeps other bulbs unaffected.

22. (c) 5 Joules

Energy = $V \times Q = 5\,\text{V} \times 1\,\text{C} = 5\,\text{J}$.

23. (a) $10^{-6}\,\Omega$

$R = \rho \frac{L}{A} = 50 \times 10^{-8} \times \frac{0.5}{0.25} = 10^{-6}\,\Omega$.

24. (c)

Shorter length and larger diameter minimize resistance.

25. (b) 10

$n^2 = 100 \Rightarrow n = 10$.

26. (d) Tungsten wire

Filament bulbs (tungsten) are non-ohmic when heated.

27. (a) $°C^{-1}$

Temperature coefficient unit.

28. (c) $\frac{12}{11}\,\Omega$

Parallel resistance: $\frac{1}{R} = \frac{1}{2} + \frac{1}{4} + \frac{1}{6} \Rightarrow R = \frac{12}{11}\,\Omega$.

29. (c) $\frac{P_1 P_2}{P_1 + P_2}$

Total power in series: $\frac{P_1 P_2}{P_1 + P_2}$.

30. (a) 3:2

Resistance ratio $R_{40}/R_{60} = 60/40 = 3:2$.

31. (a) 234 W

$P = I^2 R = 4^2 \times 14.6 = 234\,\text{W}$.

32. [d]

E only depends upon nature of battery, not current

33. (d) All of these

Resistance increases with length, temperature, and reduced area.

34. (c) Being charged

Terminal PD > EMF during charging.

35. (c) 10 A

$R_{eq} = 2\Omega$

$I = \frac{20}{2} = 10\,\text{A}$.

36. (a) 100W bulb has thicker filament

Lower resistance (higher wattage) requires thicker filament.

37. (c) 500 watt

Each heater's resistance $R = \frac{V^2}{P} = \frac{220^2}{1000} = 48.4\,\Omega$. In series, total resistance $R_{\text{total}} = 48.4 + 48.4 = 96.8\,\Omega$.

Power $P = \frac{V^2}{R_{\text{total}}} = \frac{220^2}{96.8} = 500\,\text{W}$.

38. (d) Equal to sum of component resistors

Series resistors add directly: $R_{\text{eq}} = R_1 + R_2 + \cdots$.

39. (c) Increase, decrease

Conductor resistivity increases with temperature (more lattice vibrations). Semiconductor resistivity decreases (more charge carriers).

40. (b) 6 Ω

$$R_{eq} = 2 + \frac{4}{2} + 2 = 6$$

41. (a) 3 Ω

Adjacent vertices: one side (4Ω) in parallel with three sides (12Ω). Effective resistance $\frac{4 \times 12}{4 + 12} = 3\,\Omega$.

42. (d) 3.6 Ω

Total resistance in first path = 9 ohm

Total resistance in 2nd path = 6 ohm

$$R_{eq} = \frac{9 \times 6}{9 + 6} = 3.6$$

43. (b) R

Resistance $R = \rho \frac{L}{A}$. New wire: $R' = \rho \frac{4L}{\pi (2d)^2} = \rho \frac{4L}{4\pi d^2} = \rho \frac{L}{\pi d^2} = R$.

44. (b) Halved

Resistance doubles, so conductance (inverse of resistance) halves.

45. (b) $\frac{3}{2} A$

net voltage $10 + 5 = 15V$. If resistor 10Ω, current $I = \frac{15}{10} = \frac{3}{2} A$.

46. (c) $R_2 = 2R_1$

$R = \frac{V^2}{P}$. For 200W, $R_2 = \frac{V^2}{200}$; for 400W, $R_1 = \frac{V^2}{400}$.

Thus, $R_2 = 2R_1$.

47. (d) $\frac{R}{16}$

Each part $\frac{R}{4}$. Four in parallel: $\frac{1}{R_{\text{eq}}} = 4 \times \frac{4}{R} \Rightarrow R_{\text{eq}} = \frac{R}{16}$.

48. (d) 3 Ω

Circle split into two 6Ω halves in parallel: $\frac{6 \times 6}{6 + 6} = 3\,\Omega$.

49. (d) 10V

In parallel, all resistors have the same voltage as the battery (10V).

50. (c) Resistance of filament in 40W bulb is more

Higher power (100W) means lower resistance: $R = \frac{V^2}{P}$.

UNIT 08 ELECTROMAGNETISM

SOLUTION PRACTICE TEST NO. 1

Answers and Explanations:

1. **(b) The momentum of the particle**
   The radius $r = \frac{mv}{qB}$, so $r \propto$ momentum.
2. **(a)** $F = q(E + v \times B)$
   Lorentz force formula combines electric and magnetic forces.
3. **(a)** $\frac{v}{Br}$
   From $\frac{mv}{r} = qvB$, solving $\frac{e}{m} = \frac{v}{Br}$.
4. **(d) Helix**
   Velocity has components parallel and perpendicular to B, causing helical motion.
5. **(a) Remain unaffected**
   $v \parallel B \Rightarrow$ force $= 0$.
6. **(b) Mass**
   Magnetic force $F = q(v \times B)$ is independent of mass.
7. **(d) Zero**
   Neutrons are uncharged ($q = 0$).
8. **(a) 0°**
   Flux $\Phi = BA\cos\theta$, maximized at $\theta = 0^\circ$.
9. **(a) Wb m^{-2}**
   Tesla (T) is equivalent to Wb/m^2.
10. **(c) 2r**
    $r \propto \frac{1}{B}$; halving B doubles r.
11. **(d) 4.0 cm**
    $r \propto v$; doubling v doubles r.
12. **(c)** $10\sqrt{2}$ cm
    $r \propto \sqrt{\frac{m}{q}}$; α-particle has $\sqrt{2} \times$ radius of proton.
13. **(c) 8 times**
    $F \propto qvB$; doubling all parameters multiplies F by $2 \times 2 \times 2 = 8$.
14. **(a) 0.50 weber**
    $\Phi = 0.5 \times 2 \times \cos 60^\circ = 0.5$ Wb.
15. **(c) Zero**
    Magnetic field outside a solenoid is negligible.
16. **(d) zero**
    External field of a solenoid is effectively zero.
17. **(a)** $NA^{-1}m^{-1}$
    $1\,\text{T} = 1\,\text{N}/(\text{A} \cdot \text{m})$.
18. **(c) West to east**
    Right-hand rule: current north, field circulates counterclockwise. Above the wire, field direction is west to east.
19. **(c)** 9.6×10^{-12} N
    $F = qvB\sin\theta = 1.6 \times 10^{-19} \times 4 \times 10^7 \times 3 \times 0.5 = 9.6 \times 10^{-12}$ N.
20. **(c) Deflecting force**
    Magnetic force causes charged particles to deflect from their path.
21. **(d) Same**
    Φ = N·B·A. Doubling N and halving A keeps Φ unchanged.
22. **(b)** 2.7×10^{-2} T
    $B = \mu_0 nI = 4\pi \times 10^{-7} \times 4250 \times 5 \approx 0.0267$ T.
23. **(a)** $\frac{\mu_0 nI}{2}$
    Field at the ends of a solenoid is half the central field.
24. **(d) Stationary charge**
    Stationary charges experience no magnetic force.
25. **(a) 0 degree**
    Flux $\Phi = BA\cos\theta$ is maximized at $\theta = 0^\circ$.
26. **(a) Distance**
    Magnetic force between wires $\propto \frac{1}{d}$.
27. **(d) 90**
    $F = qvB\sin\theta$; maximum at $\theta = 90^\circ$.
28. **(c) 5 m**
    $r = \frac{v}{(q/m)B} = \frac{10^7}{10^8 \times 2 \times 10^{-2}} = 5$ m.
29. **(b)** [MT^{-2}A^{-1}]
    Derived from $B = \frac{F}{IL}$.
30. **(c) Speed up**
    Electric field parallel to motion accelerates the charge; magnetic force is zero.
31. **(c)**
    Fields is strong where lines are closer each other.
32. **(a) Four times**
    Energy density $\propto B^2$; doubling B quadruples energy.
33. **(d) Electric, magnetic and gravitational fields**
    All three fields can exert forces depending on conditions.
34. **(a) Circular**
    Perpendicular velocity and magnetic field result in circular motion.
35. **(c) 20 wb**
    $\Phi = B_x \cdot A = 2 \cdot 10 = 20$ Wb (assuming $B = 2\mathbf{i} + 3\mathbf{j} - 5t\mathbf{k}$).
36. **(b)** $\frac{v}{Br}$
    From $\frac{e}{m} = \frac{v}{Br}$.
37. **(b)** $\frac{qB}{m}$
    Cyclotron frequency $\omega = \frac{qB}{m}$.
38. **(c) 2B**
    $B \propto \frac{1}{r}$; halving r doubles B.

39. (c) Along positive z-axis
Right-hand rule for anti-clockwise motion in x-y plane requires $\mathbf{B}$ along +z.

40. (c) B lies perpendicular to the plane of area A
Flux is maximized when $\mathbf{B}$ is perpendicular to the area.

Answers and Explanations:

41. (d) 9.6×10^{-19} C
Using $F = qvB\sin\theta$:
$q = \frac{F}{vB\sin\theta} = \frac{4.8\times10^{-17}}{20\times5\times0.5} = 9.6 \times 10^{-19}$ C.

42. (a)
$F = q(\mathbf{v} \times \mathbf{B}) \Rightarrow \mathrm{F}_{\max} = qvB = Bue.$

43. (b) 5 Wb
Dot product: $1 \cdot 2 + 2 \cdot 1 + 1 \cdot 1 = 2 + 2 + 1 =$ 5 Wb.

44. (c) $r = \frac{mv}{qB}$
Radius formula for circular motion in a magnetic field.

45. (b) Repel each other
Opposite currents in parallel wires repel due to magnetic force.

46. (b) Vector area
Magnetic flux $\Phi = \mathbf{B} \cdot \mathbf{A}$, involving vector area.

47. (b) 100 N
$F = ILB = 2 \times 5 \times 10 = 100$ N.

48. (b) Magnetic field
Steady current produces a magnetic field (Ampère's law).

49. (a) Magnetic flux
Weber (Wb) is the unit of magnetic flux.

50. (b) Behaves like south pole
Clockwise current induces a south pole face.

SOLUTION PRACTICE TEST NO. 2

1. (a) 0.01 Wb
$\Phi = B \cdot A = 0.2 \times 0.05 = 0.01$ Wb.

2. (c) 0 N
$F = qvB\sin0^\circ = 0.$

3. (d) 0.00015 Wb
$\Phi = 0.1 \times (0.03 \times 0.05) = 0.00015$ Wb.

4. (a) Proton
Proton has higher q/m ratio, leading to greater deflection.

5. (b) Circular
Perpendicular $\mathbf{v}$ and $\mathbf{B}$ cause circular motion.

6. (b) 15N
$F = qvB\sin30^\circ = 2 \times 5 \times 3 \times 0.5 = 15$ N.

7. (b) Weber
Weber is the unit of magnetic flux.

8. (d) Current and magnetic field
Ampère's law links current to the magnetic field it generates.

9. (b) It moves away from solenoid
Inserting an iron core weakens the solenoid's magnetic field, repelling the magnet.

10. (d) 60°
$\cos30^\circ = \frac{\sqrt{3}}{2}$, reducing flux to $\frac{\sqrt{3}}{2}$ times maximum, angle with plane area $= 90 - 30 = 60^o$

11. (d) Zero
Velocity parallel/anti-parallel to $\mathbf{B}$ results in $F = qvB\sin180^\circ = 0.$

12. (c) $\vec{P} = qnAL(\vec{v} \times \vec{B})$
Total force is the sum of forces on all charges: nAL charges, each with force $q(\vec{v} \times \vec{B})$.

13. (a) 0°
Flux $\Phi = BA\cos\theta$ is zero when $\theta = 90^\circ$, angle with plane area $= 90 - 90 = 0^o$

14. (b) Increases
Radius $r \propto v$; increasing v increases r.

15. (a) $r_\alpha = r_p < r_d$
$r \propto \sqrt{\frac{m}{q^2}}$. For equal K, α and proton have same r, deuteron has larger r.

16. (d) Remains same
$B = \mu_0 nI$. Doubling turns and current, quadrupling length keeps nI constant.

17. (a) $v = \frac{E}{B}$
Velocity selector balances electric and magnetic forces: $v = E/B$.

18. (a) $\theta = 0^\circ$
Force $F = qvB\sin\theta = 0$ when $\theta = 0^\circ$.

19. (c) anti-clockwise
Thumb side the direction of field is anticlockwise.

20. (d) 4
$F_p = 2F_\alpha \Rightarrow ev_pB = 2(2ev_\alpha B) \Rightarrow v_p = 4v_\alpha$.

21. (b) 2
$r \propto \frac{1}{q}$ for equal p. Proton $q = e$, α-particle $q = 2e$: $r_p/r_\alpha = 2$.

22. (a) 10^4 **gauss**
$1\ \mathrm{T} = 10^4$ G.

23. (d) Zero
Proton velocity parallel to $\mathbf{B}$, so $F = 0$.

24. (c)
According to right hand rule the direction of force on electron is out of the paper.

25. (a) 5 N
$F = qvB = 1 \times 10 \times 0.5 = 5$ N ($\theta = 90^\circ$).

26. (a) Electric field
Magnetic fields do no work; only electric fields can transfer energy to a charge.

27. (a) East
Using the right-hand rule for negative charges: velocity (north) × magnetic field (east) results in upward force.

28. (c) E, B **and** v **are mutually perpendicular and** $v = \frac{E}{B}$
For zero net force, electric and magnetic forces must cancel: $E = vB$ with perpendicular fields.

29. (c) Electron remains stationary
Stationary charges experience no magnetic force ($F = qvB\sin\theta = 0$).

30. (d) West
Right-hand rule: current south, magnetic field circles clockwise above the wire (west direction).

31. (d) Opposite direction as previously, with the magnitude of deflection doubled
Withdrawing faster reverses the induced current and doubles the emf (rate of flux change).

32. (c) $\frac{F}{\sqrt{2}}$
$F = qvB\sin\theta$; at 45°, $\sin 45° = \frac{\sqrt{2}}{2}$, reducing force by $\sqrt{2}$.

33. (b) 1:2
$r \propto \frac{1}{q}$. Proton ($q = e$) has twice the radius of α-particle ($q = 2e$).

34. (a) $\frac{Bq}{2\pi m}$
Cyclotron frequency formula: $f = \frac{qB}{2\pi m}$.

35. (d) Zero, if B and v are parallel
Magnetic force $F = qvB\sin\theta = 0$ when $\theta = 0°$.

36. (a) Dot product of magnetic field and area vector
Magnetic flux $\Phi = \mathbf{B}\cdot\mathbf{A}$.

37. (a) 14.8
$F = ILB = 2.75 \times 0.6 \times 9 = 14.85 \approx 14.8$.

38. (b) Bar magnet
A solenoid with current mimics a bar magnet with distinct N and S poles.

39. (b) S-pole
The field induced on magnet side is N-Pole. The field induced on farther side of magnet side is S-Pole.

40. (a) 3.2×10^{-12} **N**
$F = qvB = 2 \times 1.6 \times 10^{-19} \times 10^7 \times 1 = 3.2 \times 10^{-12}$ N.

41. (b) 5.6×10^{-5} **T**
$B = \frac{mv}{qr} = \frac{9\times10^{-31}\times10^6}{1.6\times10^{-19}\times0.1} \approx 5.6 \times 10^{-5}$ T.

42. (c) North
Force direction for electron: $-\mathbf{v}\times\mathbf{B}$ (east × up = south force; electron deflects north).

43. (a) 3.9×10^4
Using $B = \mu_0 nI \Rightarrow n = \frac{B}{\mu_0 I} = \frac{1}{4\pi\times10^{-7}\times20} \approx 3.98 \times 10^4$.

44. (a) $\frac{p}{q}$
Radius $r = \frac{mv}{qB} = \frac{p}{qB}$; proportional to $\frac{p}{q}$.

45. (a) I
Magnetic field $B \propto I$ (Ampère's law).

46. (b) Proton will move in a circle with constant speed and there will be no effect on the motion of electron
Proton's perpendicular motion causes circular path; electron's parallel motion experiences no force.

47. (a) 2.4×10^{-12} N
$F = qvB\sin\theta = 1.6 \times 10^{-19} \times 2 \times 10^7 \times 1.5 \times 0.5 = 2.4 \times 10^{-12}$ N.

48. (d) West
Right-hand rule: upward velocity northward field westward force.

49. (c) v and B are perpendicular
$F = qvB\sin\theta$ is maximized at $\theta = 90°$.

50. (d) Magnitude of momentum and energy remains unchanged
Magnetic force changes direction, not speed or energy.

SOLUTION PRACTICE TEST NO. 3

1. (c) Move in a circular orbit with its speed unchanged
Magnetic force causes centripetal motion; speed remains constant.

2. (b) 5×10^{-12} N
$F = 1.6 \times 10^{-19} \times 2.5 \times 10^7 \times 2.5 \times \sin 30° = 5 \times 10^{-12}$ N.

3. (c) 2:1
$r \propto \frac{m}{q}$: α-particle $r = \frac{4m_p}{2e}$, proton $r = \frac{m_p}{e}$ → ratio $2:1$.

4. (d) None of these
e/m is an intrinsic property, independent of external factors.

5. (a) Proton
Proton has the smallest e/m due to its large mass.

6. (a) $\frac{r_e}{r_p} = 1$
$r = \frac{p}{qB}$: same p and q (magnitude) → equal radii.

7. (b) Magnetic field applied in the direction of motion
Magnetic force $= 0$ when $\mathbf{v} \parallel \mathbf{B}$.

8. (b) 90°
Magnetic force $F = qvB\sin\theta$ is maximum at $\theta = 90°$.

9. (b) 1 MeV
For same radius, kinetic energy $KE \propto \frac{q^2}{m}$. Proton and α-particle have the same q^2/m, so energy remains 1 MeV.

10. (c) Changes the direction of motion of the particle
Magnetic force acts perpendicular to velocity, altering direction but not speed or kinetic energy.

11. (d) 1:1:2
$KE = qV$. Proton ($q = 1$), electron ($q = 1$), α-particle ($q = 2$) → ratio $1:1:2$.

12. (a) Oersted
Oersted discovered the magnetic effect of electric current.

13. (b) ms^{-1}
E/B has units $\frac{N/C}{T} = \frac{N/C}{N/(A\cdot m)} = \frac{A\cdot m}{C} = m/s$.

14. (b) Remains constant
Magnetic forces do no work; kinetic energy remains unchanged.

15. (c) Moving charges
Magnetism arises from moving charges.

16. (a) Clockwise
Right-hand rule: current direction determines clockwise magnetic field when viewed from below.

17. (b) Upward
Force direction (north) implies $\mathbf{B}$ is upward (using $\mathbf{v} \times \mathbf{B}$).

18. (d) Both a and b
Force depends on momentum (mv) and magnetic field (B).

19. (b) $4\pi \times 10^{-7}$ TmA^{-1}
Permeability of free space: $\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1}.

20. (a) $0°$
Flux $\Phi = BA\cos\theta$ is maximized at $\theta = 0°$.

21. (c) Magnetic flux density
Magnetic field strength is termed magnetic flux density.

22. (d) Circular
Magnetic field lines around a straight current-carrying wire form concentric circles.

23. (d) None of these
Magnetic flux is the dot product of $\mathbf{B}$ and vector area $\mathbf{A}$, not listed.

24. (c) Neutral particles
Neutral particles (no charge) do not produce magnetic fields.

25. (a) $B = \mu_0$ nI
Magnetic field inside a solenoid: $B = \mu_0 nI$.

26. (b) No
Magnetic field lines do not intersect.

27. (b) 1.2N
$F = ILB = 5 \times 0.02 \times 12 = 1.2$ N.

28. (a) When angle is 90
$\Phi = BA\cos 90° = 0$.

29. (d) 20 Weber
$\Phi = B \times \text{Area} = 5\,\text{T} \times 4\,\text{m}^2 = 20$ Wb.

30. (a) 39.68
Lorentz force $F = q(E + vB) = 2.5(5 + 1.5 \times 7.25) \approx 39.68$.

31. (a) In the direction opposite to electric field
Negative charge experiences force opposite to $\vec{E}$.

32. (c) Dimensionless
Relative permeability (μ_r) is a ratio with no units.

33. (b) Zero
Magnetic force does no work as it is perpendicular to motion.

34. (c) 4 times
$r \propto \frac{v}{B}$. Doubling v and halving B gives $4r$.

35. (b) Becomes twice
Flux $\Phi = BA$. Doubling B doubles Φ.

36. (d) Perpendicular to velocity and field
Magnetic force $\vec{F} = q(\vec{v} \times \vec{B})$.

37. (b) No
Magnetic field lines never intersect.

38. (b) 3 : 2
$r \propto v$. Velocity ratio $3:2 \Rightarrow$ radius ratio $3:2$.

39. (c) Negative
Flux $\Phi = BA\cos(180°) = -BA$.

40. (d) Zero
Current parallel to $\vec{B} \Rightarrow \vec{F} = I\vec{L} \times \vec{B} = 0$.

41. (b) Only electric force
Charge at rest ($\vec{v} = 0$) $\Rightarrow$ no magnetic force.

42. (d) 0 Wb
Assuming typo in vectors, $\vec{B} \cdot \vec{A} = 0$ (e.g., perpendicular components).

43. (a) Perpendicular
Magnetic field lines form circles around the current.

44. (d) Toroid
A solenoid bent into a circular shape is a toroid.

45. (d) 90
Maximum force at $\theta = 90°$.

46. (a) Scalar
Flux is a scalar (dot product).

47. (b) 1 N/Am
$1\,\text{T} = 1\,\text{N}/(\text{A} \cdot \text{m})$.

48. (d) Helical
Velocity has parallel and perpendicular components to $\vec{B}$.

49. (a) increases away from conductor
Field strength $B \propto \frac{1}{r}$, by moving away magnetic field decreases and distance between lines increases.

50. (b) Wb m^{-2}
Magnetic flux density B is measured in Wb/m^2.

SOLUTION PRACTICE TEST NO. 4

Answers and Explanations:

1. (d) $E \neq 0, B \neq 0$
The proton can maintain constant velocity if electric and magnetic forces cancel ($qE = qvB$), requiring both fields to be non-zero.

2. (d) South
Force on electron: $-\mathbf{v} \times \mathbf{B}$. East velocity × downward B → north direction; electron deflects south.

3. (b) Time period of proton will be higher
$T = \frac{2\pi m}{qB}$. Proton's larger mass results in a longer time period.

4. (c) Speed of electron will remain same
Magnetic force does no work; speed remains constant.

5. (b) Trajectory of proton is less curved
Radius $r \propto \frac{\sqrt{m}}{q}$. Proton's larger mass and smaller q/m make its path less curved.

6. (d) Velocity of the particle
$T = \frac{2\pi m}{qB}$; independent of velocity.

7. (a) Zero
Velocity parallel to $\mathbf{B} \to \mathbf{v} \times \mathbf{B} = 0$; no force.

8. (b) North
East velocity × upward B → south (right-hand rule). Electron (negative) deflects north.

9. (b) Circle
Perpendicular velocity and magnetic field result in circular motion.

10. (b) Momentum of the particle
$r = \frac{mv}{qB} \propto$ momentum.

11. (b) Kinetic energy
Magnetic force changes direction, not speed; KE remains constant.

12. (b) $4\pi \times 10^{-7}$ TmA^{-1}
Defined value of permeability of free space.

13. (b) Right wards
According to right hand rule force on negative charge is towards right.

14. (a) Helix
Parallel velocity component remains unchanged; perpendicular component causes circular motion → helical path.

15. (a) Weber
Magnetic flux unit is Weber (Wb).

16. (d) Uniform
Solenoid's interior has a uniform magnetic field.

17. (b) Upward
According to right hand rule force on negative charge is upward.

18. (a) $\phi = \vec{B} \cdot \vec{A}$
Magnetic flux is the dot product of magnetic field ($\vec{B}$) and vector area ($\vec{A}$).

19. (a) $\frac{v}{Br}$
From $qvB = \frac{mv^2}{r}$, solving for $\frac{e}{m} = \frac{v}{Br}$.

20. (d) South
Right-hand rule: current into the page creates a clockwise field. At a point to the right (east), the field direction is south.

21. (c) Exerts a force, if the charged particle is moving across the magnetic field lines
Magnetic force $F = q(\vec{v} \times \vec{B})$ is non-zero when velocity is perpendicular to $\vec{B}$.

22. (a) $1\text{ T} = 10^4$ G
1 Tesla $= 10^4$ Gauss.

23. (a) H_2
Hydrogen gas is used in e/m experiments due to low density, allowing clear observation of electron paths.

24. (a) $B = \mu_0 Ni$
For a solenoid with n turns per unit length, $B = \mu_0 nI$.

25. (c) 8×10^{-4} T
$B = \mu_0 nI = 4\pi \times 10^{-7} \times 400 \times 1.6 \approx 8 \times 10^{-4}$ T.

26. (b) $m_A V_A > m_B V_B$
Radius $r \propto mv$. Larger radius implies greater mv.

27. (c) 4×10^{-6} **tesla west**
$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \times 10^{-7} \times 2}{0.2\pi} = 4 \times 10^{-6}$ T west (right-hand rule).

28. (a) Zero
Stationary charge ($v = 0$) experiences no magnetic force.

29. (c) East
According to right hand rule force on conductor is towards east.

30. (a) Contract
Due to electronic current loop experiences force in inward direction.

31. (d) All of these
Magnetic flux density is measured in Tesla (T), equivalent to Wb/m^2 and N/(A\cdotpm).

32. (a) Amperian path
Closed path used to calculate magnetic field via Ampère's law.

33. (d) $F = qvB$
Magnetic force during circular motion is $F = qvB$.

34. (a) Zero
Flux $\Phi = BA\cos 90^\circ = 0$ when $\vec{B}$ is parallel to the surface.

35. (b) $\frac{F}{\sqrt{2}}$
Force $F \propto \sin\theta$. At 45°, $\sin 45^\circ = \frac{\sqrt{2}}{2}$, reducing force to $\frac{F}{\sqrt{2}}$.

36. (c) 8 times
$F = ILB$. Doubling I, L, and B gives $F_{\text{new}} = 8F$.

37. (b) It moves towards the solenoid
Iron core strengthens the magnetic field, attracting the magnet.

38. (a) Magnetic field at 'X' is stronger than that at 'Y' and 'Z'
Opposite currents create fields that cancel at midpoint Y, leaving stronger fields near each wire.

39. (c) Same as original
Magnetic field $B = \mu_0 nI$. Halving length and turns keeps n unchanged.

40. (a) Clockwise
Right-hand rule: current upward creates clockwise field when viewed from below.

41. (b) Downwards
Fleming's left-hand rule: magnetic field (N→S) and current (into page) produce downward force.

42. (d) Magnetic flux density will be doubled
$B \propto n$. Doubling turns doubles B.

43. (b) Both carry current in opposite direction
Parallel wires with opposite currents repel.

44. (c) $4\pi \times 10^{-10}$ T
$B = \mu_0 nI = 4\pi \times 10^{-7} \times 1000 \times 10^{-6} = 4\pi \times 10^{-10}$ T.

45. (b) 3 : 2

$r \propto v$. Velocity ratio $3:2 \Rightarrow$ radius ratio $3:2$.

46. (c) 1.256×10^{-2} Wb m^{-2}

$B = \mu_0 n I = 4\pi \times 10^{-7} \times 2000 \times 5 = 1.256 \times 10^{-2}$ T.

47. (b) 5000

$n = \frac{B}{\mu_0 I} = \frac{3.14\times10^{-2}}{4\pi\times10^{-7}\times5} \approx 5000$ turns/m.

UNIT 09 ELECTROMAGNETIC INDUCTION

SOLUTION PRACTICE TEST NO. 1

Answers and Explanations:

1. **(a) 200**
   Using the transformer ratio $\frac{V_p}{V_s} = \frac{N_p}{N_s}, \frac{220}{2200} = \frac{N_p}{2000} \Rightarrow N_p = 200$.
2. **(a) 10 weber**
   Magnetic flux $\Phi = B \cdot A = 10^3$ Wb/m$^2 \times 10^{-2}$ m^2 = 10 Wb.
3. **(b) 3V**
   Induced emf $\varepsilon = -\frac{\Delta\Phi}{\Delta t} = -\frac{(4-1)\cdot 2}{2} = 3$ V.
4. **(b) Can either increase or decrease**
   A changing magnetic flux (increase or decrease) induces emf (Faraday's Law).
5. **(d) Induced currents in A & B are in opposite directions**
   Approaching magnet increases flux in A (induced current opposes), while receding from B decreases flux (induced current opposes differently), leading to opposite currents.
6. **(b) 1.0 V**
   $\varepsilon = B \cdot l \cdot v = 2 \times 10^{-4} \times 50 \times 100 = 1$ V (speed converted to m/s: 360 km/h = 100 m/s).
7. **(d) $NBA\omega\sin\omega t$**
   Emf in rotating coil: $\varepsilon = NBA\omega\sin\omega t$.
8. **(a) Eddy current**
   Laminated cores reduce eddy current losses.
9. **(b) Current**
   Step-down transformers decrease voltage but increase current (power conservation).
10. **(c) P**
   Ideal transformers have no power loss: Input power = Output power.
11. **(a) 1 amp**
   $\frac{I_p}{I_s} = \frac{N_s}{N_p} \Rightarrow I_p = \frac{25}{100} \times 4 = 1$ A.
12. **(d) All of these**
   Transformers change voltage and current, and enable efficient power transfer (reducing losses in transmission).
13. **(c) Faraday's law**
   Faraday's Law states $\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$.
14. **(d) $\varepsilon = -vBL$**
   Maximum emf occurs when $\theta = 90°$, $\sin\theta = 1$.
15. **(b) Stationary**
   Carbon brushes remain stationary to maintain contact with the rotating slip rings.
16. **(c) $\varepsilon = N\omega AB$**
   When the coil's plane is parallel to the magnetic field, the rate of change of flux is maximum, leading to maximum induced emf. The formula is $\varepsilon = NBA\omega\sin\theta$, where $\theta = 90°$, making $\sin\theta = 1$.
17. **(c) 100π**
   Angular frequency $\omega = 2\pi f$. For $f = 50$ Hz, $\omega = 2\pi \times 50 = 100\pi$ rad/s.
18. **(c) Half revolution**
   The induced current reverses direction every half revolution due to the change in magnetic flux direction relative to the coil.
19. **(c) Plate N will be negatively charged**
   Using the right-hand rule, electrons in the rod moving out of the magnetic field (into the page) accumulate at the end connected to plate N, making it negative.
20. **(a) 0.5 V**
   Induced emf $\varepsilon = -N\frac{\Delta B}{\Delta t} \cdot A = -100 \cdot \frac{-0.05}{0.05} \cdot 0.005 = 0.5$ V.
21. **(c) The rate of change of flux is increases**
   Faraday's Law states $\varepsilon \propto \frac{\Delta\Phi}{\Delta t}$. Increasing the rate of flux change increases emf.
22. **(b) anticlockwise**
   A north pole approaching the coil induces a anticlockwise current (viewed from the left) to oppose the change via Lenz's Law.
23. **(c) Lenz's law**
   Lenz's Law explains that mechanical work done against induced forces converts to electrical energy.
24. **(a) Current generator**
   A generator converts mechanical energy (rotation) into electrical energy via electromagnetic induction.
25. **(d) All of these**
   Emf can be induced by changing the coil's area, magnetic field strength, or motion relative to the field.
26. **(d) 0 V**
   Emf $\varepsilon = vBL\sin\theta$. Motion parallel to $\mathbf{B}$ means $\theta = 0°$, so $\sin\theta = 0$.
27. **(a) Carbon brushes**
   Carbon brushes maintain contact with slip rings to transfer induced current from the rotating coil to the external circuit.
28. **(a) Induced current**
   Lenz's Law specifies the direction of the induced current opposing the change in flux.
29. **(d) Flux intensity**
   Magnetic induction (B) is also termed magnetic flux density or flux intensity.
30. **(a) Inertia**
   Inductance opposes changes in current, analogous to inertia resisting changes in motion.

31. **(b) Number of turns**
Step-down transformers reduce voltage by having fewer secondary turns.
32. **(d) Resistance**
Motional emf $\varepsilon = Bvl$ depends on B, velocity, and length, not resistance.
33. **(a) vBL**
Motional emf is given by $\varepsilon = BvL$, where B, v, and L are mutually perpendicular.
34. **(c) Eddy current loss**
Eddy currents in the core cause significant energy loss. Laminated cores minimize this.
35. **(a) Electromagnetic induction**
Faraday's Law describes induced emf due to changing magnetic flux.
36. **(c) Electromagnetic induction**
A time-varying magnetic field induces an electric field (Faraday's Law).
37. **(b) Lenz's law**
Lenz's Law states induced current opposes the change causing it.
38. **(a) A.C**
Transformers require alternating current to induce voltage via changing flux.
39. **(b) Dipole**
A current loop acts as a magnetic dipole with north and south poles.
40. **(a) Electromotive force**
Faraday's Law: $\varepsilon = -\frac{\Delta\Phi}{\Delta t}$.
41. **(a) Full load**
Transformers are designed for maximum efficiency at full load.
42. **(a) $I = \frac{\varepsilon_0}{R}\sin(\omega t)$**
Induced current follows sinusoidal variation $I = \frac{\varepsilon_{\text{peak}}}{R}\sin(\omega t)$.
43. **(b) Lenz's law**
Lenz's Law defines the direction of induced current.
44. **(b) 8.66 V**
$\varepsilon = BvL\sin\theta = 0.5 \times 5 \times 4 \times \sin 60^\circ = 8.66\,\text{V}$.
45. **(b) 50**
Current reverses once per cycle (50 Hz × 1 = 50 reversals/sec).
46. **(d) Faraday's law**
AC generators rely on Faraday's Law of electromagnetic induction.
47. **(d) $NAB\omega\sin(\omega t)$**
Emf in a generator: $\varepsilon = NAB\omega\sin(\omega t)$.
48. **(b) Induced current**
Lenz's Law determines the direction of the induced current.
49. **(a) Henry**
Inductance is measured in henry (H).
50. **(b) Anticlockwise**
Approaching north pole induces anticlockwise current to oppose the change (right-hand rule).

SOLUTION PRACTICE TEST NO. 2

Answers and Explanations:

1. **(c) Tesla**
Magnetic induction (B) is measured in tesla (T).
2. **(b) Eddy current**
Laminated insulation reduces eddy current losses.
3. **(b) Full load**
Power transformers are most efficient at full load.
4. **(a) 150 V**
$\varepsilon = BvL = 5 \times 10 \times 3 = 150\,\text{V}$.
5. **(d) Frequency level**
Transformers do not alter frequency.
6. **(a) Mutual induction**
Transformers work on mutual induction between primary and secondary coils.
7. **(d) All of these**
Motional emf $\varepsilon = BvL\sin\theta$ depends on magnetic field B, orientation θ, and length L.
8. **(c) Anticlockwise, north**
Approaching the magnet's north pole induces an anticlockwise current (viewed from above) to oppose the motion via Lenz's Law.
9. **(d) Induced currents in A and B are in opposite directions**
Coil A experiences increasing flux (current opposes), while Coil B experiences decreasing flux (current opposes differently), leading to opposite currents.
10. **(c) Rate of change of flux**
Faraday's Law: $\varepsilon \propto \frac{\Delta\Phi}{\Delta t}$.
11. **(b) Magnetic field**
Faraday's Law links changing magnetic fields to induced electric fields.
12. **(d) vBL**
Motional emf formula: $\varepsilon = BvL$.
13. **(d) Zero**
No relative motion or flux change → no induced emf.
14. **(c) Induced current reverses its direction repeatedly**
Oscillating magnet causes alternating flux changes, reversing current direction.
15. **(d) 90 V**
$\varepsilon = \left|\frac{\Delta\Phi}{\Delta t}\right| = \frac{0.9}{0.01} = 90\,\text{V}$.
16. **(c) 25 Hz**
$\omega = 157 = 2\pi f \Rightarrow f = \frac{157}{2\pi} \approx 25\,\text{Hz}$.
17. **(c) 226 V**
$\varepsilon_{\text{peak}} = NBA\omega = 30 \times 1 \times 0.04 \times 60\pi \approx 226\,\text{V}$.
18. **(b) Counterclockwise**
Increasing clockwise flux in outer loop induces counterclockwise current in inner loop to oppose the change.

19. (d) All of these

20. (b) Zero
When the coil's plane is parallel to $\mathbf{B}$, $\theta = 0°$, so $\sin\theta = 0$.

21. (a) Ends of armature coil
Slip rings connect the rotating armature coil to the external circuit.

22. (a) Current generator
Generators convert mechanical energy (rotation) into electrical energy.

23. (b) 10:1
Using $\frac{V_s}{V_p} = \frac{N_s}{N_p}$, $\frac{2200}{220} = 10:1$.

24. (b) Varying magnetic field
A changing magnetic field in the primary induces voltage in the secondary.

25. (b)

26. (c) Electric motor
Converts electrical energy to mechanical energy.

27. (a) Mutual induction
Transformers operate via mutual induction.

28. (c) 1 volt
$\varepsilon = Bvl = 0.5 \times 1 \times 2 = 1\,\text{V}$.

29. (b) $\frac{1}{2}$ revolution
Direction reverses every half rotation.

30. (d) Faraday's law
Faraday's Law explains induced emf.

31. (a) 5×10^{-3} Wb
$\Phi = NBA\cos\theta = 100 \times 0.2 \times 5 \times 10^{-4} \times 0.5 = 5 \times 10^{-3}$ Wb.

32. (b) 5 V
$\varepsilon = -N\frac{\Delta\Phi}{\Delta t} = 500 \times \frac{0.1\times0.01}{0.1} = 5\,\text{V}$.

33. (b) Less than due to gravity
Lenz's Law opposes motion, reducing acceleration.

34. (c) Frequency
Frequency remains unchanged in a transformer.

35. (d) Both a and c
$\varepsilon_{\text{max}} = NAB\omega = 2\pi NfAB$.

36. (b) 400 V
$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = 100 \times \frac{240}{60} = 400\,\text{V}$.

37. (d) 80%
$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{100}{250\times0.5} = 80\%$.

38. (b) Faraday's Law
$\varepsilon = -N\frac{\Delta\Phi}{\Delta t}$ is Faraday's Law.

39. (c) Thin coating of Varnish
Laminations are insulated with varnish.

40. (c) Electromagnetic
Time-varying current produces electromagnetic fields.

41. (a) 50%
$\text{Efficiency} = \frac{100}{200} \times 100 = 50\%$.

42. (c) Input power is same as the output power
Ideal transformers conserve power (input = output).

Note for Q25: The correct formula $Q = \frac{\Delta\Phi}{R}$ is not listed. The provided options may contain an error.

43. (b) Magnetic energy
Inductors store energy in their magnetic field when current flows.

44. (b) Rate of change of magnetic flux
Faraday's Law: $\varepsilon \propto \frac{\Delta\Phi}{\Delta t}$.

45. (c) 0.314 V
$\varepsilon_{\text{max}} = NBA\omega = 100 \times 0.01 \times 0.1 \times \pi \approx 0.314\,\text{V}$.

46. (c) Number of turns
Step-up transformers increase voltage by increasing secondary turns.

47. (d) Max
Maximum flux coupling ensures efficient power transfer.

48. (d) VsA^{-1}
Note: Mutual inductance unit is Henry (H = Vs/A),

49. (d) Constant magnetic field
Motional emf requires motion in a constant $\mathbf{B}$.

50. (a) Increase
Higher frequency increases the rate of flux change, raising secondary voltage.

SOLUTION PRACTICE TEST NO. 3

1. (c) 0.08 T
$B = \frac{\varepsilon_{\text{max}}}{NA\omega} = \frac{5000}{200\times1\times100\pi} \approx 0.08\,\text{T}$.

2. (a) Direction of induced emf opposes the change in flux
Negative sign reflects Lenz's Law.

3. (b) 120
Current peaks twice per cycle ($60 \times 2 = 120$).

4. (c) The same but to the left
Pulling the magnet reverses induced current direction.

5. (b) 0.5 V
$\varepsilon = BvL\sin\theta = 1 \times 1 \times 1 \times 0.5 = 0.5\,\text{V}$.

6. (b) 4 A
$\varepsilon = \frac{\Delta\Phi}{\Delta t} = \frac{20}{0.5} = 40\,\text{V}$; $I = \frac{40}{10} = 4\,\text{A}$.

7. (b) Ring will be repelled away
Approaching north pole induces a current in the ring to create a north pole, repelling the magnet (Lenz's Law).

8. (d) Current in wire YZ will be from Y to Z and then from Z to Y
Magnet entering induces current in one direction; exiting reverses the direction.

9. (b) 0.06 V
$\varepsilon = Bvl = 0.10 \times 3.0 \times 0.20 = 0.06\,\text{V}$.

10. (b)
Standard formula: $\varepsilon_{\text{max}} = NBA\omega$.

11. (a) 100
Current crosses zero twice per cycle (50 Hz × 2 = 100).

12. (a) $\varepsilon = N\omega AB\sin\theta$
Induced emf varies sinusoidally with angular displacement.

13. (c) Stator
AC generators use a rotor (armature) and stator. **Likely misprint; "stator" is used.**

14. (b) 180°
Electric and magnetic forces oppose each other.

15. (b) $\varepsilon = -N\frac{\Delta\phi}{\Delta t}$
Faraday's Law formula.

16. (b) 10 V
$\frac{V_s}{V_p} = \frac{N_s}{N_p} \Rightarrow V_s = 100 \times \frac{50}{500} = 10\,\text{V}$.

17. (d) 90%
Efficiency $= \frac{11\times90}{220\times5} \times 100 = 90\%$.

18. (b) Greater than 1
Step-up transformers have $N_s > N_p$, so ratio > 1.

19. (b) Two times
$\varepsilon \propto \omega$; doubling ω doubles emf.

20. (c) Generator
Generators convert mechanical energy to electrical via electromagnetic induction.

21. (b) $B\ell v$
Motional emf: $\varepsilon = B\ell v$.

22. (c) 1.5 mV
$\varepsilon = 0.3 \times 10^{-4} \times 10 \times 5 = 1.5 \times 10^{-3}\,\text{V} = 1.5\,\text{mV}$.

23. (c) Neither emf nor current is induced
A stationary coil in a static (even non-uniform) magnetic field experiences no change in flux, so no induction.

24. (b) Wb
Magnetic flux (Φ) is measured in Weber (Wb).

25. (d) 5
$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = 500 \times 1 \times (0.1 \times 0.1) = 5\,\text{V}$.

26. (a) $\frac{3A_oB_o}{t}$
$\varepsilon = \frac{\Delta(BA)}{\Delta t} = \frac{(4B_o - B_o)A}{t} = \frac{3A_oB_o}{t}$.

27. (d) Energy
Lenz's Law ensures energy conservation by opposing flux changes.

28. (d) 2200 V
$V_s = V_p \times 20 = 110 \times 20 = 2200\,\text{V}$.

29. (d) 1:1
Ideal transformers conserve power: $P_{\text{primary}} = P_{\text{secondary}}$.

30. (b) 5:6
$\frac{I_{\text{input}}}{I_{\text{output}}} = \frac{N_s}{N_p} = \frac{5}{6}$.

31. (b) 10 V, 5 A
$V_p = \frac{V_s}{10} = \frac{100}{10} = 10\,\text{V}$, $I_p = I_s \times 10 = 0.5 \times 10 = 5\,\text{A}$.

32. (d) All of these
Core material, insulation, and coil resistance all affect efficiency.

33. (a) $N_s < N_p$
Step-down transformers have fewer secondary turns.

34. (d) 2:1 step-down
$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{20}{10} = 2:1$.

35. (a) Current
Step-up transformers increase voltage but decrease current.

36. (a) 0.2
$I_{\text{secondary}} = \frac{P_{\text{primary}}}{V_{\text{secondary}}} = \frac{200\times2}{2000} = 0.2\,\text{A}$.

37. (a) Hysteresis
Repeated magnetization/demagnetization causes hysteresis loss.

38. (c) 4:3
$\frac{I_s}{I_p} = \frac{N_p}{N_s} = \frac{20}{15} = 4:3$.

39. (d) All of these
Step-up increases voltage, decreases current, and maintains power.

40. (b) Eddy current loss
Laminations reduce eddy currents.

41. (c) 14 W
Output $= 0.7 \times 20 = 14\,\text{W}$.

42. (b) Diameter of wire
Larger diameter reduces resistance.

43. (b) Smaller area
A smaller hysteresis loop minimizes energy loss.

44. (b)
Greater efficiency requires low-resistance materials (silver/copper), same core for magnetic coupling, and electrical insulation.

45. (d) Coils are electrically insulated but magnetically connected
Transformer coils are electrically isolated but share magnetic flux via the core.

46. (d) All of these
For ideal transformers: $\frac{V_s}{V_p} = \frac{N_s}{N_p}$, $\frac{I_p}{I_s} = \frac{N_s}{N_p}$, and $\frac{V_s}{V_p} = \frac{I_p}{I_s}$.

47. (b) Secondary voltage 240 V, current 5 A
$V_s = 120 \times \frac{200}{100} = 240\,\text{V}$; $I_s = 10 \times \frac{100}{200} = 5\,\text{A}$.

48. (a) Statically induced emf
Transformers use static induction (no moving parts).

49. (a) 1.2 A
$V_s = 240 \times \frac{500}{1000} = 120\,\text{V}$; $I = \frac{120}{100} = 1.2\,\text{A}$.

50. (d) Secondary power rating is less than 500 W
Power is conserved: $100\,\text{V} \times 5\,\text{A} = 500\,\text{W} = 1000\,\text{V} \times 0.5\,\text{A}$.

SOLUTION PRACTICE TEST NO. 4

Answers and Explanations:

1. **(d) None of the above**
   Induced current depends on flux change, time, and resistance.
2. **(c) Anticlockwise**
   Induced current creates a north pole to repel the approaching magnet (Lenz's Law).
3. **(b) Lenz's law**
   Lenz's Law determines the direction of induced emf.
4. **(b) Magnitude of induced emf is directly proportional to rate of change of flux**
   Faraday's Law states $\varepsilon \propto \frac{\Delta\Phi}{\Delta t}$.
5. **(b) Anticlockwise**
   Induced current opposes the approaching north pole (clockwise when viewed from the ring).
6. **(d) 4.0 C**
   $Q = \frac{\Delta\Phi}{R} = \frac{10-2}{2} = 4$ C.
7. **(c) $\frac{4\pi}{3}$ V**
   $\varepsilon_{\text{max}} = NBA\omega = 50 \times 0.05 \times 0.008 \times \frac{200\pi}{3} = \frac{4\pi}{3}$ V.
8. **(b) $\frac{1}{2}\omega BR^2$**
   The emf between the center and rim of a rotating disk is $\varepsilon = \frac{1}{2}B\omega R^2$
9. **(a) A metal is kept in varying magnetic field**
   Eddy currents arise from changing magnetic fields inducing currents in conductors.
10. **(a) Hysteresis losses**
    Soft iron cores reduce hysteresis losses due to low retentivity.
11. **(a) 240 V, 5 A**
    $V_s = 120 \times \frac{200}{100} = 240$ V; $I_s = 10 \times \frac{100}{200} = 5$ A.
12. **(a) 100 A**
    $P_{\text{in}} = P_{\text{out}} \Rightarrow I_{\text{in}} = \frac{11000 \times 2}{220} = 100$ A.
13. **(c) 100 V**
    Transformation ratio $\frac{N_s}{N_p} = \frac{5}{3} \Rightarrow V_s = 60 \times \frac{5}{3} = 100$ V.
14. **(a) Lenz's law**
    Lenz's Law dictates the direction of induced current to oppose the change in flux.
15. **(d) Armature**
    The rotating coil in an AC generator is called the armature.
16. **(c) Perpendicular & not along sides of the wires**
    When the coil sides move parallel to the magnetic field, $\mathbf{v} \times \mathbf{B}$ is perpendicular to the wire, causing no emf along its length.
17. **(d) All of these**
    Induced current depends on coil area, angular frequency, and number of turns.
18. **(b) No current will be induced in the coil**
    Rotating a magnet about its axis does not change the magnetic flux through the coil.
19. **(d) Law of conservation of energy**
    Lenz's Law ensures energy conservation by opposing flux changes.
20. **(c) $\frac{2BA}{t}$**
    Flux changes from $+BA$ to $-BA$, so $\Delta\Phi = 2BA \Rightarrow \varepsilon = \frac{2BA}{t}$.
21. **(b) Resistance of circuit**
    Induced emf ($\varepsilon = -\frac{\Delta\Phi}{\Delta t}$) is independent of resistance, but current depends on it.
22. **(d) 50 Hz**
    $f = \frac{\omega}{2\pi} = \frac{314}{2\pi} \approx 50$ Hz.
23. **(d) $2\pi BAf$**
    Maximum emf: $\varepsilon_{\text{max}} = NBA\omega = 2\pi BAf$.
24. **(a) 170 V**
    $\varepsilon_{\text{max}} = 150 \times 0.15 \times 0.02 \times 120\pi \approx 170$ V.
25. **(c) May increase or decrease the magnetic flux through the circuit**
    Induced current opposes the change in flux, which can either increase or decrease the net flux depending on the scenario.
26. **(c) $V_0 \sin\omega t$**
    AC voltage varies sinusoidally; the standard form is $V = V_0 \sin(\omega t)$.
27. **(b) Double**
    Induced emf $\varepsilon \propto \omega$; doubling angular speed doubles voltage.
28. **(d) Transformer**
    Mutual inductance is fundamental to transformer operation.
29. **(b) Increased**
    Stronger magnetic field increases the rate of flux change, boosting induced current.
30. **(c) Both a and b**
    Henry (H) measures both self-inductance and mutual inductance.
31. **(c) Power**
    Ideal transformers conserve power (neglecting losses).
32. **(d) $V_s > V_p$**
    Step-up transformers increase secondary voltage.
33. **(c) Doubles**
    Motional emf $\varepsilon \propto B$; doubling flux doubles emf.
34. **(a) 1:20**
    $\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{11}{220} = \frac{1}{20}$.
35. **(c) Iron**
    Iron cores minimize energy losses in transformers.
36. **(a) Voltage**
    Faraday's Law: $\varepsilon \propto N$; more turns increase voltage.
37. **(d) Both A and B**
    Changing magnetic field induces both emf and current.
38. **(c) Volt**
    Unit of emf is volt (V).

39. (c) 0.1 T

$B = \frac{\varepsilon}{vl} = \frac{1}{10\times1} = 0.1\,\text{T}.$

40. (b) Perpendicular to the field

Emf is zero when the coil is perpendicular (no flux change).

41. (d) Split rings

AC generators use slip rings; split rings are for DC motors.

42. (a) Maximum

Parallel alignment maximizes the rate of flux change, inducing peak emf.

43. (b) 314 rad s^{-1}

$\omega = 2\pi f = 2\pi \times 50 = 314\,\text{rad/s}.$

44. (b) $\frac{\epsilon_0}{\sqrt{2}}$

At 45°, $\sin(45°) = \frac{\sqrt{2}}{2}$, reducing emf by $\frac{1}{\sqrt{2}}$.

45. (a) 10V

$\varepsilon = Bvl = 0.5 \times 5 \times 4 = 10\,\text{V}.$

46. (b) 160

$N_p = N_s \times \frac{V_p}{V_s} = 40 \times \frac{200}{50} = 160.$

47. (d) High voltage and low current

High voltage reduces I^2R power loss in transmission lines.

48. (c) 220 V

Standard household voltage in Pakistan is 220 V.

49. (a) Transformer

Transformers are used to step up or step down voltages in power transmission.

50. (c) Mutual induction

Transformers operate based on mutual induction between primary and secondary coils.

51. (d) Both B and C

Transformers have coils wound on a soft iron core and are magnetically linked.

52. (d) Both A and B

Soft iron cores enhance flux linkage and ensure flux passes through both coils.

53. (d) All of these

Ideal transformers have no losses, no resistance, and purely inductive coils.

54. (c) Equal to one

In an ideal transformer, the rate of flux change is the same in both coils.

55. (c) Secondary coil

The secondary coil is connected to the load.

56. (d) All of these

Losses include eddy currents, hysteresis, flux leakage, and resistance.

57. (a) $\eta = \frac{P_{\text{out}}}{P_{\text{in}}} \times 100\%$

Efficiency is the ratio of output to input power.

58. (c) Winding the two coils one over another

Close winding minimizes flux leakage.

59. (a) Secondary voltage is greater than primary voltage

Step-up transformers increase secondary voltage.

60. (a) 10

Turns ratio $\frac{N_p}{N_s} = \frac{V_p}{V_s} \Rightarrow N_p = \frac{220}{2200} \times 100 = 10.$

61. (c) Power

Power (input = output) remains unchanged in ideal transformers.

62. (a) 60 V

$V_s = V_p \times \frac{3}{2} = 40 \times 1.5 = 60\,\text{V}.$

63. (a) Reduce energy due to eddy currents

Laminated cores reduce eddy current losses.

64. (a) 4 A

$I_s = I_p \times \frac{N_p}{N_s} = 8 \times \frac{140}{280} = 4\,\text{A}.$

65. (d) 250 A

$I_p = I_s \times \text{turn ratio} = 10 \times 25 = 250\,\text{A}.$

66. (d) 160 W

$P_{\text{out}} = 200 \times 0.8 = 160\,\text{W}.$

67. (b) 120 V

$V_s = V_p \times \frac{6}{2} = 40 \times 3 = 120\,\text{V}$ (assuming step-up ratio 6:2).

UNIT 10 ELECTRONICS

SOLUTION PRACTICE TEST NO. 1

Answers and Explanations:

1. **(c)** $20/\pi$
   The DC component (average voltage) for a full-wave rectifier is $V_{dc} = \frac{2V_p}{\pi}$. Given $V_p = 10V$, $V_{dc} = \frac{20}{\pi}$.
2. **(a) AC to DC**
   A rectifier converts alternating current (AC) to direct current (DC).
3. **(b) 50**
   In a half-wave rectifier, the output frequency equals the input frequency (50 Hz). Thus, 50 pulses per second.
4. **(a) 100 Hz**
   Full-wave rectification doubles the ripple frequency. For 50 Hz input, ripple frequency = $2 \times 50 = 100$ Hz.
5. **(a) Full wave**
   Ripple factor is lower in full-wave rectifiers compared to half-wave.
6. **(c) 4**
   A full-wave bridge rectifier requires 4 diodes.
7. **(b)** $V_0/2$
   For a half-wave rectifier, RMS voltage is $V_{\text{rms}} = \frac{V_0}{2}$ (where V_0 is peak voltage).
8. **(c) 600**
   Full-wave rectifier produces 2 pulses per cycle. At 60 Hz, pulses per second = $2 \times 60 = 120$. Over 5 seconds: $120 \times 5 = 600$.
9. **(a) 1**
   In a center-tap full-wave rectifier, only one diode conducts at a time during each half-cycle.
10. **(a) 60** (Note: Discrepancy exists)
    A half-wave rectifier produces 60 pulses per second (matching 60 Hz). Over 2 seconds: $60 \times 2 = 120$. However, 120 is not listed. Assuming a typo, the closest answer is **(a) 60** (pulses per second).
17. **(b) B**
    During conduction, the diode's cathode (terminal B) becomes negative in a standard rectifier setup.
18. **(b) D_4 and D_2 conduct**
    In a full-wave bridge rectifier, diodes D_2 and D_4 conduct during the negative half-cycle of the input.
19. **(b) Power of half signal wasted (about 50%)**
    Half-wave rectification only uses one half of the AC cycle, wasting 50% of the input power.
20. **(a) 0.1 A**
    If the battery voltage is 2V and total resistance is 20Ω, $I = V/R = 2/20 = 0.1$ A.
21. **(c) It uses both cycles as input**
    Full-wave rectifiers utilize both halves of the AC cycle, doubling efficiency compared to half-wave.
22. **(d)** Diode is forward biased
    Anode is at high potential and cathode is at low potential.
23. **(c) Full wave rectifier**
    A bridge rectifier configuration (terminals B and D) produces full-wave rectified output.
24. **(a) 10 ms**
    Ripple frequency = 2×50 Hz $= 100$ Hz. Time period = $1/100 = 0.01$ s $= 10$ ms.
25. **(c) Pulsating**
    Rectifier output is pulsating DC, not smooth.
26. **(a) 50**
    Half-wave rectifier produces one pulse per cycle. At 50 Hz, pulses per second = 50.
27. **(d)**
28. **(b) Rectification, inversion**
    AC to DC = rectification; DC to AC = inversion.
29. **(c) Ideal diode is an open switch**
    Incorrect. An ideal diode is a closed switch in forward bias and open in reverse bias.
30. **(d) All of these**
    Full-wave rectifiers have higher efficiency, average DC, and output voltage compared to half-wave.
31. **(b) Increase the potential barrier**
    Reverse biasing widens the depletion layer, increasing the potential barrier.
32. **(d) Concentration of positive and negative charges near the junction**
    The potential barrier arises due to the fixed positive (n-side) and negative (p-side) ions in the depletion region.
33. **(b) Rectifier**
    PN-junction diodes are primarily used to convert AC to DC (rectification).
34. **(b) Electrons and holes move away from the junction depletion**
    Reverse biasing widens the depletion region, causing carriers to move away from the junction.
35. **(b) filter**
    Filters (e.g., capacitors) smooth the pulsating DC output of a rectifier.
36. **(a) The current in the reverse biased condition is generally very small**
    Reverse bias allows only a tiny leakage current.
37. **(d) Not a rectifier**
    during positive half current flows downward and

during negative half current flows upward through resistance and output is pure A.C.

38. (b) 2

In a bridge rectifier, two diodes conduct during each half-cycle.

39. (d) $T_1 = 2T_0$

Full-wave rectification doubles the ripple frequency ($f_0 = 2f_1$), so $T_0 = T_1/2$.

40. (d)

During positive half current flows downward and during negative half current flows upward through resistance and output is pure A.C.

41. (a) Half wave rectifier

Removing one diode from a full-wave bridge rectifier converts it to half-wave.

42. (b) $5 - 0.7$ **V**

The diode drops ~0.7V in forward bias, leaving $5 - 0.7 = 4.3$ V across the resistor.

43. (c) 2 KΩ

$R = V/I = 5\,\text{V}/2.5\,\text{mA} = 2000\,\Omega = 2\,\text{k}\Omega$.

44. (a) $\frac{V_0}{\sqrt{2}}$

RMS value of full-wave rectified output equals the RMS of the input AC ($V_{\text{rms}} = \frac{V_0}{\sqrt{2}}$).

45. (c) Pure D.C

Since battery is connected diode is always forward biased.

46. (b) $\frac{5}{4}$ A

RMS voltage: $V_{\text{rms}} = \frac{250}{2}$. Current: $I_{\text{rms}} = \frac{250}{2\times 100} = \frac{5}{4}$

47. (a) D_1 **and** D_4 **conduct**

In a full-wave bridge rectifier, diodes D_1 and D_4 conduct during the positive half-cycle.

48. (b) The P-end is connected to the positive terminal of the battery

Forward bias requires the P-side to connect to the battery's positive terminal.

49. (b) 0.7 V

Silicon diodes have a typical potential barrier of ~0.7 V.

50. (c) In reverse bias

A reverse-biased PN-junction acts as an insulator due to the widened depletion region.

SOLUTION PRACTICE TEST NO. 2

Answers and Explanations:

1. (b) Zero

During the negative half-cycle ($T/2 - T$) in a half-wave rectifier, the diode is reverse-biased, resulting in no output.

2. (d) 20

Input frequency: $f = \frac{1}{T} = \frac{1}{50\text{ ms}} = 20$ Hz. Half-wave ripple frequency matches input.

3. (b) 20 ms

$$2\pi f = 100\pi \Rightarrow f = 50 \Rightarrow T = \frac{1}{50} = 20ms$$

4. (b) Becomes equal to source voltage

Reverse-biased diode blocks current, causing the full source voltage to drop across it.

5. (a) Diode conducts only during positive half cycle

6. (a) It has no charge carriers

The depletion layer lacks free charge carriers, resulting in high resistance.

7. (d) Missing electrons

Holes in a PN-junction arise from the absence of electrons in the crystal lattice.

8. (c) Zero for both halves of A.C

During the positive half-cycle, upper diode is reverse biased and lower diode is forward biased. No current flows and output is zero

9. (c) From B to A

During negative half cycle terminal B becomes positive and A becomes negative.

10. (a) Forward biased

During the positive half-cycle, the diode is forward-biased, allowing current to flow.

11. (c)

In 'c' option anode is at low potential and cathode is at high potential.

12. (b) Full wave rectifier

A bridge rectifier configuration (input across A-C, output across B-D) produces full-wave rectification.

13. (d) Zero

No current passes through the resistance in both halves.

14. (d) $1:10^6$

The forward-to-reverse bias resistance ratio for a diode is approximately $1:10^6$.

15. (d) 10^6 **ohm**

Reverse-biased diodes exhibit very high resistance (~megaohms).

16. (a) To convert ac into dc

A rectifier converts alternating current (AC) to direct current (DC).

17. (c) 100 Hz

Full-wave rectification doubles the input frequency (50 Hz → 100 Hz).

18. (a) Majority charge carriers

Forward current in a diode is due to majority carriers (holes in P-side, electrons in N-side).

19. (b) Voltage and current

A diode's I-V curve plots current (I) against voltage (V).

20. (d) Four

A full-wave bridge rectifier requires four diodes.

21. (a) conductance

The slope of I-V graph represents conductance.

22. (a) $\frac{3}{7}$
Germanium (Ge) barrier ≈ 0.3 V; Silicon (Si) ≈ 0.7 V. Ratio = $0.3/0.7 = 3/7$.

23. (a) Rectification
Rectification is the process of converting AC to DC.

24. (a) 2
A center-tapped full-wave rectifier uses two diodes.

25. (d)
The product of frequency and time period is always one.

26. **(a) A p-n junction diode**
A diode allows current in one direction only, matching the described behavior.

27. **(d) Zero**
A reverse-biased diode blocks current, resulting in negligible current flow.

28. **(b) 100**
At 50 Hz, half-wave rectifier produces 50 pulses/second. Over 2 seconds: $50 \times 2 = 100$.

29. **(c) Semiconductor Diode**
Diodes are used in rectifiers to convert AC to DC.

30. **(c) Rectification**
Rectification is the process of converting AC to DC.

31. **(d) Filter circuit**
Filters (e.g., capacitors) smooth the pulsating DC output.

32. **(a)** $1{:}10^6$
Diode resistance ratio (forward:reverse) is approximately $1{:}10^6$.

33. **(a)** $\left(0 \rightarrow \frac{T}{4}\ and\ \frac{3T}{4} \rightarrow \mathrm{T}\right)$
During the time $0 \rightarrow \frac{T}{4}\ and\ \frac{3T}{4} \rightarrow \mathrm{T}$ diode is reverse biased. So output is zero.

34. **(b) Full wave rectification**
Full-wave rectification is more efficient and widely used.

35. **(c) Becomes equal to potential barrier**
Forward-biased diode drops ~0.7V (Si), matching the barrier potential.

36. **(a) 1.21**
Ripple factor for half-wave rectification is approximately 1.21.

37. **(b) 40.60%**
Maximum theoretical efficiency of a half-wave rectifier is ~40.6%.

38. **(b) Pulsating**
Rectifiers produce pulsating DC without filtering.

39. **(c) zero**
Diode is forward biased and no current passes.

40. **(a) (6-0.7) V**
Diode drops 0.7V, leaving $6 - 0.7 = 5.3$ V across the resistor.

41. **(c) 20**
Input frequency: $f = \frac{1}{50\text{ ms}} = 20$ Hz. Half-wave retains input frequency.

42. **(a) Forward biased**
During the negative half-cycle, the diode is forward-biased.

43. **(b)**
b option is output wave form for full wave rectification.

44. **(c) Remove ripple from the rectified output**
Filters (e.g., capacitors) smooth the pulsating DC by reducing ripple.

45. **(d) All of the above**
Bridge rectifiers eliminate the need for a center-tapped transformer, use diodes with lower PIV ratings, and are more compact.

46. **(a) One diode**
Half-wave rectification requires only one diode.

47. **(c) Both cycles**
Full-wave rectifiers utilize both half-cycles of the AC input.

48. **(d) either lower or upper**
In half wave rectification diode conducts only during one half.

49. **(d) either positive or negative half cycle**

50. **(a) 80.60%**
The maximum theoretical efficiency of a full-wave rectifier is ~81.2%, closest to 80.60%.

51. **(c)** $10/\pi$
Average DC voltage for half-wave: $V_{dc} = \frac{V_p}{\pi} = \frac{10}{\pi}$.

52. **(c) 0.482**
The ripple factor for a full-wave rectifier is approximately 0.482.

53. **(b) Half wave D.C**
Removing one diode from a bridge rectifier converts it to a half-wave rectifier.

54. **(a)**
During positive half diode is reverse biased and current only passes through load resistance R.

55. **(c) 2 KΩ**
$R = \frac{V}{I} = \frac{5\text{ V}}{2.5\text{ mA}} = 2000\,\Omega = 2\text{ k}\Omega$.

56. **(a) Zero**
No current passes through the resistance in both halves.

57. **(a)**
If diode 'X' is removed, the circuit conducts only during positive half cycle (half wave rectifier)

UNIT 11 MODERN PHYSICS

SOLUTION PRACTICE TEST NO. 1

Answers and Explanations:

1. **(b)** 10^{-4}
   The ratio of momenta is $\frac{f_\gamma}{f_X} = \frac{10^{22}}{10^{18}} = 10^4$.
2. **(b)**
   Explanation: For the same intensity current will be same and stopping potential will be higher for higher frequency.
3. **(a) $8 \times 10^{-19}\, J$**
   $$K.E_{max} = eV_o = 5eV = 5 \times 1.6 \times 10^{-19} = 8 \times 10^{-19}\, J$$
4. **(a) 375 nm**
   Threshold wavelength $\lambda \propto \frac{1}{\phi}$. Since $\phi_N = 2\phi_O$, $\lambda_N = \frac{\lambda_O}{2} = \frac{750}{2} = 375$ nm.
5. **(b) 2.66 eV**
   Explanation: Photon energy $E = \frac{1240 \text{ eV\cdotpnm}}{332 \text{ nm}} \approx 3.73$ eV. Retarding potential $= E - \phi = 3.73 - 1.07 = 2.66$ eV.
6. **(c) Energy is emitted or absorbed in discrete packets**
   Explanation: Quantum theory states energy is quantized into photons.
7. **(a) 620 nm**
   Explanation: $\lambda_{\text{threshold}} = \frac{1240 \text{ eV\cdotpnm}}{2 \text{ eV}} = 620$ nm.
8. **(a)** $E = pc$
   Explanation: From $E = hf$ and $p = \frac{h}{\lambda}$, using $c = f\lambda$, $E = pc$.
9. **(d) Wavelength of radiation should be decreased**
   Explanation: Shorter wavelength (higher frequency) increases photon energy, boosting electron KE.
10. **(a) 14.8 V**
    Stopping potential $V = \frac{E_{\text{photon}} - \phi}{e} = \frac{22.5 - 7.7}{1} = 14.8$ V.
11. **(d)**
    Explanation: since frequency is same so stopping potential is same and photoelectric current will be greater for greater intensity.
12. **(c) Red**
    Explanation: Red light has a lower frequency than orange. Since orange light doesn't emit photoelectrons, red light (with even lower energy) cannot either.
13. **(d) Both p and E decrease**
    Explanation: Momentum $p = \frac{h}{\lambda}$ and energy $E = \frac{hc}{\lambda}$. Increasing wavelength reduces both.
14. **(d) The photocurrent is doubled**
    Explanation: Intensity affects the number of photons, doubling the photocurrent. Energy per photon remains unchanged.
15. **(d) Photoelectric effect and diffraction**
    Explanation: Photoelectric effect (particle nature) and diffraction (wave nature) demonstrate duality.
16. **(a) Spontaneous emission of photoelectrons**
    Explanation: When frequency meets or exceeds the threshold, electrons are spontaneously emitted.
17. **(c)** 0°
    Compton shift $\Delta\lambda = \frac{h}{mc}(1 - \cos\theta)$. At $\theta = 0^\circ$, $\Delta\lambda = 0$.
18. **(c) Photocell**
    A photocell converts light energy into electrical energy.
19. **(d) Pair production**
    Explanation: High-energy gamma photons produce electron-positron pairs near a nucleus.
20. **(d) The stopping potential will increase**
    Explanation: Shorter wavelength (higher energy) increases the maximum kinetic energy of electrons, requiring a higher stopping potential.
21. **(d) Threshold frequency**
    Explanation: The minimum frequency required to eject photoelectrons is the threshold frequency.
22. **(b) 1.1 eV**
    $K.E_{\text{max}} = E_{\text{photon}} - \phi = 3.4 \text{ eV} - 2.3 \text{ eV} = 1.1$ eV.
23. **(d) 50 photons of blue light**
    Explanation: Blue light has the highest frequency (and energy per photon), so 50 blue photons have the greatest total energy.
24. **(c)** $\lambda_s > \lambda_i$
    Explanation: Compton scattering increases the wavelength ($\lambda_s > \lambda_i$) due to energy loss.
25. **(d) Annihilation of matter**
    Explanation: Pair production (energy → matter) is reversed in annihilation (matter → energy).
26. **(c) No rest mass & no charge**
    Explanation: Photons are massless and uncharged.
27. **(c) Frequency**
    Explanation: $E = hf$, so photon energy is directly proportional to frequency.
28. **(d) All of them**
    Explanation: Wave theory fails to explain photoelectric effect, Compton effect, and blackbody radiation.
29. **(a) Increase**
    Explanation: Absorbing a photon increases the electron's energy.
30. **(a) Photoelectric effect**
    Explanation: The photoelectric effect demonstrates light's particle nature.

31. (c) Z^2

Explanation: The Rydberg constant for hydrogen-like atoms scales with Z^2, where Z is the atomic number.

32. (d) Momentum of photon

Explanation: Momentum $p = \frac{h}{\lambda}$ links wave (λ) and particle (p) properties.

33. (c) Max Planck

Explanation: The Planck constant is named after Max Planck, not listed in the options.

34. (d) Intensity of incident light

Explanation: Photocurrent depends on the number of photons (intensity).

35. (b) Opposite direction

Explanation: Annihilation produces two photons moving oppositely to conserve momentum.

36. (a) Zero

Explanation: Photons have zero rest mass.

37. (c) 2.43 pm

Explanation: The Compton wavelength is approximately 2.43 pm.

38. (a) 9.9 eV

$E_{\text{photon}} = \phi + eV = 4.2\text{ eV} + 5.7\text{ eV} = 9.9\text{ eV}$.

39. (c) The intensity of the source is decreased

Explanation: Lower intensity reduces the number of emitted electrons.

40. (d) Diffraction

Explanation: Diffraction demonstrates wave nature, not particle nature.

41. (b) 20 photons of green light

Explanation: Green light has higher energy per photon than red, orange, or yellow.

42. (b) Vo

Explanation: Stopping potential depends on photon energy, not distance/intensity.

43. (d) Stopping potential will increase

Explanation: Reduced wavelength (higher energy) increases stopping potential (assuming typo in question).

44. (d) For a given metal there is a minimum frequency of light below which no emission occurs

Explanation: Threshold frequency is a key feature of the photoelectric effect.

45. (d) Is same for all metals irrespective of frequency and intensity of incident photons

Explanation: Slope equals Planck's constant (h), a universal constant.

46. (c) Infrared radiation has lower frequency than X-rays

Infrared frequencies are lower than X-rays.

47. (c) 2×10^{-19} J

$\phi = hf = (6.626 \times 10^{-34})(3 \times 10^{14}) \approx 1.9878 \times 10^{-19}$ J.

48. (d) There is no photo emission

Explanation: Wavelength $400\text{ nm} > 300\text{ nm}$ (threshold), so no emission.

49. (b) More with ultraviolet light

Explanation: Ultraviolet photons have higher energy, leading to greater stopping potential.

50. (c)

Since slope of the graph is proportional to Planck's constant and will remain constant. Hence for different metal threshold frequencies will be different but slope remain same.

SOLUTION PRACTICE TEST NO. 2

Answers and Explanations:

1. (d) Annihilation

Proton and antiproton annihilate each other, converting mass into energy.

2. (d) All of these

Photons, electrons, and alpha particles all exhibit wave-particle duality.

3. (a) Microwaves, radio waves, infrared

These are all electromagnetic waves; sound is mechanical.

4. (c) Einstein

Einstein received the Nobel Prize for explaining the photoelectric effect.

5. (a) Compton

Compton scattering confirmed the photon's particle nature.

6. (a) Higher

Photons travel at speed c in vacuum, slower in water.

7. (a) 1

Energy $\approx \frac{1240\text{ nm}}{\lambda}$ eV $= 1$ eV.

8. (d) h/λ

Photon momentum formula.

9. (a) Red

Longer wavelength (red) implies smaller momentum.

10. (c) Decreases

Photon loses energy, reducing frequency.

11. (d)

Correct Compton shift formula: $\Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$.

12. (b) Quantum theory

Compton effect supports photon-particle behavior.

13. (c)

Quantum theory states energy is quantized.

14. (b) 4.125×10^{-7} m

$\lambda = \frac{hc}{\phi} \approx 413$ nm.

15. (a) 1.09×10^{15} Hz

$f_0 = \frac{\phi}{h} \approx 1.09 \times 10^{15}$ Hz.

16. (b) Particle-like behavior

Photoelectric effect demonstrates light as particles (photons).

17. (d) Electrons come out of a metal with different velocities not greater than a certain value

Explanation: Photoelectrons have a range of kinetic energies up to a maximum determined by $K.E_{\text{max}} = hf - \phi$.

18. (d) 3×10^8 m s^{-1}

Explanation: Photons travel at the speed of light in a vacuum, 3×10^8 m/s.

19. (a) Less than nano-second

Explanation: Photoelectron emission is nearly instantaneous.

20. (c) $\frac{h}{2m_0c}$

Explanation: Compton shift formula for 60°: $\Delta\lambda = \frac{h}{2m_ec}$.

21. (b) Compton's effect

Compton scattering demonstrates light's particle nature.

22. (b) X-rays

Compton effect is observed with X-rays scattering off electrons.

23. (a) 6.63×10^{-32} J

Explanation: Closest approximation for a radio wave photon's energy.

24. (a) 4×10^{-5}

Explanation: Momentum ratio $\frac{p_X}{p_Y} = \frac{f_X}{f_Y} = 4 \times 10^{-5}$.

25. (c) On the difference in energy of incident photon and work function of metal

Explanation: Stopping potential $V = \frac{E_{\text{photon}} - \phi}{e}$.

26. (d) 3×10^{-27} kg ms^{-1}

Explanation: Momentum $p = \frac{E}{c} = 3 \times 10^{-27}$ kg m/s.

27. (c) Long radio waves, infrared, ultraviolet

Explanation: Descending order of wavelength: radio > infrared > ultraviolet.

28. (c) From 400 nm to 750 nm

Visible spectrum ranges approximately 400–750 nm.

29. (a) Red

Explanation: Red light has the longest wavelength, hence the least momentum.

30. (d) K.E of photoelectrons is directly proportional to intensity incident photon beam

Explanation: **Incorrect statement**, but no valid option provided. (Question likely flawed.)

31. (d) Energy

Explanation: Conservation of energy governs the photoelectric effect.

32. (c) Has wavelength less than or equal to certain maximum wavelength

Explanation: Emission occurs if wavelength ≤ threshold wavelength.

33. (d) All of these

Explanation: $K.E_{\text{max}} = hf - \phi$, depending on f, ϕ, and threshold frequency.

34. (d) Average K.E decreases

Explanation: By increasing wavelength reduces photon energy, lowering maximum KE. Thus average K.E also decreases.

35. (d) Photoelectric effect

Explanation: Wave theory can't explain the photoelectric effect, which requires particle nature (photons).

36. (a) 1.4 eV

Explanation: $K.E_{\text{max}} = 3.4\text{ eV} - 2\text{ eV} = 1.4\text{ eV}$.

37. (c)

Explanation: $K.E_{\text{max}}$ vs frequency is a linear graph with slope h, starting at threshold frequency.

38. (b) 2.2×10^{-27} kg m/s

Explanation: $p = \frac{h}{\lambda} = \frac{6.626\times10^{-34}}{3\times10^{-7}} \approx 2.2 \times 10^{-27}$.

39. (c) $\frac{hc}{E} = \lambda$

Explanation: As $E = \frac{hc}{\lambda}$

40. (a) Indigo

Explanation: Indigo has the shortest wavelength (highest frequency), giving the highest photon energy.

41. (d) Reduce to zero

Explanation: Halving frequency drops it below threshold; no emission.

42. (a) Violet light

Explanation: Violet has higher frequency than blue/green, enabling emission.

43. (d) 2:1

Explanation: Frequency and wavelength are inversely proportional to each other. Ratio in frequency will be inverse of ratio in wavelength.

44. (a) 6.63×10^{-26} Ns

Explanation: $p = \frac{h}{\lambda} = \frac{6.626\times10^{-34}}{1\times10^{-8}} = 6.63 \times 10^{-26}$. (Assuming typo in options, closest is (a).)

45. (d) 3.2×10^{-19} J

Explanation: $K.E = 2\text{ eV} = 3.2 \times 10^{-19}$ J.

46. (a) 10^{15} Hz

Explanation: $f = \frac{4\times1.6\times10^{-19}}{6.626\times10^{-34}} \approx 10^{15}$ Hz.

47. (a) 8×10^{14} Hz

Explanation: $f_0 = \frac{3.3\times1.6\times10^{-19}}{6.626\times10^{-34}} \approx 8 \times 10^{14}$ Hz.

48. (a) 2.3 eV, 2.7 eV

Explanation: Potassium (~2.3 eV) and sodium (~2.7 eV) work functions.

49. (a) Neutral

Explanation: Photons carry no charge.

50. (b) 400 nm

Explanation: Ultraviolet (invisible) lies below 400 nm.

SOLUTION PRACTICE TEST NO. 3

Answers and Explanations:

1. (d) Both a and b

Compton effect conserves momentum and energy.

2. (d) $1 \propto \frac{1}{d^2}$

Explanation: Intensity $\propto \frac{1}{d^2}$, so current follows.

3. (c) X-ray production

Explanation: X-rays are produced when electrons decelerate (reverse of photoelectric effect).

4. (d) Energy remains same because the frequency of radiation remains same

Explanation: Photon energy $E = hf$ depends only on frequency, which remains constant in different media.

5. (d) Number of photons striking the cathode per unit time

Explanation: Blue photons have higher energy; same power means fewer photons, reducing photocurrent.

6. (c) The frequency of radiation should be increased

Explanation: $K.E_{max} = hf - \phi$. Higher frequency increases photon energy.

7. (d) 1.5×10^{13} Hz

$f = \frac{pc}{h} = \frac{(3.3\times10^{-29})(3\times10^{8})}{6.6\times10^{-34}} \approx 1.5 \times 10^{13}$ Hz.

8. (c) A, B, C

Photon energy 3.1 eV $\geq \phi$ for A (2 eV), B (2.4 eV), and C (2.8 eV).

9. (a) Violet

Explanation: Momentum $p = \frac{h}{\lambda}$; violet has the shortest wavelength.

10. (a) 45°

$\Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$. For $\Delta\lambda = 0.3\frac{h}{m_e c}$, $\theta \approx 45^\circ$.

11. (d) All of these

12. (c) Photoelectric effect

Explanation: X-ray production (electron deceleration) is the reverse of the photoelectric effect.

13. (c) 1.02 MeV

Explanation: Minimum energy required is twice the electron rest mass (2×0.511 MeV).

14. (d) All have same wavelength

$\lambda = \frac{h}{p}$; same momentum implies same wavelength.

15. (d) All of these

Explanation: Charge momentum and energy all are conserved in pair production.

16. (a) Positron & electron

Pair production creates an electron-positron pair.

17. (c) Compton's effect

Compton scattering demonstrates both wave (wavelength shift) and particle (photon-electron collision) nature.

18. (c) 1 micrometer

Explanation: $\lambda = \frac{c}{f} = \frac{3\times10^{8}}{3\times10^{14}} = 1\,\mu$m.

19. (a) Less

Explanation: White light has longer wavelength (λ) than X-rays; $p = \frac{h}{\lambda}$, so lower momentum.

20. (c) 1.6×10^{16} Hz

Explanation: $f = \frac{E}{h} = \frac{66.3\times1.6\times10^{-19}}{6.6\times10^{-34}} \approx 1.6 \times 10^{16}$ Hz.

21. (b) 6×10^{14} Hz

Explanation: $f = \frac{c}{\lambda} = \frac{3\times10^{8}}{500\times10^{-9}} = 6 \times 10^{14}$ Hz.

22. (d) Planck's constant

Explanation: Planck's constant (h) has units of J·s.

23. (c) In between UV to IR

Explanation: Visible light (white light) spans ~400–700 nm, between UV and IR.

24. (c) Remain same

Explanation: Reflection reverses momentum direction but magnitude remains the same.

25. (b) Einstein

Einstein explained the photoelectric effect, introducing the work function concept.

26. (c) Photons

Particle-antiparticle annihilation (e.g., electron and positron) produces photons.

27. (b) Cosmic radiation

Positrons were discovered in cosmic rays by Carl Anderson.

28. (c) $\frac{h}{fc}$

Photon momentum $p = \frac{h}{\lambda} = \frac{hf}{c}$. Assuming notation error, (c) is closest.

29. (b) Nature of surface only

Work function depends on the material and surface condition, but "nature of surface" broadly covers this.

30. (d) $E = \frac{z}{2}$

Correct relation: $E = \frac{hc}{z}$. $E = \frac{z}{2}$ is dimensionally invalid.

31. (c) X-rays, visible, microwave

Ascending wavelength order: X-rays (shortest), visible, microwave (longest).

32. (c) Photons

Same as Q26; annihilation produces photons.

33. (a) 2:1

Maximum K.E for $1eV = 1 - 0.5 = 0.5$

Maximum K.E for $2.5eV = 2.5 - 0.5 = 2$

$V_{max} \propto \sqrt{K.E_{max}}$

$v_2/v_1 = \sqrt{\frac{2.0}{0.5}} = 2.$

34. (c)

$E = \frac{hc}{\lambda}$: Calculated energy $\sim 6.6 \times 10^{-28}$ J,

35. (b) Stopping potential

Stopping potential $V_s \propto (f - f_0)$, dependent on incident frequency.

36. (d) $f' < f$

Compton scattering reduces photon energy, decreasing frequency.

37. (a) Photoelectric effect
Photocathodes emit electrons via the photoelectric effect.

38. (a)
$\emptyset = hf_o \Rightarrow f_o = \frac{f}{\emptyset}$
Correct threshold frequency $\sim 1.09 \times 10^{15}$ Hz.

39. (a) 1 eV
$E = \frac{1240 \text{ eV\cdotpnm}}{1240 \text{ nm}} = 1$ eV.

40. (c) Red, blue
Red photons have lower energy, so more photons for the same total energy; blue has fewer.

41. (c) $[M/L]^{-2}$
Assuming typo, dimensions of $x = m^{-2}$ are $[M]^{-2}$. Options repeated; likely intended (c).

42. (c) 10 photons of violet light
Violet has the highest energy per photon; 10 violet photons yield the highest total energy.

43. (d)
For different intensities current will be different and stopping potential will be smaller for larger work function and vice versa.

44. (b) 4 eV
The work function ϕ is negative Y intercept on the K.E axis when $f = 0$.

45. (d)
Photon energy $E = hf$ is linear with frequency. The correct graph is a straight line through the origin

46. (a)
For same energy photons stopping potential will be same and photoelectric current will be higher for higher intensity.

47. (d) Angular momentum
Planck's constant h has units of J·s (kg·m^2/s), matching angular momentum ($L = r \times p$).

48. (c) 3×10^8 m/s
Zero rest mass particles (e.g., photons) travel at the speed of light in vacuum.

49. (a) Speed of light
$E/p = c$. The ratio equals the speed of light. (Options missing; likely answer is 3×10^8 m/s).

UNIT 12 ATOMIC SPECTRA

SOLUTION PRACTICE TEST NO. 1

Answers and Explanations:

1. (a) 5:9
The Balmer series' maximum wavelength (n=3→2) and minimum (n=∞→2) ratio is 5:9.

2. (c) Spectral lines
Spectral lines result from electron transitions between energy levels.

3. (b) +3.4 eV
Kinetic energy equals the magnitude of the total energy in Bohr's model.

4. (c) 9r₀
Radius scales with n^2; $3^2 = 9$.

5. (d) 0.66 eV
Energy difference: $E_4 - E_3 = -0.85 - (-1.51) = 0.66$ eV.

6. (d) 10.2 eV
Assuming the question refers to excitation from ground (n=1) to first excited (n=2), energy difference is 10.2 eV.

7. (c) $\frac{nh}{2\pi}$
Angular momentum: $L = \frac{nh}{2\pi}$.

8. (b) 10.2 eV
Transition from n=2→1: $\Delta E = 10.2$ eV.

9. (d) $1/R_H$
Lyman series' shortest λ: $1/\lambda_{\text{min}} = R_H \Rightarrow \lambda_{\text{min}} = 1/R_H$.

10. (b) -1.51 eV
Second excited state is n=3: $E_3 = -13.6/9 = -1.51$ eV.

11. (b) $\frac{h}{2\pi}$
$\Delta L = \frac{h}{2\pi}$ between successive orbits.

12. (b) Pfund series
Transitions to n=5 form the Pfund series.

13. (d) J.J. Balmer
Balmer identified the Balmer series.

14. (a) $v_n \propto \frac{1}{n}$
Speed $v \propto 1/n$.

15. (d) $4/R_H$
Shortest λ in Balmer: $1/\lambda = R_H/4 \Rightarrow \lambda = 4/R_H$.

16. (b) $16r_i$
Radius: $r_4 = 4^2 r_i = 16r_i$.

17. (c) Balmer series
Balmer lies in the visible spectrum.

18. (c) 4
Longest λ in Paschen (n=4→3).

19. (d) Lyman series
Lyman series is in UV.

20. (d) $\frac{9}{4}$
Ratio $E_2/E_3 = (-3.4)/(-1.51) \approx 9/4$.

21. (d) $\frac{2}{5}$ **v**
Velocity $v \propto \frac{1}{n}$. For $n = 5$, velocity is $v \times \frac{2}{5}$.

22. (d) $\frac{R_H c}{4}$
Shortest wavelength (highest frequency) in Balmer: $\lambda = \frac{4}{R_H}$. Frequency $f = \frac{c}{\lambda} = \frac{R_H c}{4}$.

23. (c) Four times
Radius $r \propto n^2$. First excited state ($n = 2$): $4r$.

24. (d) $\frac{3}{4}$
Longest λ: $\frac{4}{3R_H}$; shortest λ: $\frac{1}{R_H}$. Ratio: $\frac{1/R_H}{4/(3R_H)} = \frac{3}{4}$.

25. (c) 4r
Radius $r_n = n^2 r$. For $n = 2$, $4r$.

26. (a) Angular momentum
Angular momentum $L = \frac{nh}{2\pi}$, an integral multiple of $\frac{h}{2\pi}$.

27. (c) h/π
For $n = 2$, $L = \frac{2h}{2\pi} = \frac{h}{\pi}$.

28. (a) H_α
Longest λ corresponds to $n = 3 \to 2$ (H-alpha).

29. (c) Brackett series is in infrared region
Balmer (visible), Lyman (UV), Paschen, Brackett and Pfund (IR).

30. (c) $9/R_H$
Shortest λ in Paschen: $\lambda = \frac{9}{R_H}$.

31. (b) $mvr = \frac{nh}{2\pi}$
Bohr's quantization condition for angular momentum.

32. (d) Infrared radiations
Infrared has longer wavelengths than visible, UV, and X-rays.

33. (b) 3.4 eV
Ionization energy from $n = 2$: $\frac{13.6}{4} = 3.4$ eV.

34. (c) $\frac{nh}{2\pi}$
Angular momentum formula: $L = \frac{nh}{2\pi}$.

35. (a) $n = 2$ **to** $n = 1$
Largest energy difference ($\Delta E = 10.2$ eV) gives highest frequency.

36. (d) Infinite
Hydrogen has infinite spectral lines as $n \to \infty$.

37. (a) Neil Bohr
Bohr proposed stationary orbits.

38. (c) 3.4 eV
Kinetic energy equals the magnitude of total energy (I

-3.4 |= 3.4 eV).

39. (b) $n = 2$

Radius ratio $\frac{21.2}{5.3} = 4$, so $n = 2$.

40. (a) 3.40 eV

Energy transition $\infty \rightarrow 2: 0 - (-3.4) = 3.4$ eV.

41. (c) $\frac{h}{2\pi}$

For $n = 1, L = \frac{h}{2\pi}$.

42. (d) n=6 to n=2

The transition from n=6 to n=2 has a smaller energy difference (≈3.02 eV) compared to n=2→1 (10.2 eV), resulting in the lowest frequency photon.

43. (d) 1.51 eV

Ionization energy from n=3: $E = \frac{13.6}{9} \approx 1.51$ eV.

44. (c) Minimum energy

The lowest orbit (n=1) has the most negative energy, indicating the minimum energy state.

45. (c) 2.55 eV

Transition from n=4→2: $\Delta E = -0.85 - (-3.4) =$ 2.55 eV.

46. (b) $\frac{9R}{4}$

Radius $r \propto n^2$. Third orbit: $\frac{3^2}{2^2}R = \frac{9}{4}R$.

47. (c) 3

Electron reaches n=3, emitting 3 spectral lines (3→2, 3→1, 2→1).

48. (b) $\frac{13.6}{9}$ **eV**

Ionization energy from n=3: $\frac{13.6}{9}$ eV.

49. (c) 10^{-10} **m**

Atomic radius ≈ $1\,\mathring{A} = 10^{-10}$ m.

50. (a) 10.2 eV

Energy required: $\Delta E = -3.4 - (-13.6) = 10.2$ eV.

SOLUTION PRACTICE TEST NO. 2

Answers and Explanations:

1. **(d)** n^2
2. **(c) Ultraviolet**
3. **(b) Balmer series**
4. **(b) 0.136 eV**
5. **(a) 4**
6. **(c)** $-\frac{1}{2}$
7. **(a) P.E increase and K.E decrease**
8. **(a) -1 : 1**
9. **(b) 5:27**
10. **(b) n=4 to n=3**
11. **(b)** $\frac{3h}{2\pi}$

    Angular momentum in Bohr's model: $L = \frac{nh}{2\pi}$. For $n = 3, L = \frac{3h}{2\pi}$.
12. **(d) 6**

    Number of spectral lines from $n = 4$: $\frac{4\times3}{2} = 6$.
13. **(d) 4 times**

    Radius $r \propto n^2$. First excited state ($n = 2$): $4r_1$.
14. **(b) Negative**

    Energy in bound states of hydrogen is always negative.
15. **(b) 0.818** μm **and 1.87** μm

    Paschen series: Longest λ (n=4→3) = 1.87 µm; shortest λ (n=∞→3) = 0.818 µm.
16. **(a) From n = 2 to n = 1**

    Maximum energy change: $\Delta E = 10.2$ eV (2→1).
17. **(a)** $\frac{27}{32}\lambda$

    Wavelength ratio: $\lambda' = \frac{27}{32}\lambda$ (using Rydberg formula).
18. **(b)** $\frac{9}{4}$

    Energy ratio: $E_2/E_3 = \frac{9}{4}$.
19. **(d) Both B and C**

    Electrons move in fixed orbits and radiate energy during transitions.
20. **(a) Visible**

    Balmer series (n≥3→2) lies in the visible region.
21. **(a)** 1.05×10^{-34} Js

    Angular momentum change: $\Delta L = \frac{h}{2\pi} \approx 1.05 \times 10^{-34}$ Js.
22. **(d)** $n = 4, n = 5$ **to** ∞

    Brackett series transitions: $n = 5,6,\ldots \rightarrow n = 4$.
23. **(d) Largest change of total energy**

    Lyman series (n→1) involves the largest energy differences.
24. **(b) decrease**

    Lower series (e.g., Balmer) have more possible transitions.
25. **(d) Equal to the circumference of the first orbit**

    De Broglie wavelength: $\lambda = 2\pi r_1$ (circumference).
26. **(b) A heavy element with a high melting point**

    Molybdenum's properties suit X-ray production.
27. **(c) 3**

    Transitions from $n = 3$: 3→2, 3→1, 2→1.
28. **(c) -6.8 eV**

    Potential energy: $PE = 2 \times$ Total Energy $= -6.8$ eV.
29. **(c) U.V region**

    Lyman series lies in the ultraviolet.
30. **(d)** $\frac{16}{3R_H}$

    Using Rydberg formula: $\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3R_H}{16} \Rightarrow \lambda = \frac{16}{3R_H}$.
31. **(c) Sun**

    Helium was first detected in the Sun's spectrum.
32. **(a) 2 L**

    Angular momentum $L \propto n$. For $n = 4, L = 2L_{\text{initial}}$.
33. **(c) Line spectrum**

    Hydrogen emits discrete lines, characteristic of a line spectrum.
34. **(d) Stationary wave**

    De Broglie wavelength forms standing waves in Bohr orbits.

35. (d) $\frac{Ke^2}{2r_n}$
Kinetic energy formula in Bohr's model.

36. (c) $\frac{36}{5R_H}$
Longest λ: $\frac{1}{\lambda} = R_H\left(\frac{1}{4} - \frac{1}{9}\right) \Rightarrow \lambda = \frac{36}{5R_H}$.

37. (b) 3 and 2
Red line (H-alpha) corresponds to $n = 3 \rightarrow 2$.

38. (b) $1.0974 \times 10^7\ \text{m}^{-1}$
Rydberg constant value.

39. (d) 3.4, 1.5, 0.85
Ionization energies for $n = 2,3,4$: $\frac{13.6}{n^2}$.

40. (b) Decreases
Energy levels converge as n increases.

41. (d) All of these

42. (a) Is greater in outer orbit than in inner orbits
Energy becomes less negative with higher n.

43. (b) Paschen series is a line spectrum in the infrared
Paschen series lies in the infrared region.

44. (b) 2.55 eV
Energy difference: $E_4 - E_2 = -0.85 - (-3.4) = 2.55$ eV.

45. (b) Conservation of angular momentum
Bohr used angular momentum quantization.

46. (d) 10
Number of spectral lines: $\frac{n(n-1)}{2} = \frac{5\times4}{2} = 10$.

47. (c) 10.2 V
Excitation potential for $n = 1 \rightarrow 2$: 10.2 eV.

48. (c) 1.632×10^{-18} J
$10.2\ \text{eV} \times 1.6 \times 10^{-19}\ \text{J/eV} = 1.632 \times 10^{-18}$ J.

49. (a) $\frac{25}{9}$
Ratio: $\frac{\lambda_{\text{long}}}{\lambda_{\text{short}}} = \frac{25}{9}$.

50. (d) -0.54 eV
Energy at $n = 5$: $E_5 = \frac{-13.6}{25} = -0.544$ eV.

51. (b) 4.77Å
The radius of the nth orbit in Bohr's model is proportional to n^2. For $n = 3$, the radius is $3^2 \times 0.53\ \text{Å} = 4.77\ \text{Å}$.

52. (c) 2.11x10^{3}4 J sec
Angular momentum $L = \frac{nh}{2\pi}$. For $n = 2$, $L = \frac{2h}{2\pi} = \frac{h}{\pi} \approx 2.11 \times 10^{-34}$ Js.

53. (a) 1.215x10^7 m
Using Rydberg formula: $\lambda = \frac{4}{3R_H} \approx 1.215 \times 10^{-7}$ m $= 121.5$ nm.

54. (c) 12.09 eV
Energy required: $\Delta E = E_3 - E_1 = -1.51\ \text{eV} - (-13.6\ \text{eV}) = 12.09$ eV.

55. (b) $\frac{2\pi ke^2}{nh}$
Velocity in nth orbit: $v = \frac{2\pi ke^2}{nh}$.

56. (d) 1.9 eV
Energy difference:
$E_2 - E_3 = -3.4\ \text{eV} - (-1.51\ \text{eV}) = 1.89\ \text{eV} \approx 1.9$ eV.

57. (a) Assumes that the angular momentum of electrons is quantized
Bohr's model quantizes angular momentum.

58. (d) Half of it P.E
Kinetic energy is half the magnitude of potential energy.

59. (c) Continuous
Black body spectrum is continuous.

60. (c) Neon street sign
Neon signs emit line spectra.

61. (a) Absorption
Dark lines in the solar spectrum are due to absorption.

62. (b) Discrete
Atomic spectra are discrete.

63. (d) Bracket
Transitions ending at $n = 4$ form the Brackett series.

64. (b) $\frac{hc}{(E_1-E_0)}$
Wavelength $\lambda = \frac{hc}{E_1-E_0}$.

65. (d) $\sqrt{\frac{2V_e}{m}}$
Velocity $v = \sqrt{\frac{2eV}{m}}$.

UNIT 13 NUCLEAR PHYSICS

SOLUTION PRACTICE TEST NO. 1

Answers and Explanations:

1. **(b) Baryons**
Baryons (like protons and neutrons) have masses equal to or greater than protons, while mesons are lighter.

2. **(a)** $\bar{d}$
Top quark (+2/3) + Strange quark (-1/3) = +1/3. The anti-down quark ($\bar{d}$) has charge +1/3.

3. **(a)** α **and** β
Alpha (+ve) and Beta (-ve) deflect oppositely in a magnetic field; gamma rays (neutral) do not bend.

4. **(b)** γ**-rays**
Gamma rays penetrate deeply, making them suitable for tumor irradiation.

5. **(c) Cobalt-60**
Cobalt-60 is widely used in radiotherapy for cancers like liver cancer.

6. **(a)** $M - Z$
Neutrons = Mass number (M) - Atomic number (Z).

7. **(c) Decay of a neutron in a nucleus**
Beta decay involves a neutron converting into a proton, emitting an electron.

8. **(d) All of the above**
Radioactivity is irreversible, spontaneous, and a self-disintegration process.

9. **(c) 2.5 g**
After 2 half-lives (540 days), 10g → 5g → 2.5g. Beta particles (electrons) escape, leaving ≈2.5g of material.

10. **(b)** ${}^{14}_{6}C, {}^{14}_{7}N$
Isobars have the same mass number (14) but different atomic numbers (6 vs. 7).

11. **(c) 8** μ**Ci**
Activity doubles every half-life backward: 2 → 4 → 8 μCi in 2 months.

12. **(b)**
In β^+ decay, a proton converts to a neutron, emitting a positron created from binding energy.

13. **(c) Iron**
Iron (Fe) has the highest binding energy per nucleon, making it the most stable.

14. **(c) 8,6**
Mass difference: 200 - 168 = 32 ⇒ 8 α-particles (each -4). ΔZ from α: 8 × 2 = 16. To adjust Z, 6 β^- emissions (+1 each) offset to final Z.

15. **(b) Increases**
Heavier nuclei require more neutrons to stabilize, increasing the neutron-to-proton ratio.

16. **(c)** γ**-ray**
Gamma rays travel at light speed, faster than α or β particles.

17. **(d)** 4.5×10^9 **years, 1620 years**
Uranium-238: ~4.5 billion years; Radium-226: ~1600 years.

18. **(b) Half life**
Defined as the time for half the radioactive material to decay.

19. **(d) Both a and b**
Explanation: Radiation effects are categorized into somatic (affecting the individual) and genetic (affecting offspring). The Curie effect is unrelated to biology.

20. **(d) 20 times more damaging than X-rays**
Explanation: Alpha particles have a higher Relative Biological Effectiveness (RBE) due to greater ionization, making them 20 times more damaging.

21. **(d) 2 mSv per year**
Explanation: The average annual background radiation dose is approximately 2-3 mSv.

22. **(a) Chlorine-36**
Explanation: Chlorine-36 is used as a tracer in pesticides. Other isotopes listed are used for different medical purposes.

23. **(c)** $\frac{63}{64}$
Explanation: After 6 half-lives, $\frac{1}{2^6} = \frac{1}{64}$ remains. Decayed atoms = $1 - \frac{1}{64} = \frac{63}{64}$.

24. **(c) 6**
Explanation: Ratio X:Y = 1:7 ⇒ 1/8 remains. $\frac{1}{8} = \left(\frac{1}{2}\right)^3$, so 3 half-lives (3 × 2 hours = 6 hours).

25. **(d) 30 sec**
Explanation: $\frac{1}{4}$ remains after two half-lives: $T_{1/2} = \frac{60}{2} = 30$ sec.

26. **(c) Disintegration constant**
Explanation: The decay equation $\Delta N = -\lambda N \Delta t$ defines λ as the disintegration constant.

27. **(c) One alpha and two beta**
Explanation: One alpha (loses 2 protons) and two beta (gains 2 protons) results in no net change in proton count, forming an isotope.

28. **(d) Energy must be doubled**
Explanation: Absorbed dose (Gy) = energy (J) per kg. Doubling energy doubles the dose.

29. **(b) β-radiations**
Explanation: Carbon-14 undergoes beta decay (β^-) to become Nitrogen-14.
30. **(a) 1 Gy**
Explanation: 1 Gy = 100 rad. Thus, 100 rad = 1 Gy.
31. **(a) 1000**
Explanation: Radiation sickness typically occurs at doses ≥ 1000 mSv (1 Sv).
32. **(b) Do not produce same biological effect**
Explanation: Different radiations have varying RBEs, leading to different biological impacts.
33. **(c)**
34. **(c) 0.25 of original amount**
Explanation: 11400 years = 2 half-lives. Remaining amount = $\left(\frac{1}{2}\right)^2 = \frac{1}{4}$.
35. **(a) Atomic**
Explanation: The atomic number equals the number of protons in the nucleus.
36. **(c) 240s**
Explanation: 7/8 decayed ⇒ 1/8 remains. $\frac{1}{8} = \left(\frac{1}{2}\right)^3$, so 3 half-lives (3 × 80 s = 240 s).
37. **(a) Alpha rays**
Explanation: Helium atoms (as alpha particles) exhibit wave-particle duality similar to alpha rays.
38. **(c) Radioactive**
Explanation: Radioactive dating measures isotope decay to estimate ages.
39. **(c) Spin dependent but charge independent**
Explanation: Nuclear forces are independent of charge (act similarly between protons and neutrons) but depend on the spin of the particles.
40. **(b) 92 protons**
Explanation: Isotopes of an element share the same atomic number (protons). Uranium-238 and all its isotopes have 92 protons.
41. **(b) 2mg**
Explanation: 49.2 years ÷ 12.3 years/half-life = 4 half-lives. 32 mg × $\left(\frac{1}{2}\right)^4$ = 2 mg.
42. **(c) Ze**
Explanation: The total nuclear charge is $Z \times e$, where Z is the atomic number.
43. **(c) 0.693**
Explanation: Half-life $T_{1/2} = \tau \ln 2 \approx 1 \times 0.693 = 0.693$ years.
44. **(d) 0.0024**
Explanation: Mass defect $\Delta m = \frac{2.23\ \text{MeV}}{931.5\ \text{MeV/amu}} \approx 0.0024$ amu
45. **(c) Gamma**
Explanation: Gamma rays and X-rays both have high penetrating power due to their short wavelength.
46. **(c) 3**
Explanation: A hydrogen atom's proton contains 3 quarks (2 up, 1 down); the electron is a lepton, not composed of quarks.
47. **(a) Th-234**
Explanation: U-238 loses 4 nucleons (2 protons, 2 neutrons) during alpha decay, forming Thorium-234.
48. **(b) 1/1024**
Explanation: After 10 half-lives, remaining fraction = $\left(\frac{1}{2}\right)^{10} = \frac{1}{1024}$.
49. **(c) Three types**
Explanation: Radioactive waste is classified as low-level, intermediate-level, and high-level.
50. **(c) Sievert**
Explanation: The Sievert (Sv) is the SI unit for equivalent dose, accounting for biological effects.

SOLUTION PRACTICE TEST NO. 2

Answers and Explanations:

1. **(b) Excite the Nucleus**
Explanation: Gamma photons entering a nucleus can increase its energy state, causing excitation.
2. **(a) Curie**
Explanation: 3.7×10^{10} decays/s defines 1 Curie (Ci).
3. **(a) Radioactive nucleus**
Explanation: Beta particles (electrons) are emitted from the nucleus during neutron-to-proton conversion.
4. **(d) All of these**
Explanation: Tracers are used in medicine, agriculture, and environmental studies.
5. **(c) 60 minutes**
Explanation: 200 → 25 is 3 half-lives. Total time = 180 minutes ⇒ $T_{1/2} = 60$ minutes.
6. **(d) None of these**
Explanation: LED TVs emit non-ionizing radiation (light), not alpha, beta, or gamma.
7. **(c) Tritium**
Explanation: Momentum $p = mv$. Tritium (heaviest isotope) has the highest mass, hence highest momentum at the same velocity.
8. **(c) Film badge dosimeter**
Explanation: Film badges measure cumulative radiation exposure for workers.
9. **(d) Both A and B**
Explanation: Alpha and beta particles can cause skin damage due to their ionizing properties.
10. **(a) -4**
Explanation: Alpha decay reduces nucleon number by 4; beta and gamma decays do not affect it. Total change = -4.
11. **(d) All of these**
Explanation: Somatic effects include immediate bodily impacts like cancer, hair loss, and reduced white blood cells.

12. (a) Somatic
Explanation: Skin cell damage is a direct bodily effect, classified as somatic.

13. (d) 1/8
Explanation: 72000 years ÷ 24000/half-life = 3 half-lives. Remaining fraction = $\left(\frac{1}{2}\right)^3 = \frac{1}{8}$.

14. (d) Decay of atomic nucleus
Explanation: Radioactivity arises from unstable nuclei undergoing decay.

15. (c) Different for different elements
Explanation: Decay rate depends on the element-specific disintegration constant (λ).

16. (c) Mass number
Explanation: Mass number = protons + neutrons.

17. (b) 10 days
Explanation: Half-life is independent of physical conditions like pressure and temperature.

18. (a) 3%
Explanation: After 5 half-lives, remaining = $\left(\frac{1}{2}\right)^5 \approx 3\%$.

19. (b) Eight months
Explanation: Decaying 3/4 means 1/4 remains (2 half-lives). Total time = 4 months × 2 = 8 months.

20. (a) 8 days
Explanation: 25% remaining = 2 half-lives. Half-life = 16 days ÷ 2 = 8 days.

21. (c) De-excitation of nucleus
Explanation: Gamma rays are emitted when a nucleus transitions from a higher to lower energy state.

22. (a) 15 hours
Explanation: Sodium-24 has a half-life of ~15 hours.

23. (c) 560 days
Explanation: 16g → 1g requires 4 half-lives (16→8→4→2→1). Total time = 4 × 140 = 560 days.

24. (d) Released
Explanation: Binding energy is released when nucleons form a stable nucleus.

25. (d) Nucleons it contains
Explanation: Mass number = total protons + neutrons (nucleons).

26. (a) ^{238}U contains 3 more neutrons
Explanation: ^{238}U has 146 neutrons vs. 143 in ^{235}U (difference of 3).

27. (a) & (d) Brain & eyes
Explanation: Neutrons are highly penetrating and cause significant damage to soft tissues like the brain & eyes.

28. (d) 8 mJ
Explanation: Absorbed energy = dose (Gy) × mass. 20 mrad = 0.2 mGy. Energy = 0.0002 J/kg × 40 kg = 0.008 J = 8 mJ.

29. (b) Mass number reduces by 4
Explanation: Alpha decay reduces mass by 4; beta decay does not affect mass. Total mass change = -4.

30. (c) It is a short wavelength electromagnetic photon
Explanation: Alpha particles are helium nuclei, not electromagnetic waves. This statement is false.

31. (d) 15 days
Explanation: 32g → 2g is 4 half-lives (32→16→8→4→2). Half-life = 60 days ÷ 4 = 15 days.

32. (c) $\frac{7N_0}{8}$
Explanation: After 3 half-lives, $\frac{1}{8}$ remains. Decayed nuclei = $N_0 - \frac{N_0}{8} = \frac{7N_0}{8}$.

33. (b) $\frac{1}{64}$
Explanation: $\frac{7}{8}$ decayed in 12 days ⇒ 3 half-lives. After 24 days (6 half-lives), remaining = $\frac{1}{2^6} = \frac{1}{64}$.

34. (b) 10^{-15} m
Explanation: Nuclear size is femtometer scale (10^{-15} m).

35. (d) Both a and b
Explanation: β^- increases atomic number by 1; β^+ decreases it by 1.

36. (c) saRn^{222}
Explanation: Ra-226 ($Z = 88$) loses 4 nucleons (α decay) → Rn-222 ($Z = 86$).

37. (c) 1.67×10^{-27} kg, 930 MeV
Explanation: 1 amu ≈ 1.67×10^{-27} kg; energy ≈ 931 MeV.

38. (d) Isobars
Explanation: Beta decay changes atomic number, keeping mass number constant.

39. (b) $\alpha = 6, \beta = 4$
Explanation: 6α (mass -24, Z -12) + 4β (Z +4) reduces Th-232 (Z=90) to Pb-208 (Z=82).

40. (b) 1 : 1
Explanation: Alpha decay reduces protons and neutrons by 2 each.

41. (a) $8\alpha, 6\beta$
Explanation: U-238 → Pb-206: 8α (mass -32) and 6β (Z compensation).

42. (c) Activity
Explanation: Curie measures activity (decays per second).

43. (b) Neutrons
Explanation: Hadrons (e.g., neutrons) are composed of quarks.

44. (b) 8 months
Explanation: 3/4 decayed ⇒ 1/4 remains (2 half-lives). Total time = 4 months × 2 = 8 months.

45. (a) Alpha radiation
Explanation: Alpha particles (charged, heavy) interact strongly and have short range.

46. (c) Positron
Explanation: The positron (e^+) is the electron's antiparticle.

47. (a) 1/32

Explanation: After 5 half-lives, remaining = $\frac{1}{2^5} = \frac{1}{32}$.

48. (c) 172 and 69

Explanation: A: 180,72 → A_1:176,70 → A_2:176,71 → A_3:172,69 → A_4:172,69.

49. (c) 15/16

Explanation: After 4 half-lives (6400 years), fraction decayed = $1 - \frac{1}{16} = \frac{15}{16}$.

50. (c) s^{-1}

Explanation: Decay constant (λ) has units of per second.

SOLUTION PRACTICE TEST NO. 3

Answers and Explanations:

1. **(a) Curie**
2. **(d) 931 MeV**
3. **(c) Chadwick**
4. **(b) 6,4**
   Explanation: 6α (mass -24) and 4β (Z adjustment from 90→82).
5. **(c) May be unstable**
   Explanation: Daughter nuclei can be unstable and decay further.
6. **(c) No change in proton/neutron number**
   Explanation: Gamma emission involves energy release, not particle loss.
7. **(a)** $^{224}_{88}$Ra
   Explanation: Decay chain steps do not produce Ra-224.
8. **(d) Both a and b**
   Explanation: Alpha particles ionize heavily but penetrate poorly.
9. **(d)** 3.7×10^{10} dis/s
   Explanation: 1 Curie equals 3.7×10^{10} decays per second.
10. **(d) Both a and b**
    Explanation: $10\,\text{Gy} = 10\,\text{J/kg} = 1000\,\text{rad}$.
11. **(c)** $T_h = 0.693T_m$
    Explanation: Half-life $T_h = \frac{\ln 2}{\lambda}$, mean life $T_m = \frac{1}{\lambda}$.
12. **(c) 1:4**
    Explanation: After 80 min, A: $1/16$, B: $1/4$. Ratio $1/16 : 1/4 = 1:4$.
13. **(c) 25 mg**
    Explanation: After 2 half-lives (540 days), 100 mg → 25 mg.
14. **(b) Proton**
    Explanation: Proton mass ≈ 1.67×10^{-27} kg; others are lighter/massless.
15. **(c)** $1.97 \times 10^{-5}\,\text{s}^{-1}$
    Explanation: $\lambda = \frac{\ln 2}{9.75\times3600} \approx 1.97 \times 10^{-5}\,\text{s}^{-1}$.
16. **(b) 3:2**
    Explanation: After 48 hours, mass ratio = $\frac{3/16}{1/8} = 3:2$.
17. **(b) 4000**
    Explanation: ~4000 mSv causes ~60% mortality.
18. **(a) 1**
    Explanation: RBE for X-rays and γ-rays is 1; higher for α.
19. **(d) Absorbed dose**
    Explanation: Absorbed dose (Gy) quantifies energy deposited.
20. **(c)** m^2s^{-2}
    Explanation: $1\,\text{Gy} = 1\,\text{J/kg} = 1\,\text{m}^2/\text{s}^2$.
21. **(a) 10 mSv**
    Explanation: TV exposure is minimal; closest option given.
22. **(d) All of these**
    Explanation: Radiation can cause cancer, genetic defects, and cataracts.
23. **(a) Strong force**
    Explanation: Nuclear forces are strong interactions.
24. **(b) Inside nucleus**
    Explanation: Gamma rays originate from nuclear de-excitation.
25. **(b)** $N = A - Z$
    Explanation: Neutrons = Mass number (A) − Atomic number (Z).
26. **(b) Cancer**
    Explanation: Radiation is directly linked to cancer; "burning" and "flu" are not primary effects.
27. **(a) Fast moving electrons**
    Explanation: Beta particles are high-speed electrons emitted during β^- decay.
28. **(c) 0**
    Explanation: Gamma rays are neutral electromagnetic radiation.
29. **(b) UV**
    Explanation: Ozone absorbs and reflects harmful ultraviolet (UV) radiation.
30. **(b) 134**
    Explanation: Radon-220: Neutrons = 220 − 86 (atomic number) = 134.
31. **(b) 234,92**
    Explanation: Pu-238 (Z=94) emits α → mass -4, Z -2. New nucleus: U-234 (Z=92).
32. **(b) Electron**
    Explanation: Positrons have the same mass as electrons but opposite charge.
33. **(b) Hadrons**
    Explanation: Hadrons (e.g., protons, neutrons) are composed of quarks.
34. **(b)** 1.72×10^4 **years**
    Explanation: $3 \times 5730 = 17{,}190$ years ≈ 1.72×10^4.
35. **(a)** $7\alpha, 7\beta$
    Explanation: Th-238 → Pb-210: 7α (mass -28, Z -14) + 7β (Z +7) adjusts Z from 90 to 82.

36. **(b) Medical**
Explanation: Gamma radiographs are used in medical imaging.
37. **(c) 11 protons and 13 neutrons**
Explanation: Mass number 24 = protons (11) + neutrons (13).
38. **(c) Daughter nucleus has one proton more**
Explanation: β^- decay converts a neutron to a proton, increasing Z by 1.
39. **(d) Neutrino**
Explanation: Neutrinos are neutral; other particles have charge.
40. **(a) Becquerel**
Explanation: SI unit of radioactivity is Becquerel (Bq).
41. **(c)** $\frac{1}{8}$
Explanation: 3 half-lives → $\left(\frac{1}{2}\right)^3 = \frac{1}{8}$.
42. **(c) Neutron**
Explanation: Chadwick discovered the neutron in 1932.
43. **(a) Isobars**
Explanation: Beta decay changes atomic number, creating isobars (same mass number).
44. **(b) 70%**
Explanation: $T_{1/2} = 0.693\tau \approx 69.3\%$ of mean life.
45. **(d) Not affected (nuclear phenomenon)**
Explanation: Radioactivity is independent of physical/chemical changes.
46. **(b) +2e**
Explanation: Alpha particles are He^{2+}, charge +2e.
47. **(d) Radium and polonium**
Explanation: Marie and Pierre Curie discovered radium and polonium.
48. **(b) 10 s**
Explanation: $\frac{1}{64} = \left(\frac{1}{2}\right)^6$. Total time = 6 half-lives ⇒ $T_{1/2} = \frac{60}{6} = 10\,\text{s}$.
49. **(b)** $\frac{N_0}{2}$
Explanation: Activity $A = \lambda N$. If $A = \frac{A_0}{2}$, then $N = \frac{N_0}{2}$.
50. **(c) More than half of the active nuclei decay**
Explanation: After one mean life (τ), ~63% of nuclei decay, leaving ~37% undecayed.

SOLUTION PRACTICE TEST NO. 4

Answers and Explanations:

1. **(d) All of these**
2. **(b) One disintegration per second**
3. **(d) 0.01 J kg⁻¹**
4. **(d) All of these**
5. **(c)** $\frac{10^6}{\sqrt{2}}$
6. **(c) Atomic mass and number remain same, energy state changes**
7. **(d)** $Y = X$
8. **(b)** $A_1 = 4A_3$
9. **(a) Mean life**
10. **(a)** $D_e = D \times RBE$
11. **(c) 0.01 gray**
12. **(b) Gray**
13. **(c) 2 mSv**
14. **(a)** $D = \frac{E}{m}$
15. **(d) Relative biological effectiveness**
16. **(a) 1.5**
Explanation: Temporary low fertility is typically caused by an equivalent dose of around 1.5 Sv.
17. **(c) U**
Explanation: Uranium has more neutrons than protons (e.g., U-238 has 92 protons, 146 neutrons).
18. **(b) N-14**
Explanation: Beta decay of C-14 converts a neutron to a proton, forming Nitrogen-14.
19. **(b) 2**
Explanation: A neutron consists of one up quark and two down quarks.
20. **(d) 2.31 min**
Explanation: $T_{1/2} = \tau \times \ln 2 \approx 200 \times 0.693 \approx 138.6\,\text{s} \approx 2.31\,\text{min}$.
21. **(b) Cobalt-60**
Explanation: Cobalt-60 is widely used in radiotherapy for gamma radiation.
22. **(c) Half of decay**
Explanation: Half-life is the time for half the radioactive nuclei to decay.
23. **(b) 3200 years**
Explanation: 25g remaining after two half-lives: $1600 \times 2 = 3200$ years.
24. **(d) Pb**
Explanation: Lead (Pb) effectively shields gamma radiation due to its high density.
25. **(b) Neutron**
Explanation: Isotopes differ in neutron count while retaining the same atomic number.
26. **(b) 0.693/λ**
Explanation: Half-life formula: $T_{1/2} = \frac{\ln 2}{\lambda}$.
27. **(c) 143**
Explanation: Neutrons = $235 - 92 = 143$.
28. **(b) 8**
Explanation: Neutrons = $14 - 6 = 8$.
29. **(b) 1620 years**
Explanation: For the second material (half-life 810 years), $2 \times 810 = 1620$ years.
30. **(a) 12 g**
Explanation: After 12 minutes (one half-life), half of 24g remains: 12g.
31. **(a) Isotopes**
Explanation: Isotopes have the same Z (protons) but different A (neutrons).

32. (a) Quarks
Explanation: Protons and neutrons are composed of quarks.

33. (b) Bones
Explanation: Phosphorus is primarily absorbed by bones.

34. (c) 300 rem
Explanation: 300 rem (3 Sv) can cause radiation burns.

35. (c) Phosphorous 32
Explanation: P-32 is used for treating skin conditions.

36. (b) 10
Explanation: Absorbed dose $= \frac{1000\,\text{J}}{100\,\text{kg}} = 10$ Gy.

37. (a) 1 Gy x RBE
Explanation: Sievert = Gray × RBE.

38. (b)
Explanation: Doses ≤ 3 Sv (2-3 Sv) may not cause severe burns.

39. (d) $\pm$e
Explanation: Negative Beta particles (β^-) carry a charge of −e.
Positive Beta particles (β^+) carry a charge of +e.

40. (a) 23.5 min
Explanation: Uranium-239 has a short half-life of ~23.5 minutes.

41. (a) 1:4
Explanation: After 6 years, activity ratio ≈ 1:4 (simplified calculation based on decay factors).

42. (c) Nuclear transmutation
When a radioactive element emits radiation and transforms into a new element, the process is called nuclear transmutation.

43. (b) asX^{216}
Each α-particle emission reduces the mass number by 4 and atomic number by 2.
Each β-particle emission increases the atomic number by 1 (mass number unchanged).
Initial: asRa^{228} (Z=88, A=228).
After 3α: asX^{216} (Z=82, A=216).
After 1β: asX^{216} (Z=83, A=216).

44. (c) Beta
The nuclear reaction shows a neutron converting into a proton ($\frac{23}{27}$Th → $\frac{23}{4}$Pa), which is characteristic of β^- decay.

45. (d) All of these
Iodine is absorbed by the thyroid gland.
Phosphorus and strontium are absorbed by bones.
Cobalt is absorbed by the liver.

46. (b) Gray
The SI unit of absorbed dose is Gray (Gy), where 1 Gy = 1 J/kg.

47. (a) Becquerel
The activity of a radioactive source is measured in Becquerel (Bq), where 1 Bq = 1 decay per second.

48. (d) All of these
Radioactive radiations can ionize atoms, damage living tissues, and penetrate the body.

49. (a) $\frac{12}{6}C$ and $\frac{14}{6}C$
Both isotopes have the same atomic number (Z=6), meaning they contain the same number of protons.

50. (a) Constant
The product of half-life ($t_{1/2}$) and decay constant (λ) is $\ln(2)$, which is a constant (~0.693).

SOLUTION PRACTICE TEST NO. 5

Answers and Explanations:

1. (b) Smaller
In heavy elements, the number of neutrons exceeds the number of protons to stabilize the nucleus.

2. (c) -4
The nucleon number decreases by 4 due to the α-particle emission (mass number -4). β and γ emissions do not change the nucleon number.

3. (a) The same mass
All β-particles are electrons, so they have the same mass, but their speeds and energies vary.

4. (a) 140 days
The activity reduces to $\frac{1}{8}$ in 3 half-lives ($\frac{1}{2^3}$). Thus, $t_{1/2} = \frac{420}{3} = 140$ days.

5. (c) $\frac{208}{81}$
β^+ emission: Proton → Neutron, so Z decreases by 1 (82→81), but mass number (208) stays the same.
γ emissions do not change Z or A.
Final nuclide: $\frac{208}{81}$. (Note: The options seem inconsistent; likely a typo in the question.)

6. (c) One Becquerel
1 Bq = 1 decay per second.

7. (b) β-emission
In β-emission, a neutron dissociates into a proton, electron, and antineutrino.

8. (c) 7.6 days
Three-fourths decay means one-fourth remains, which is 2 half-lives ($\frac{1}{2^2}$). Thus, time = 2 × 3.8 = 7.6 days.

9. (d) Both B and C
Heavy nuclei have more neutrons than protons (to counter proton repulsion) and are more likely to undergo fission than fusion.

10. (b) 138 neutrons and 88 protons
Explanation: Radium-226 ($Z = 88$) has neutrons = $226 - 88 = 138$.

11. (d) 0.01 Sv
Explanation: 1 rem = 0.01 sievert.

12. (b) Liver
Explanation: Cobalt is primarily absorbed by the liver.

13. (d) 91, 234
Explanation: After α-decay (A=234, Z=90) followed by β-decay (Z=91), the resulting nuclide is ${}^{234}_{91}$Pa.

14. (b) 1 kg
Explanation: 72 days = 3 half-lives. Remaining = 8 × $(1/2)^3 = 1$ kg.

15. (a)
Explanation: 4α emissions reduce $A = 236$ to $236 - 16 = 220$, $Z = 92 - 8 = 84$.

16. (b) 2
Explanation: Nucleus contains protons and neutrons.

17. (a) $-\frac{\Delta N}{N}$
Explanation: Decay constant $\lambda = -\frac{\Delta N}{N \Delta t}$ (assuming Δt is implicit).

18. (c) 3%
Explanation: After 5 half-lives, remaining = $(1/2)^5 \approx 3\%$.

19. (c) 4 hours
Explanation: $1/16$ remaining = 4 half-lives. Half-life = $16/4 = 4$ hours.

20. (d) $\frac{1}{\sqrt{2}}$
Explanation: After 0.5 half-lives, fraction remaining = $\sqrt{1/2}$.

21. (a) $-\frac{1}{3}e$
Explanation: Strange quark charge is $-\frac{1}{3}e$.

22. (d) 99.9%
Explanation: Over 99.9% of an atom's mass is in the nucleus.

23. (d) 8 and 6
Explanation: $\Delta A = 32$ (8α) and $\Delta Z = 16$. Beta emissions adjust Z: 8α (Z↓16) + 6β (Z↑6) → net Z↓10.

24. (a) 10 days
Explanation: Reduction factor $16 = (1/2)^4 \Rightarrow 4$ half-lives. $40/4 = 10$ days.

25. (d)

26. (d) $\frac{1}{\sqrt{2}}$
Explanation: Same as Q20.

27. (b) Nuclear process does not depend on external factor
Explanation: Radioactivity is independent of external conditions.

28. (b) Un-decayed nuclei
Explanation: Activity $A = \lambda N$, proportional to undecayed nuclei.

29. (a) Three quarks
Explanation: Baryons (e.g., protons, neutrons) consist of three quarks.

30. (c) 7/8
Explanation: After 3 half-lives, decayed fraction = 1 − $(1/2)^3 = 7/8$.

31. (c) 20
Explanation: $1/8$ remaining = 3 half-lives. Half-life = 60 min$/3 = 20$ min.

32. (b) All the three α, β and γ one after another
Explanation: A nucleus may emit α or β particles followed by γ-rays during de-excitation.

33. (b) Maximum in α-particles
Explanation: α-particles have high mass and charge, leading to greater ionization.

34. (a) 0.4 Ci
Explanation: After 10 days (2 half-lives), activity reduces to $1.6 \rightarrow 0.8 \rightarrow 0.4$ Ci.

35. (d) 2/3
Explanation: 7/8 atoms of X decayed in three half-lives and 3/4 atoms of Y decayed in two half-lives.

$$3T_{1/2}(X) = 2T_{1/2}(Y)$$
$$\frac{T_{1/2}(X)}{T_{1/2}(Y)} = \frac{2}{3}$$

36. (a) 1.675×10^{-27} **kg**
Explanation: Neutron mass is approximately 1.675×10^{-27} kg.

37. (a) α-particle
Explanation: α-particles ionize most due to their high charge and mass.

38. (d) Is not affected by electric and magnetic field
Explanation: Radioactive decay is a nuclear process, independent of external fields.

39. (a) $Z - 6, A - 12$
Explanation: Each α-particle reduces A by 4 and Z by 2. Three α emissions reduce A by 12 and Z by 6.

40. (a) $1.007276u$
Explanation: Proton mass on the unified atomic mass scale.

41. (b) Absorbed dose
Explanation: Absorbed dose measures energy per unit mass (Gray).

42. (d) All of these
Explanation: High radiation causes sterility, death, and blood disorders.

43. (b) Has exponentially decreasing relationship with time
Explanation: Decay follows $N(t) = N_0 e^{-\lambda t}$.

44. (a) 8,9,0
Explanation: For ${}^{17}_{8}$O, protons = 8, neutrons = 9, electrons in nucleus = 0.

45. (c) $\lambda T = \log_2 2$
Explanation: Though technically $T_{1/2} = \ln 2/\lambda$, the closest option is $\lambda T = \log_2 2 = 1$.

46. (c) 235
Explanation: Nucleons (protons + neutrons) = mass number $A = 235$.

47. (a) Radioactive sodium-24
Explanation: Sodium-24 is used as a tracer in blood flow studies.

48. (c) 10
Explanation: Natural α-particles have an RBE of ~10-20.

49. (a) 1 mSv per week
Explanation: Safe limit for nuclear workers is ~1 mSv/week.

50. (b) 2.5
Explanation: Sterility for ~2 years occurs at ~2.5 Sv.

SOLUTION PRACTICE TEST NO. 6

Answers and Explanations:

1. (d) All of these
Explanation: Radiation effects depend on the type, energy, and body part exposed.

2. (d) Both A and B
Explanation: Low-level radiation can cause ulceration and stiffening of lungs.

3.

4. (b) Protons
Explanation: Isotopes share the same number of protons (atomic number).

5. (c) Sphere
Explanation: Nuclei are generally spherical.

6. (b) IR
Explanation: Greenhouse effect traps infrared (IR) radiation.

7. (c) No deflection
Explanation: Gamma rays are neutral and not deflected by electric fields.

8. (a) Directly proportional
Explanation: Decay rate is proportional to the initial number of nuclei.

9. (c) 0.27 Ci
Explanation: 10^{10} Bq $= \frac{10^{10}}{3.7\times10^{10}} \approx 0.27$ Ci.

10. (d) 25% (assuming "%" denotes 25%)
Explanation: After 40 hours (2 half-lives), 25% remains.

11. (c) Unchanged
Explanation: Gamma emission doesn't alter mass or atomic number.

12. (a) 12 g
Explanation: 36 minutes = 3 half-lives → 12g remains after 12 minutes (1 half-life).

13. (a) Mass
Explanation: Absorbed dose is energy per unit mass (Gy = J/kg).

14. (b) 10^6 Bq
Explanation: 1 rutherford = 10^6 Bq.

15. (b) Cancerous cells
Explanation: Radiation targets and destroys cancer cells.

16. (a) 0
Explanation: Electrons are fundamental particles (leptons), not composed of quarks.

17. (b) 414 days
Explanation: 12.5% remaining = 3 half-lives → $3 \times 138 = 414$ days.

18. (b) An isotope of the original one
Explanation: α + 2β emissions result in the same Z but reduced A, forming an isotope.

19. (b) Density
Explanation: Nuclear density remains constant regardless of mass number.

20. (b) Loss energy
Explanation: Gamma emission reduces nuclear energy without changing composition.

21. (a) Radioactivity
Explanation: Curie measures activity (decays per second).

22. (d) Ten gray
Explanation: 10 J/kg $= 10$ Gy.

23. (a) Becquerel
Explanation: Activity is measured in Becquerel (Bq) or Curie (Ci).

24. (c) γ-rays
Explanation: Cobalt-60 primarily emits gamma rays.

25. typing mistake

26. (d) Never
Explanation: Radioactive decay follows an exponential curve; thus, the Earth will never completely lose all radium.

27. (a) Greater than 82
Explanation: Elements with atomic number $Z > 82$ (e.g., uranium, radium) are naturally radioactive.

28. (c) $4\alpha, 1\beta$
Explanation: Mass difference: $228 - 212 = 16$. Adjusting for charge: Z reduces from 90 to 83. 4α (Z↓8) + 1β (Z↑1) gives net Z↓7.

29. (c) 93.75%
Explanation: After 4 half-lives (8 years), decayed fraction = $1 - \frac{1}{16} = 93.75\%$.

30. (b) 6.67×10^8
Mean life $\tau = \frac{1}{\lambda} = \frac{1}{1.5\times10^{-9}} \approx 6.67 \times 10^8$ s.

31. (c) Change in charge no. but not in mass no.
Explanation: Beta decay changes atomic number (Z) but leaves mass number (A) unchanged.

32. (a) 8 days
Explanation: Iodine-131 has a half-life of approximately 8 days.