JEE (Main) PHYSICS SOLVED PAPER

2023
31st Jan Shift 2

Section A

Q. 1. Given below are two statements:

Statement I: In a typical transistor, all three regions emitter, base and collector have same doping level.

Statement II: In a transistor, collector is the thickest and base is the thinnest segment.

In the light of the above statements, choose the most appropriate answer from the options given below.

(1) Both Statement I and Statement II are correct

(2) Statement I is incorrect but Statement II is correct

(3) Statement I is correct but Statement II is incorrect

(4) Both Statement I and Statement II are incorrect

Q. 2. If the two metals A and B are exposed to radiation of wavelength 350 nm. The work functions of metals A and B are 4.8 e V and 2.2 e V. Then choose the correct option.

(1) Both metals A and B will emit photo–electrons

(2) Metal A will not emit photo–electrons

(3) Metal B will not emit photo–electrons

(4) Both metals A and B will not emit photo–electrons

Q. 3. Heat energy of 735 J is given to a diatomic gas allowing the gas to expand at constant pressure. Each gas molecule rotates around an internal axis but do not oscillate. The increase in the internal energy of the gas will be:

(1) 525 J **(2)** 441 J **(3)** 572 J **(4)** 735 J

Q. 4. Match List I with List II

	List I		List II
A.	Angular momentum	I.	$[ML^2 T^{-2}]$
B.	Torque	II.	$[ML^{-2} T^{-2}]$
C.	Stress	III.	$[ML^2 T^{-1}]$
D.	Pressure gradient	IV.	$[ML^{-1} T^{-2}]$

Choose the correct answer from the options given below:

(1) A – III, B – I, C – IV, D – II

(2) A – II, B – III, C – IV, D – I

(3) A – IV, B – II, C – I, D – III

(4) A – I, B – IV, C – III, D – II

Q. 5. A stone of mass 1 kg is tied to end of a massless string of length 1 m. If the breaking tension of the string is 400 N, then maximum linear velocity, the stone can have without breaking the string, while rotating in horizontal plane, is:

(1) 40 m s^{-1} **(2)** 400 m s^{-1} **(3)** 20 m s^{-1} **(4)** 10 m s^{-1}

Q. 6. A microscope is focused on an object at the bottom of a bucket. If liquid with refractive index $\frac{5}{3}$ is poured inside the bucket, then microscope have to be raised by 30 cm to focus the object again. The height of the liquid in the bucket is:

(1) 12 cm **(2)** 50 cm **(3)** 18 cm **(4)** 75 cm

Q. 7. The number of turns of the coil of a moving coil galvanometer is increased in order to increase current sensitivity by 50%. The percentage change in voltage sensitivity of the galvanometer will be:

(1) 0% **(2)** 75% **(3)** 50% **(4)** 100%

Q. 8. A body is moving with constant speed, in a circle of radius 10 m. The body completes one revolution in 4 s. At the end of 3rd second, the displacement of body (in m) from its starting point is:

(1) 15π **(2)** $10\sqrt{2}$ **(3)** 30 **(4)** 5π

Q. 9. The H amount of thermal energy is developed by a resistor in 10 s when a current of 4 A is passed through it. If the current is increased to 16 A, the thermal energy developed by the resistor in 10 s will be:

(1) $\frac{H}{4}$ **(2)** 16 H **(3)** 4H **(4)** H

Q. 10. A long conducting wire having a current I flowing through it, is bent into a circular coil of N turns. Then it is bent into a circular coil of n turns. The magnetic field is calculated at the centre of coils in both the cases. The ratio of the magnetic field in first case to that of second case is:

(1) $n : N$ **(2)** $n^2 : N^2$ **(3)** $N^2 : n^2$ **(4)** $N : n$

Q. 11. A body weight W, is projected vertically upwards from earth's surface to reach a height above the earth which is equal to nine times the radius of earth. The weight of the body at that height will be:

(1) $\frac{W}{100}$ **(2)** $\frac{W}{91}$ **(3)** $\frac{W}{3}$ **(4)** $\frac{W}{9}$

Q. 12. The radius of electron's second stationary orbit in Bohr's atom is R. The radius of 3rd orbit will be:

(1) $\frac{R}{3}$ **(2)** 3R **(3)** 2.25R **(4)** 9R

Q. 13. A hypothetical gas expands adiabatically such that its volume changes from 08 litres to 27 litres. If the ratio of final pressure of the gas to initial pressure of the gas is $\frac{16}{81}$. Then the ratio of $\frac{C_p}{C_v}$ will be:

(1) $\frac{1}{2}$ **(2)** $\frac{4}{3}$ **(3)** $\frac{3}{2}$ **(4)** $\frac{3}{1}$

Q. 14. For a solid rod, the Young's modulus of elasticity is 3.2×10^{11} Nm^{-2} and density is 8×10^{3} kg m^{-3}. The velocity of longitudinal wave in the rod will be:
(1) 145.75×10^{3} ms^{-1} **(2)** 18.96×10^{3} ms^{-1}
(3) 3.65×10^{3} ms^{-1} **(4)** 6.32×10^{3} ms^{-1}

Q. 15. A body of mass 10 kg is moving with an initial speed of 20 m/s. The body stops after 5 s due to friction between body and the floor. The value of the coefficient of friction is: (Take acceleration due to gravity, $g = 10$ m s^{-2})
(1) 0.3 **(2)** 0.5 **(3)** 0.2 **(4)** 0.4

Q. 16. Given below are two statements:
Statement I: For transmitting a signal, size of antenna (l) should be comparable to wavelength of signal (at least $l = \frac{\lambda}{4}$ in dimension)
Statement II: In amplitude modulation, amplitude of carrier wave remains constant (unchanged). In the light of the above statements, choose the most appropriate answer from the options given below.
(1) Statement I is correct but Statement II is incorrect
(2) Both Statement I and Statement II are correct
(3) Statement I is incorrect but Statement II is correct
(4) Both Statement I and Statement II are incorrect

Q. 17. An alternating voltage source $V = 260\sin(628t)$ is connected across a pure inductor of 5 mH. Inductive reactance in the circuit is:
(1) 0.318 Ω **(2)** 6.28 Ω **(3)** 3.14 Ω **(4)** 0.5 Ω

Q. 18. Under the same load, wire A having length 5.0 m and cross section 2.5×10^{-5} m^2 stretches uniformly by the same amount as another wire B of length 6.0 m and a cross section of 3.0×10^{-5} m^2 stretches. The ratio of the Young's modulus of wire A to that of wire B will be:
(1) 1 : 1 **(2)** 1 : 10 **(3)** 1 : 2 **(4)** 1 : 4

Q. 19. Match List I with List II

	List I		List II
A.	Microwaves	I.	Physiotherapy
B.	UV rays	II.	Treatment of cancer
C.	Infra–red light	III.	Lasik eye surgery
D.	X–ray	IV.	Aircraft navigation

Choose the correct answer from the options given below:
(1) A – IV, B – III, C – I, D – II
(2) A – IV, B – I, C – II, D – III
(3) A – III, B – II, C – I, D – IV
(4) A – II, B – IV, C – III, D – I

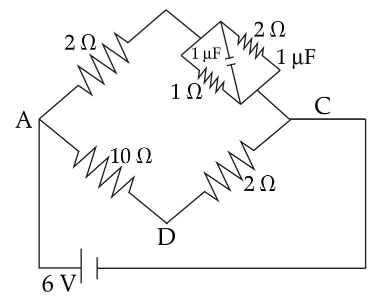
Q. 20. Considering a group of positive charges, which of the following statements is correct?
(1) Both the net potential and the net electric field cannot be zero at a point.
(2) Net potential of the system at a point can be zero but net electric field can't be zero at that point.
(3) Net potential of the system cannot be zero at a point but net electric field can be zero at that point.
(4) Both the net potential and the net field can be zero at a point.

Section B

Q. 21. A series LCR circuit consists of R = 80 Ω, X_L = 100 Ω, and X_C = 40 Ω. The input voltage is 2500 cos (100πt) V. The amplitude of current, in the circuit, is _____A.

Q. 22. Two bodies are projected from ground with same speeds 40 ms^{-1} at two different angles with respect to horizontal. The bodies were found to have same range. If one of the body was projected at an angle of 60°, with horizontal then sum of the maximum heights, attained by the two projectiles, is _____m. (Given $g = 10$ ms^{-2})

Q. 23. For the given circuit, in the steady state, $|V_B - V_D|$ = _____V.



Q. 24. Two parallel plate capacitors C_1 and C_2 each having capacitance of 10 μF are individually charged by a 100 V D.C. source. Capacitor C_1 is kept connected to the source and a dielectric slab is inserted between its plates. Capacitor C_2 is disconnected from the source and then a dielectric slab is inserted in it. Afterwards the capacitor C_1 is also disconnected from the source and the two capacitors are finally connected in parallel combination. The common potential of the combination will be ____V. (Assuming Dielectric constant = 10)

Q. 25. Two light waves of wavelengths 800 and 600 nm are used in Young's double slit experiment to obtain interference fringes on a screen placed 7 m away from plane of slits. If the two slits are separated by 0.35 mm, then shortest distance from the central bright maximum to the point where the bright fringes of the two wavelength coincide will be ______ mm.

Q. 26. A ball is dropped from a height of 20 m. If the coefficient of restitution for the collision between ball and floor is 0.5, after hitting the floor, the ball rebounds to a height of _____ m.

Q. 27. If the binding energy of ground state electron in a hydrogen atom is 13.6 e V, then, the energy required to remove the electron from the second excited state of Li^{2+} will be: $x \times 10^{-1}$ e V. The value of x is___.

Q. 28. A water heater of power 2000 W is used to heat water. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}. The efficiency of heater is 70%. Time required to heat 2 kg of water from 10°C to 60°C is _____s.

(Assume that the specific heat capacity of water remains constant over the temperature range of the water).

Q. 29. Two discs of same mass and different radii are made of different materials such that their thicknesses are 1 cm and 0.5 cm respectively. The densities of materials are in the ratio 3 : 5. The moment of inertia of these discs respectively about their diameters will be in the ratio of $\frac{x}{6}$. The value of x is ______.

Q. 30. The displacement equations of two interfering waves are given by $y_1 = 10\sin\left(\omega t + \frac{\pi}{3}\right)$ cm, $y_2 = 5[\sin \omega t + \sqrt{3}\cos \omega t]$ cm respectively. The amplitude of the resultant wave is _____ cm.

Answer Key

Q. No.	Answer	Topic Name	Chapter Name
1	(2)	Transistor	Semiconductors
2	(2)	Emissions of electrons	Photoelectric effect
3	(1)	Molar heat capacity	Kinetic theory of gases
4	(1)	Dimensional formula	Unit and dimensions
5	(3)	Centripetal force	Circular motion
6	(4)	Refraction	Ray optics
7	(1)	Moving coil galvanometer	Magnetism
8	(2)	Angular velocity	Circular motion
9	(2)	Heating effect of current	Electric current
10	(3)	Biot Savart law	Magnetic effect of current
11	(1)	Acceleration due to gravity	Gravitation
12	(3)	Hydrogen like atoms	Atoms
13	(2)	Thermodynamic processes	Thermodynamics
14	(4)	Wave speed	Waves
15	(4)	Friction	Newton's law of motion
16	(1)	Amplitude modulation	Communication system
17	(3)	Inductor in AC circuit	AC
18	(1)	Hook's law	Bulk property of matter
19	(1)	Electromagnetic spectrum	Electromagnetic waves
20	(3)	Electric field & potential	Electrostatics
21	[25]	RLC circuit in series	AC
22	[80]	Projectile motion	Motion in 2D
23	[1]	R C circuit	Capacitor
24	[55]	Dielectric	Capacitor
25	[48]	YDSE	Wave optics
26	[5]	Collision	Centre of mass
27	[136]	Binding energy	Atom
28	[300]	Heat & Temperature	Thermometry
29	[5]	Moment of inertia	Rotational mechanics
30	[20]	Resultant amplitude	Waves motion

SOLUTIONS

Section A

1. Option (2) is correct.

In a typical transistor, the middle layer called the base is very thin of the order of 1 μm as compared to the width of the two layers at the sides. And the collector is the thickest one.

Base is very lightly doped, Emitter is heavily doped and Collector is modestly doped.

From the above discription,

Statement – I is false and Statement – II is true.

2. Option (2) is correct.

For emissions of photons, $E = \dfrac{hc}{\lambda} \geq W$

Given, $\lambda = 350 \text{ nm} = 350 \times 10^{-9}$ m.

$W_A = 4.8$ e V $W_B = 2.2$ ev

Therefore $E = \dfrac{hc}{\lambda} = \dfrac{1240}{350} = 3.54$ eV

Since $W_A > E$ and $W_B < E$, Hence B will emit photo electrons while A will not.

3. Option (1) is correct.

Given, $Q = 735$ J

Process = Isobaric process (P = constant)

$\Delta U = ?$

We know that, at constant pressure

$Q = nC_P dT = 735$ ......(i)

The change in internet energy is given by

$\Delta U = nC_V dT$ ....(ii)

Dividing equation (i) by (ii), we get

$\Rightarrow \dfrac{735}{\Delta U} = \dfrac{C_p}{C_v}$

$\Rightarrow \dfrac{735}{\Delta U} = 1.4$ ($\because v = 1.4$, for diatomic gas)

$\Rightarrow \Delta U = \dfrac{735}{1.4}$

$\Rightarrow \Delta U = 525$ J

4. Option (1) is correct.

(A) Angular momentum (L) = $I\omega$

$\Rightarrow L = mR^2 \times \dfrac{V}{R} = mVR$

$\Rightarrow L = [M^1][L\,T^{-1}][L]$

$\Rightarrow L = [M^1 L^2 T^{-1}]$

(B) Torque (τ) $= RF\sin\theta$

$\Rightarrow \tau = [L^1][M^1 L^1 T^{-2}]$

($\because \sin\theta$ is dimensionless)

$\Rightarrow \tau = [M^1 L^2 T^{-2}]$

(C) Stress (σ) $= \dfrac{\text{Force}}{\text{Area}}$

$\Rightarrow \sigma = \dfrac{F}{A} = \dfrac{[M^1 L^1 T^{-2}]}{[L^2]}$

$\Rightarrow \sigma = [M^1 L^{-1} T^{-2}]$

(D) Pressure gradient $= \dfrac{\text{Pressuse difference}}{\text{Horizontal distance}}$

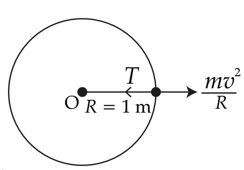
$\Rightarrow$ Pressure gradient $= \dfrac{dP}{dx}$

$\Rightarrow$ Pressure gradient $= \dfrac{[M L^{-1} T^{-2}]}{[L]} = [M^1 L^{-2} T^{-2}]$

5. Option (3) is correct.

Given, $R = 1$ m

$T_{max} = 400$ N



In circular motion

Centripetal force

= Centrifugal force

$\Rightarrow T = \dfrac{mV^2}{R}$

$\Rightarrow 400 = \dfrac{1 \times V^2}{1}$

$\Rightarrow V^2 = 400$

$\Rightarrow V = \sqrt{400} = 20 \text{ m s}^{-1}$

6. Option (4) is correct.

Given, refractive index of liquid, $\mu = \dfrac{5}{3}$

Let real depth of object $= h$

appaerent depth of object $= h'$

We know that, $\mu = \dfrac{\text{real depth}}{\text{apparent depth}}$

Shift in microscope $= h - h'$

$30 = h - \dfrac{3}{5}h'$

$h = 30 \times \dfrac{5}{2} = 75$ cm

Height of liquid column will be 75 cm.

7. Option (1) is correct.

Current sensitivity of galvanometer $\dfrac{Q}{i} = \dfrac{NAB}{K}$

No. of turns increased by 50% $N^1 = \dfrac{3}{2}N$

As the number of turns increases, current sensitivity also increases.

Now the voltage sensitivity of galvanometer is given by,

$\dfrac{Q}{V} = \dfrac{Q}{i\,G_r} = \dfrac{NAB}{KG_r}$ ($\because V = i\,G_r$)

where, G_r = Resistance of galvanometer.

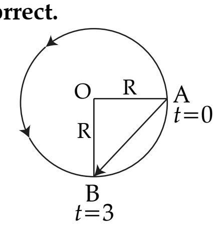
As N increases, the length of wire increases, which increases the galvanic resistance. The percentage change in N is equal to the percentage change in G_r

$\dfrac{Q}{V} = \dfrac{NAB}{K\,G_r}$

$\boxed{\begin{matrix} N\uparrow \\ G_r\uparrow \end{matrix}}$

So, there would not be any change in voltage sensitivity.

8. Option (2) is correct.



Given., $R = 10$ m

$T = 4$ s

Angular velocity, $\omega = \dfrac{2\pi}{T} = \dfrac{2\pi}{4} = \dfrac{\pi}{2}$ rad s^{-1}

Now the angular displacement in 3 s,

$\theta = \omega \times t = \dfrac{\pi}{2} \times 3 = \dfrac{3\pi}{2}$

After time t = 3 sec, the object is at point B.

Now the displacement = $|\overline{AB}|$

From ΔOAB

$$AB = \sqrt{(OA)^2 + (OB)^2}$$
$$= \sqrt{(10)^2 + (10)^2}$$
$$= \sqrt{100 + 100}$$
$$= \sqrt{200} = 10\sqrt{2} \text{ m}$$

9. Option (2) is correct.

Heat developed by a resistor is given by

$$H = i^2Rt$$

Given, $i_1 = 4$ A

$t_1 = t_2 = 10$ s

$H_1 = H$

$H_2 = ?$

According to the question,

$$H_1 = i_1Rt_1$$
$$\Rightarrow H = (4)^2 \times R \times 10$$
$$\Rightarrow H = 160R \quad \text{.... (i)}$$

Now $H_2 = i_2^2 R\, t_2$

$$\Rightarrow H_2 = (16)^2 \times R \times 10$$
$$\Rightarrow H_2 = 16 \times 160\, R$$
$$\Rightarrow H_2 = 16 \times H$$

10. Option (3) is correct.

Let the length of wire is l.

If the wire is bent into circular loop of N turns, then the length of N loops will be N $\times$ $2\pi R_1$

where, R_1 is the radius of one circular loop

& if the same wire is bent in n turns of circular loop, then $l = n2\pi R_2$

where, R_2 is the radius of the one circular loop

Now the magnetic field due to circular loop at the center is

$$B = \mu_0 \frac{ni}{2R}$$

Here, the magnetic field due to N loop of coil is

$$B_1 = \mu_0 \frac{Ni}{2R_1} \quad \text{.... (i)}$$

Similarly,

$$B_2 = \mu_0 \frac{n\,i}{2R_2} \quad \text{... (ii)}$$

Dividing (i) by (ii), we get

$$\Rightarrow \frac{B_1}{B_2} = \frac{\mu_0 \frac{Ni}{2R_1}}{\mu_0 \frac{n\,i}{2R_2}} \Rightarrow \frac{B_1}{B_2} = \frac{N}{n}\frac{R_2}{R_1}$$

Since, $l = N \times 2\pi R_1 = n \times 2\pi R_2$

Therefore $\frac{R_2}{R_1} = \frac{N}{n}$

$$\Rightarrow \frac{B_1}{B_2} = \frac{N}{n} \times \frac{N}{n} = \left(\frac{N}{n}\right)^2 \Rightarrow \frac{B_1}{B_2} = \left(\frac{N}{n}\right)^2$$

11. Option (1) is correct.

Effective acceleration at height h above the earth surface,

$$g' = \frac{g}{\left(1 + \frac{h}{R}\right)^2}$$

$$\Rightarrow g' = \frac{g}{\left(1 + \frac{9R}{R}\right)^2} \quad (\because h = 9\text{R, given})$$

$$\Rightarrow g' = \frac{g}{(10)^2} = \frac{g}{100}$$

Since gravity is getting reduced by 100 times hence weight will also reduce by 100 times. i.e.

$$W = mg' = \frac{mg}{100} = \frac{W}{100}$$

12. Option (3) is correct.

Radius of the orbit in Bohr's atom is given by.

$$R_n = \frac{\varepsilon_0 n^2 h^2}{\pi\, m\, Z\, e^2} = \frac{n^2}{Z} r_0 \Rightarrow r_n \propto \frac{n^2}{Z}$$

Hence $\frac{r_3}{r_2} = \frac{3^2}{2^2} = \frac{9}{4}$

$$\Rightarrow r_3 = 2.25 r_2$$

13. Option (2) is correct.

Given,

$V_1 = 8L$

$V_2 = 27L$

$\frac{P_2}{P_1} = \frac{16}{81}$

In adiabatic process

$$PV^\gamma = \text{constant}$$
$$\Rightarrow P_1V_1^{\gamma} = P_2V_2^{\gamma}$$
$$\Rightarrow \left(\frac{V_1}{V_2}\right)^\gamma = \frac{P_2}{P_1} \Rightarrow \left(\frac{8}{27}\right)^\gamma = \frac{16}{81}$$
$$\Rightarrow \left(\frac{2}{3}\right)^{3\gamma} = \left(\frac{2}{3}\right)^4$$
$$\Rightarrow 3\gamma = 4 \Rightarrow \gamma = \frac{4}{3} = \frac{C_P}{C_V}$$

14. Option (4) is correct.

Given: $\gamma = 3.2 \times 10^{11}$ N m^{-2}

$P = 8 \times 10^{3}$ kg m^{-3}

$V = ?$

Speed of longitudinal wave in a thin rod or wire is given by

$$V = \sqrt{\frac{\gamma}{P}}$$
$$V = \sqrt{\frac{3.2 \times 10^{11}}{8 \times 10^3}} = \sqrt{0.4 \times 10^8}$$
$$\Rightarrow V = \sqrt{40 \times 10^6} = 6.32 \times 10^3 \text{ m s}^{-1}$$

15. Option (4) is correct.

Given $m = 10$ kg, $u = 20$ m s^{-1}

$v = 0$ m s^{-1}, $t = 5$ s, $\mu = ?$

Using first equation of motion

$$a = \frac{v-u}{t}$$

$$\Rightarrow \quad a = \frac{0-20}{5} = -4 \text{ m s}^{-2}$$

Now the force causing this acceleration will be

$$F = ma = 10 \times -4 = -40 \text{ N}$$

This force is equal to friction force

$$f = F$$

$$\Rightarrow \quad \mu mg = 40$$

$$\Rightarrow \quad \mu = \frac{40}{mg} = \frac{40}{10} = 0.4$$

16. Option (1) is correct.

The length of antenna is inversely proportional to the frequency and directly proportional to wavelength. When the length of antenna is $1\frac{1}{4}^{th}$ of the wavelength, The transmission and reception conversion efficiency of antenna is maximum.

Therefore first statement is correct.

In amplitude modulation, the amplitude of the carrier signal varies in accordance with the information signal.

Therefore statement II is incorrect.

17. Option (3) is correct.

Given,
$$V = 260\sin(628t)$$
$$L = 5 \text{ mH} = 5 \times 10^{-3} \text{ H}$$
$$X_L = ?$$

Comparing the instantaneous voltage with general formula

$$V = V_0 \sin \omega t \quad \text{..... (i)}$$
$$V = 260\sin(628t) \quad \text{..... (ii)}$$

From (i) & (ii) $\quad \omega = 628$

Now inducting reactance of inductor is

$$X_L = \omega L = 628 \times 5 \times 10^{-3}$$
$$X_L = 3.14\ \Omega$$

18. Option (1) is correct.

Given:
$$l_A = 5 \text{ m}$$
$$A_A = 2.5 \times 10^{-5} \text{ m}^2$$
$$l_B = 6 \text{ m}$$
$$A_B = 3 \times 10^{-5} \text{ m}^2$$
$$F_A = F_B = F$$
$$\Delta l_A = \Delta l_B = \Delta l$$

Applying Hook's law,

$$\Rightarrow \quad \frac{F}{A} = Y\frac{\Delta l}{l}$$

$$\Rightarrow \quad F = \frac{Y\,\Delta l\,A}{l} \quad \text{...(i)}$$

Putting the values in above equation,

$$\frac{F_A}{F_B} = \frac{\dfrac{Y_A \Delta l_A A_A}{l_A}}{\dfrac{Y_B \Delta l_B A}{l_B}}$$

$$\Rightarrow \quad \frac{Y_B \Delta l_A A_B}{l_B} = \frac{Y_A \Delta l_A A_A}{l_A}$$

$$(\because F_A = F_B = F \ \& \ \Delta l_B = \Delta l_A = \Delta l)$$

$$\Rightarrow \quad \frac{Y_B A_B}{l_B} = \frac{Y_A A_A}{l_A} \Rightarrow \frac{Y_A}{Y_B} = \frac{l_A \times A_B}{l_B \times A_A}$$

$$\Rightarrow \quad \frac{Y_A}{Y_B} = \frac{5}{6} \times \frac{3 \times 10^{-5}}{2.5 \times 10^{-5}} \Rightarrow \frac{Y_A}{Y_B} = \frac{1}{1}$$

19. Option (1) is correct.

(A) **Microwave:** Microwave is considered suitable for radar system because they have short wavelength.

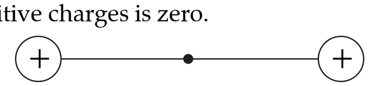
(B) **UV Rays:** LASIK uses UV laser to remove a thin layer of corneal tissues.

(C) **Infrared light:** Infrared radiation physiotherapy is an innovative therapy that is used to manage acute or chronic pain in patients.

(D) **X-ray:** X-ray are higher energy radiations used in the treatment of cancer cells.

20. Option (3) is correct.

Electric field is a vector quantity and its value could be zero because of group of +ve charges. For example, Electric field at the mid point of line joining two positive charges is zero.



But the potential is a scalar quantity and due to group of +ve charges it would be never zero as it would be added algebraically.

Section B

21. The correct answer is [25].

Given:
$$R = 80\ \Omega$$
$$X_L = 100\ \Omega$$
$$X_C = 40\ \Omega$$
$$V = 2500\cos(100\pi t) \text{ V}$$
$$V_0 = 2500 \text{ V}$$

Modulus of impedance in R-L-C series circuit is given by $\quad V_0 = 2500$ V

$$|Z| = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\Rightarrow \quad |Z| = \sqrt{(80)^2 + (100-40)^2}$$

$$\Rightarrow \quad |Z| = \sqrt{6400 + 3600} = \sqrt{10000}$$

$$\Rightarrow \quad |Z| = 100\ \Omega$$

Now, $\quad I_0 = \dfrac{V_0}{|Z|}$

$$\Rightarrow \quad I_0 = \frac{2500}{100} = 25 \text{ A}$$

22. The correct answer is [80].

Given:
$$u_1 = u_2 = u = 40 \text{ m s}^{-1}$$
$$R_1 = R_2 = R$$
$$\theta_1 = 60^0$$

For a given value of u, range at θ and $(90 - \theta)$ are equal

Here, $\quad \theta_2 = 90^0 - 60^0 = 30^0$

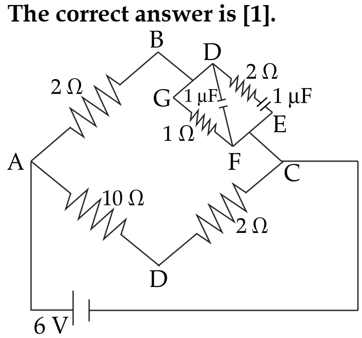
maximum height of projectile is given by

$$H = \frac{u^2 \sin^2\theta}{2g}$$

So, $$H_1 + H_2 = \frac{u^2 \sin^2\theta_1}{2g} + \frac{u^2\sin^2\theta_2}{2g}$$

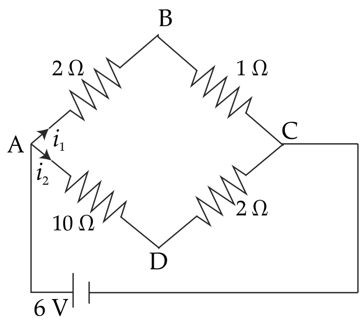
$\Rightarrow$ $$H_1 + H_2 = \frac{u^2}{2g}\left(\sin^2\theta_1 + \sin^2\theta_2\right)$$
$$= \frac{(40)^2}{2\times 10}\times\left(\sin^2 60^0 + \sin^2 30^0\right)$$
$$= \frac{1600}{20}\times\left(\frac{3}{4}+\frac{1}{4}\right)$$
$$= 80 \times 1 = 80 \text{ m}$$

23. The correct answer is [1].



In steady state the current will flow through 1 Ω resistance as DF & DE becomes open.

Now the circuit can be drawn like this:



Let i_1 current following in ABC and i_2 in ADC line.

R_e across ABC line is 2 + 1 = 3 Ω

V across ABC line = 6 V

$$i_1 = \frac{V}{R_e} = \frac{6}{3} = 2 \text{ A}$$

Now R_e' across line ADC is 10 + 2 = 12 Ω

$$i_2 = \frac{V}{R_e} = \frac{6}{12} = \frac{1}{2} \text{ A}$$

Thus, $V_A - V_B = i_1 R_{AB}$
$= 2\times 2 = 4$

$\Rightarrow$ $6 - V_B = 4$

$\Rightarrow$ $V_B = 2$ V

Now, $V_A - V_D = i_2$

$$R_{AD} = \frac{1}{2}\times 10 = 5$$

$\Rightarrow$ $6 - V_D = 5$

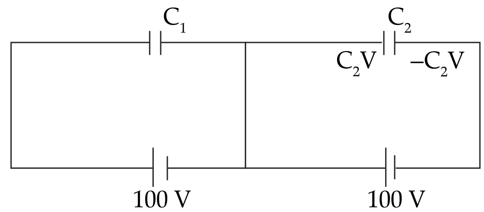
$\Rightarrow$ $V_D = 1$ V

$\therefore$ $V_B - V_D = 2 - 1 = 1$ V

24. The correct answer is [55].

Given $C_1 = C_2 = 10\ \mu$F
$V = 100$ V & $K = 10$

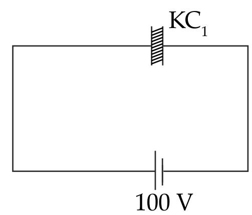
Let's take two individual parallel plate capacitors



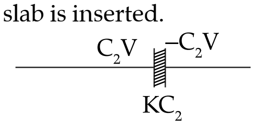
(i) (ii)

Charge on each plate of (ii) capacitor is $+C_2V$ and $-C_2V$ respectively

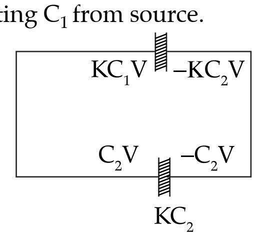
Afterwards, dielectric slab is inserted in C_1.



Afterwards C_2 is disconnected from the source and then dielectic slab is inserted.



Finally both the capacitors are connected in parallel by disconnecting C_1 from source.



Applying charge conservation, $Q_1 = Q_2$

$$KC_1V + C_2V = (KC_1V + KC_2)V_{\text{common}}$$

$$V_{\text{common}} = \frac{(K+1)CV}{2KC} = \frac{K+1}{2K}.V$$

$\Rightarrow$ $$V_{\text{common}} = \frac{10+1}{2\times 10}\times 100$$

$\Rightarrow$ $V_{\text{common}} = 55$ V

25. The correct answer is [48].

Given: $D = 7$ m
$d = 0.35$ mm $= 0.35\times 10^{-3}$ m
$\lambda_1 = 800\times 10^{-9}$ m
$\lambda_2 = 600\times 10^{-9}$ m

Let n_1 is the number of bright fringe of first wave of wave length λ_1 from central maximum coincide with n_2, the number of bright fringe of second wave of wave length λ_2 from central maxima.

Mathematically,

$$y = \frac{n\lambda D}{d} \quad \text{....(i)}$$

where, y is same for both the waves as they coincide

$\therefore \quad y = \frac{n_1\lambda_1 D}{d} = \frac{n_2\lambda_2 D}{d}$

$\Rightarrow \quad \frac{n_1}{n_2} = \frac{\lambda_1}{\lambda_2} = \frac{600\times10^{-9}\,\text{m}}{800\times10^{-9}\,\text{m}}$

$\Rightarrow \quad \frac{n_1}{n_2} = \frac{3}{4}$

Therefore 3rd maxima of λ_1 and 4th maxima of λ_2 will concide.

Putting the value of $\lambda_1 = 3$ in eq. (i), we get

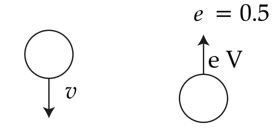
$$\gamma = \frac{3\times800\times10^{-9}\times7}{35\times10^{-5}}$$

$\Rightarrow \quad \gamma = 3\times160\times10^{-4}$ m

$\Rightarrow \quad \gamma = 48$ mm

26. The correct answer is [5].

Given: $h = 20$ m
$u = 0$
$e = 0.5$



Velocity of ball just before collision

$$v^2 = u^2 + 2gh$$

$\Rightarrow \quad V = \sqrt{2gh} = \sqrt{2\times10\times20} = 20\ \text{m s}^{-1}$

Velocity after collision

$$V_f = \text{e V} = 0.5\times20 = 10\ \text{m s}^{-1}$$

The maximum height reached after collision

$$h = \frac{v^2 - u^2}{2g} = \frac{(10)^2}{2\times10} = \frac{100}{20} = 5\ \text{m}$$

27. The correct answer is [136].

Energy required to remove the electron from the n^{th} exited state is given by

$$E = 13.6\times\frac{Z^2}{n^2} \qquad ...(i)$$

where,

Atomic no. $(Z) = 3$

Second exited state $(n) = 3$

Substituting above values in eq. (i),

$$E = 13.6\times\frac{Z^2}{n^2} = 13.6\times\frac{3^2}{3^2}$$

$\Rightarrow \quad E = 136\times10^{-1}$ e V

28. The correct answer is [300].

Given:

$P_{rated} = 2000$ W, $\quad \eta = 70\%$

$s = 4200\ \text{J Kg}^{-1}\text{K}^{-1}$, $\quad m = 2$ kg

$T_1 = 10°\text{C}$, $\quad T_2 = 60°\text{C}$

Power used $= P_{\text{rated}}\times\eta$

$\Rightarrow \quad P_{\text{used}} = 2000\times\frac{700}{1000} = 1400$ W

Heat required to change temperature

$$Q = m\Delta T$$

$$= 2\times4200\times(60-10) = 42\times10^4\ \text{J}$$

Now

$$P_{\text{used}} = \frac{Q}{t}$$

$\Rightarrow \quad t = \frac{Q}{P_{\text{used}}} = \frac{420000}{1400} = 300\ s$

29. The correct answer is [5].

Given, $M_1 = M_2$

$t_1 = 1\text{ cm} = 1\times10^{-2}$ m

$t_2 = 0.5\text{ cm} = 0.5\times10^{-2}$ m

$\frac{\rho_1}{\rho_2} = \frac{3}{5}$

According to the question,

$M_1 = M_2$

$\Rightarrow \quad \rho_1 V_1 = \rho_2 V_2 \qquad (\because M = \rho V)$

$\Rightarrow \quad \rho_1\pi r_1^2 t_1 = \rho_1\pi r_2^2 t_2$

$\Rightarrow \quad \frac{r_1^2}{r_2^2} = \frac{\rho_2 t_2}{\rho_1 t_1}$

$\Rightarrow \quad \frac{r_1^2}{r_2^2} = \frac{5}{3}\times\frac{0.5\times10^{-2}}{1\times10^{-2}}$

$\Rightarrow \quad \frac{r_1^2}{r_2^2} = \frac{5}{6}$

Moment of inertia of a circular disc about its diameter

$$I = \frac{MR^2}{4}$$

$\therefore \quad \frac{I_1}{I_2} = \frac{\frac{M_1 r_1^2}{4}}{\frac{M_2 r_2^2}{4}} \qquad (\because M_1 = M_2)$

$\Rightarrow \quad \frac{I_1}{I_2} = \frac{r_1^2}{r_2^2} = \frac{5}{6}$

30. The correct answer is [20].

The displacement equation of two waves are

$$y_1 = 10\sin\left(\omega t + \frac{\pi}{3}\right) \qquad \ldots (i)$$

& $\quad y_2 = 5\left(\sin\omega t + \sqrt{3}\cos\omega t\right)$

$\Rightarrow \quad y_2 = 5\times2\left(\frac{1}{2}\sin\omega t + \frac{\sqrt{3}}{2}\cos\omega t\right)$

$\Rightarrow \quad y_2 = 10\left(\cos\frac{\pi}{3}.\sin\omega t + \sin\frac{\pi}{3}\cos\omega t\right)$

$\Rightarrow \quad y_2 = 10\sin\left(\omega t + \frac{\pi}{3}\right) \qquad \ldots. (ii)$

From (i) & (ii) we conclude that y_1 and y_2 are in same phase Therefore, Resultant amplitude,

$A_r = A_1 + A_2$

$= 10 + 10$

$= 20$ cm.