JEE (Main) PHYSICS SOLVED PAPER

2021

24^{th} February Shift 1

Time : 1 Hour **Total Marks : 100**

General Instructions :

1. *In Chemistry Section, there are 30 Questions (Q. no. 1 to 30).*
2. *In Chemistry, Section A consists of 20 multiple choice questions & Section B consists of 10 numerical value type questions. In Section B, candidates have to attempt any five questions out of 10.*
3. *There will be only one correct choice in the given four choices in Section A. For each question for Section A, 4 marks will be awarded for correct choice, 1 mark will be deducted for incorrect choice questions and zero mark will be awarded for not attempted question.*
4. *For Section B questions, 4 marks will be awarded for correct answer and zero for unattempted and incorrect answer.*
5. *Any textual, printed or written material, mobile phones, calculator etc. is not allowed for the students appearing for the test.*
6. *All calculations / written work should be done in the rough sheet is provided with Question Paper.*

Physics

Section A

Q. 1. Four identical particles of equal masses 1 kg made to move along the circumference of a circle of radius 1 m under the action of their own mutual gravitational attraction. The speed of each particle will be :

(1) $\sqrt{\frac{(1+2\sqrt{2})G}{2}}$ **(2)** $\sqrt{G(1+2\sqrt{2})}$

(3) $\sqrt{\frac{G}{2}(2\sqrt{2}-1)}$ **(4)** $\sqrt{\frac{G}{4}(1+2\sqrt{2})}$

Q. 2. Consider two satellites S_1 and S_2 with periods of revolution 1 hr, and 8 hr, respectively revolving around a planet in circular orbits. The ratio of angular velocity of satellite S_1 to the angular velocity of satellite S_2 is

(1) 8 : 1 **(2)** 1 : 8

(3) 2 : 1 **(4)** 1 : 4

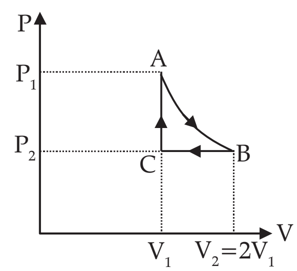
Q. 3. n mole of a perfect gas undergoes a cyclic process ABCA (see figure) consisting of the following processes –

$A \rightarrow B$: Isothermal expansion at temperature T so that the volume is doubled from V_1 to $V_2 = 2V_1$ and pressure changes from P_1 to P_2.

$B \rightarrow C$: Isobaric compression at pressure P_2 to initial volume V_1.

$C \rightarrow A$: Isochoric change leading to change of pressure from P_2 to P_1.

Total workdone in the complete cycle ABCA is :



(1) 0 **(2)** $nRT\left(\ln 2+\frac{1}{2}\right)$

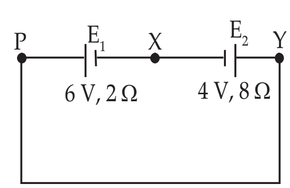
(3) $nRT \ln 2$ **(4)** $nRT\left(\ln 2-\frac{1}{2}\right)$

Q. 4. Two equal capacitors are first connected in series and then in parallel. The ratio of the equivalent capacities in the two cases will be :

(1) 2 : 1 **(2)** 1 : 4

(3) 4 : 1 **(4)** 1 : 2

Q. 5. A cell E_1 of emf 6 V and internal resistance 2 Ω is connected with another cell E_2 of emf 4 V and internal resistance 8 Ω (as shown in the figure). The potential difference across points X and Y is



(1) 3.6 V **(2)** 10.0 V
(3) 5.6 V **(4)** 2.0 V

Q. 6. If Y, K and η are the values of Young's modulus, bulk modulus and modulus of rigidity of any material respectively. Choose the correct relation for these parameters.

(1) $K = \frac{Y\eta}{9\eta - 3Y} N/m^2$

(2) $\eta = \frac{3YK}{9K + Y} N/m^2$

(3) $Y = \frac{9K\eta}{3K - \eta} N/m^2$

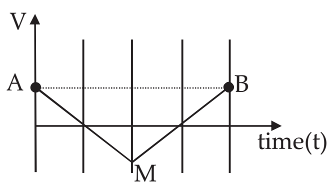
(4) $Y = \frac{9K\eta}{2\eta + 3K} N/m^2$

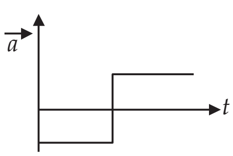
Q. 7. Two stars of masses *m* and 2*m* at a distance *d* rotate about their common centre of mass in free space. The period of revolution is

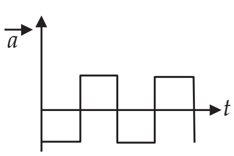
(1) $2\pi\sqrt{\frac{d^3}{3Gm}}$ **(2)** $\frac{1}{2\pi}\sqrt{\frac{3Gm}{d^3}}$

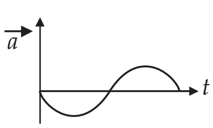
(3) $\frac{1}{2\pi}\sqrt{\frac{d^3}{3Gm}}$ **(4)** $2\pi\sqrt{\frac{3Gm}{d^3}}$

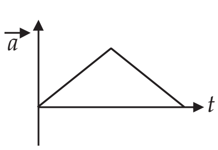
Q. 8. If the velocity-time graph has the shape AMB, what would be the shape of the corresponding acceleration-time graph ?



(1) 

(2) 

(3) 

(4) 

Q. 9. Given below are two statements :

Statement – I: Two photons having equal linear momenta have equal wavelengths.

Statement-II: If the wavelength of photon is decreased, then the momentum and energy of a photon will also decrease.

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

(1) Statement-I is false but Statement-II is true
(2) Both Statement-I and Statement-II are true
(3) Both Statement-I and Statement-II are false
(4) Statement-I is true but Statement-II is false

Q. 10. A current through a wire depends on time as $i = \alpha_0 t + \beta t^2$

Where α_0 = 20 A/s and β = 8 As^{-2}. Find the charge crossed through a section of the wire in 15 s.

(1) 2100 C **(2)** 260 C
(3) 2250 C **(4)** 11250 C

Q. 11. Match List I with List II

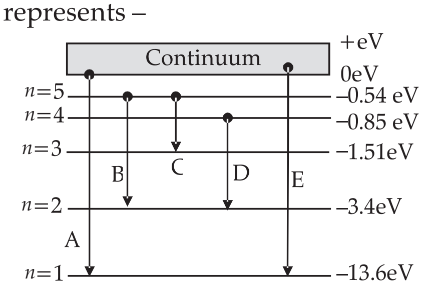
List-I	List-II
(a) Isothermal	(i) Pressure constant
(b) Isochoric	(ii) Temperature constant
(c) Adiabatic	(iii) Volume constant
(d) Isobaric	(iv) Heat content is constant

Choose the correct answer from the options given below :

(1) (a) – (ii), (b) – (iv), (c) – (iii), (d) – (i)
(2) (a) – (ii), (b) – (iii), (c) – (iv), (d) – (i)
(3) (a) – (i), (b) – (iii), (c) – (ii), (d) – (iv)
(4) (a) – (iii), (b) – (ii), (c) – (i), (d) – (iv)

Q. 12. In the given figure, the energy levels of hydrogen atom have been shown along with some transitions marked A, B, C, D and E.

The transitions A, B and C respectively represents –



(1) The series limit of Lyman series, third member of balmer series and second member of paschen series

(2) The first member of the Lyman series, third member of Balmer series and second member of paschen series

(3) The ionization potential of hydrogen, second member of Balmer series and third member of Paschen series

(4) The series limit of Lyman series, second member of Balmer series and second member of Paschen series.

Q. 13. The focal length f is related to the radius of curvature r of the spherical convex mirror by

(1) $f = r$ **(2)** $f = -\frac{1}{2}r$

(3) $f = +\frac{1}{2}r$ **(4)** $f = -r$

Q. 14. Moment of inertia (M.I.) of four bodies, having same mass and radius, are reported as:

I_1 = M.I. of thin circular ring about its diameter,

I_2 = M.I. of circular disc about an axis perpendicular to disc and going through the centre,

I_3 = M.I. of solid cylinder about its axis and

I_4 = M.I. of solid sphere about its diameter.

Then –

(1) $I_1 = I_2 = I_3 < I_4$ **(2)** $I_1 + I_2 = I_3 + \frac{5}{2}I_4$

(3) $I_1 + I_3 < I_2 + I_4$ **(4)** $I_1 = I_2 = I_3 > I_4$

Q. 15. The workdone by a gas molecule in an isolated system is given by, $W = \alpha\beta^2 e^{-\frac{x^2}{\alpha kT}}$, where x is the displacement, k is the Boltzmann constant and T is the temperature. α and β are constants. Then the dimensions of β will be:

(1) $[M^0LT^0]$ **(2)** $[M^2LT^2]$

(3) $[MLT^{-2}]$ **(4)** $[ML^2T^{-2}]$

Q. 16. If an emitter current is changed by 4 mA, the collector current changes by 3.5 mA. The value of β will be:

(1) 7 **(2)** 0.875

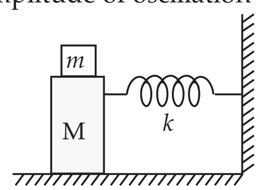
(3) 0.5 **(4)** 3.5

Q. 17. In a Young's double slit experiment, the width of the one of the slit is three times the other slit. The amplitude of the light coming from a slit is proportional to the slit-width. Find the ratio of the maximum to the minimum intensity in the interference pattern.

(1) 4 : 1 **(2)** 2 : 1

(3) 3 : 1 **(4)** 1 : 4

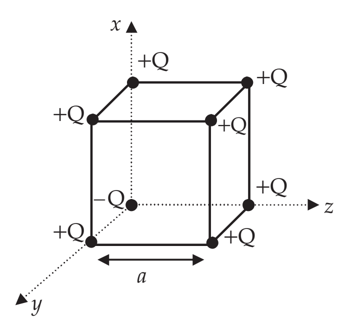
Q. 18. In the given figure, a mass M is attached to a horizontal spring which is fixed on one side to a rigid support. The spring constant of the spring is k. The mass oscillates on a frictionless surface with time period T and amplitude A. When the mass is in equilibrium position, as shown in the figure, another mass m is gently fixed upon it. The new amplitude of oscillation will be:



(1) $A\sqrt{\frac{M}{M+m}}$ **(2)** $A\sqrt{\frac{M}{M-m}}$

(3) $A\sqrt{\frac{M-m}{M}}$ **(4)** $A\sqrt{\frac{M+m}{M}}$

Q. 19. A cube of side 'a' has point charges +Q located at each of its vertices except at the origin where the charge is – Q. The electric field at the centre of cube is



(1) $\frac{2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

(2) $\frac{Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

(3) $\frac{-2Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

(4) $\frac{-Q}{3\sqrt{3}\pi\varepsilon_0 a^2}(\hat{x}+\hat{y}+\hat{z})$

Q. 20. Each side of a box made of metal sheet in cubic shape is 'a' at room temperature 'T', the coefficient of linear expansion of the metal sheet is 'α'. The metal sheet is heated uniformly, by a small temperature ΔT, so that its new temeprature is $T + \Delta T$. Calculate the increase in the volume of the metal box

(1) $\frac{4}{3}\pi a^3 \alpha \Delta T$ (2) $4\pi a^3 \alpha \Delta T$

(3) $3a^3 \alpha \Delta T$ (4) $4a^3 \alpha \Delta T$

Section B

Q. 21. A resonance circuit having inductance and resistance 2×10^{-4} H and 6.28 Ω respectively oscillates at 10 MHz frequency. The value of quality factor of this resonator is________. [$\pi = 3.14$]

Q. 22. A ball with a speed of 9 m/s collides with another identical ball at rest. After the collision, the direction of each ball makes an angle of 30° with the original direction. The ratio of velocities of the balls after collision is $x : y$, where x is _________.

Q. 23. An audio signal $v_m = 20\sin 2\pi(1500t)$ amplitude modulates a carrier $v_c = 80 \sin 2\pi (100{,}000t)$. The value of percent modulation is ________.

Q. 24. The coefficient of static friction between a wooden block of mass 0.5 kg and a vertical rough wall is 0.2. The magnitude of horizontal force that should be applied on the block to keep it adhered to the wall will be ______ N. [$g = 10$ ms^{-2}]

Q. 25. An inclined plane is bent in such a way that the vertical cross-section is given by $y = \frac{x^2}{4}$ where y is in vertical and x in horizontal direction. If the upper surface of this curved plane is rough with coefficient of friction $\mu = 0.5$, the maximum height in cm at which a stationary block will not slip downward is _____ cm.

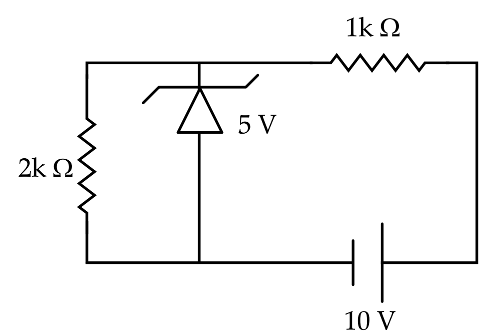
Q. 26. An electromagnetic wave of frequency 5 GHz, is travelling in a medium whose relative electric permittivity and relative magnetic permeability both are 2. Its velocity in this medium is _______ $\times 10^7$ m/s.

Q. 27. A hydraulic press can lift 100 kg when a mass 'm' is placed on the smaller piston. It can lift _______ kg when the diameter of the larger piston is increased by 4 times and that of the smaller piston is decreased by 4 times keeping the same mass 'm' on the smaller piston.

Q. 28. A common transistor radio set requires 12 V (D.C.) for its operation. The D.C. source is constructed by using a transformer and a rectifier circuit, which are operated at 220 V (A.C.) on standard domestic A.C. supply. The number of turns of secondary coil are 24, then the number of turns of primary are ________.

Q. 29. An unpolarized light beam is incident on the polarizer of a polarization experiment and the intensity of light beam emerging from the analyzer is measured as 100 Lumens. Now, if the analyzer is rotated around the horizontal axis (direction of light) by 30° in clockwise direction, the intensity of emerging light will be________ Lumens.

Q. 30. In connection with the circuit drawn below, the value of current flowing through 2 kΩ resistor is _______ $\times 10^{-4}$ A.



❑❑❑

Answer Key

Q. No.	Answer	Topic Name	Chapter Name
1	1	The Universal Law of Gravitation	Gravitation
2	1	Orbital Velocity of a Satellite	Gravitation
3	4	Work and Internal Energy	Thermodynamics
4	2	The Combination of Capacitors in Series and Parallel	Electrostatics
5	3	Potential Difference and EMF of a Cell	Current Electricity
6	1	Young's Modulus, Bulk Modulus, Modulus of Rigidity	Properties of Solids and Liquids Elastic
7	1	Centripetal Force and its applications	Laws of Motion
8	1	Velocity-Time, Position-Time Graph	Kinematics
9	4	Matter Waves-Wave Nature of Particle	Dual Nature of Matter and Radia-tion
10	4	Electric Current	Current Electricity
11	2	The Second Law of Thermodynamics Reversible and Irreversible Processes	Thermodynamics
12	1	Hydrogen Spectrum	Atoms and Nuclei
13	3	Mirror Formula	Optics
14	4	Moment of Inertia	Rotational Motion
15	3	Dimensional analysis and its Applications	Physics and Measurement
16	1	Characteristics of a Transistor: Transistor as an amplifier (Common Emitter Configuration) and Oscillator	Electronic Devices
17	1	Young's Double-Slit Experiment and Expression For Fringe Width	Wave Optics
18	1	Spring -Restoring Force and Force Constant: Energy in S.H.M. - Kinetic and Potential Energies	Oscillations and Waves
19	3	Electric Field: Electric Field due to a Point Charge	Electrostatics
20	3	Thermal Expansion	Properties of Solids and Liquids
21	2000	Quality Factor	Electromagnetic Induction and alternating Currents
22	1	Law of Conservation of Linear Momentum and its applications	Laws of Motion
23	25	Amplitude and Frequency Modulation	Communication Systems
24	25	Static and Kinetic Friction	Laws of Motion
25	25	Static and Kinetic Friction, Laws of Friction	Laws of Motion
26	15	Electromagnetic Waves and Their Character-istics, Transverse Nature of Electromagnetic Waves	Electromagnetic Waves
27	25600	Pascal's Law and its applications	Properties of Solids and Liquids Elastic
28	440	AC Generator and Transformer	Electromagnetic Induction and Alternating Currents
29	75	Polarization	Wave Optics
30	25	Zener Diode as a Voltage Regulator	Electronic Devices

JEE (Main) PHYSICS SOLVED PAPER

2021

24^{th} February Shift 1

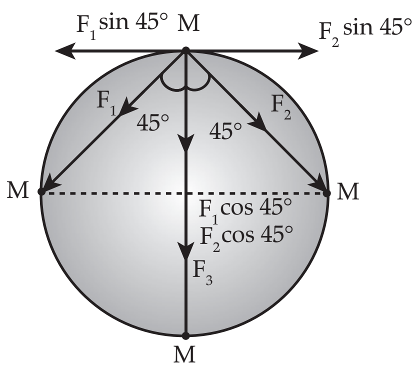
ANSWERS WITH EXPLANATIONS

Physics

Section A

1. Option (4) is correct.

There are three gravitational forces on each masses.



So, $F_g = F_1 \cos 45° + F_2 \cos 45° + F_3$

$$\Rightarrow \quad F_g = \frac{2GMM}{\left(R\sqrt{2}\right)^2} \cos 45° + \frac{GMM}{(2R)^2}$$

$$\Rightarrow \quad F_g = \frac{2GMM}{\left(2R^2\sqrt{2}\right)} + \frac{GMM}{4R^2}$$

$$\Rightarrow \quad F_g = \frac{GM^2}{R^2}\left(\frac{1}{\sqrt{2}} + \frac{1}{4}\right)$$

This gravitational force will be balanced by centripetal force.

Hence, $\frac{GM^2}{R^2}\left(\frac{1}{\sqrt{2}} + \frac{1}{4}\right) = \frac{Mv^2}{R}$

$$v^2 = \frac{GM}{R}\left(\frac{1}{4} + \frac{1}{\sqrt{2}}\right)$$

$$\Rightarrow \quad v = \sqrt{\frac{GM}{R}\left(\frac{1}{4} + \frac{1}{\sqrt{2}}\right)}$$

As per the question,

$M = 1$ kg

$R = 1$ m

So, $v = \sqrt{G\left(\frac{1}{4} + \frac{1}{\sqrt{2}}\right)}$

$$\Rightarrow \quad v = \sqrt{\frac{G\left(1 + 2\sqrt{2}\right)}{4}}$$

$$\Rightarrow \quad v = \frac{1}{2}\sqrt{G\left(1 + 2\sqrt{2}\right)}$$

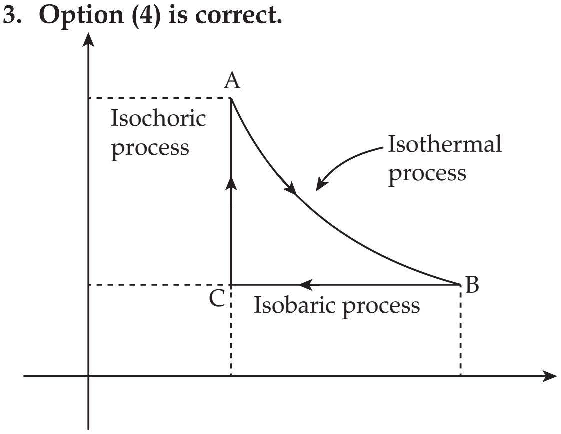
2. Option (1) is correct.

Let time period of revolutions are $T_1 = 1$ hr and $T_2 = 8$ hr

Since, $T \propto \frac{1}{\omega}$

$$\Rightarrow \quad \frac{\omega_1}{\omega_2} = \frac{T_2}{T_1} = \frac{8}{1}$$

3. Option (4) is correct.



As A → B is isothermal process

$$\Rightarrow \quad W_{AB} = nRT \ln\left(\frac{V_2}{V_1}\right)$$

$$= nRT \ln\left(\frac{2V_1}{V_1}\right)$$

$$= nRT \ln(2)$$

As B → C is isobaric process

$$\Rightarrow \quad W_{BC} = P \Delta V$$

$$= nR \Delta T$$

$$= nR\left(\frac{T}{2} - T\right)$$

$$= -nR\frac{T}{2}$$

As C $\to$ A is isochoric process

$\Rightarrow \quad W_{CA} = 0$

Work done by gas in complete cycle ABCA

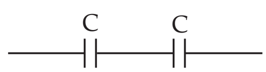
$$W = W_{AB} + W_{BC} + W_{CA}$$

$$= nRT\ln(2) + \left(-nR\frac{T}{2}\right) + 0$$

$$W = nRT\left(\ln(2) - \frac{1}{2}\right)$$

4. Option (2) is correct.

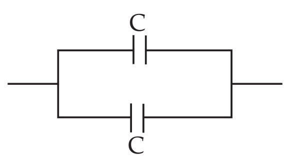
Case I : Series connection,



$$\frac{1}{C_1} = \frac{1}{C} + \frac{1}{C} = \frac{2}{C}$$

$$\Rightarrow \quad C_1 = \frac{C}{2}$$

Case II : Parallel connection,

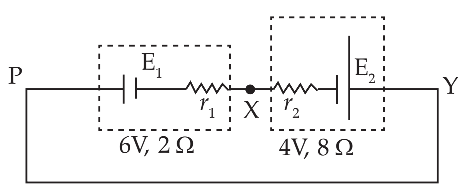


$$C_2 = C + C$$
$$= 2C$$

Hence, the required ratio,

$$\frac{C_1}{C_2} = \frac{1}{4}$$

5. Option (3) is correct.



$$E_1 = 6\text{ V}$$
$$r_1 = 2\,\Omega$$
$$E_2 = 4\text{ V}$$
$$r_2 = 8\,\Omega$$
$$R_{eq} = r_1 + r_2 = 8\,\Omega + 2\,\Omega$$
$$= 10\,\Omega$$

$$E_{eq} = E_1 - E_2$$
$$E_{eq} = (6 - 4)\text{ V}$$
$$E_{eq} = 2\text{ V}$$
$$I = \frac{E_{eq}}{R_{eq}} = \frac{2\text{ V}}{10\,\Omega}$$
$$I = 0.2\text{ A}$$

Hence, the potential difference across X and Y

$$V = E_2 + Ir_2$$

($\because$ direction of flow of current is anti clock)

$\Rightarrow \quad V = 4 + 0.2 \times 8$

$\Rightarrow \quad V = (4 + 1.6)\text{ V}$

$\Rightarrow \quad V = 5.6\text{ V}$

6. Option (1) is correct.

Given,

Young's modulus $= Y$

Bulk modulus $= K$

Modulus of rigidity $= \eta$

We know, relation between young modulus and bulk modulus,

$$Y = 3K(1 - 2\sigma)$$

$$\Rightarrow \quad 1 - 2\sigma = \frac{Y}{3K}$$

$$\Rightarrow \quad \sigma = \frac{1}{2}\left(1 - \frac{Y}{3K}\right) \quad \text{...(i)}$$

And, relation between young modulus and modulus of rigidity,

$$Y = 2\eta(1 + \sigma)$$

$$\Rightarrow \quad \sigma = \frac{Y}{2\eta} - 1 \quad \text{...(ii)}$$

From equation (i) and (ii)

$$\frac{1}{2}\left(1 - \frac{Y}{3K}\right) = \frac{Y}{2\eta} - 1$$

$$\Rightarrow \quad \frac{Y}{2\eta} + \frac{Y}{6K} = \frac{1}{2} + 1$$

$$\Rightarrow \quad \frac{Y}{2\eta} + \frac{Y}{6K} = \frac{3}{2}$$

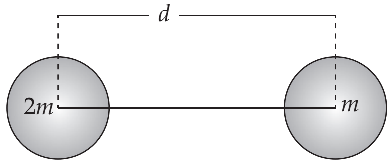
$$\Rightarrow \quad \frac{1}{6K} = \frac{3}{2Y} - \frac{1}{2\eta}$$

$$\Rightarrow \quad \frac{1}{6K} = \frac{3\eta - Y}{2Y\eta}$$

$$\Rightarrow \quad K = \frac{2Y\eta}{6(3\eta - Y)} = \frac{Y\eta}{9\eta - 3Y}$$

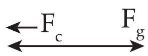
$$\Rightarrow \quad K = \frac{Y\eta}{9\eta - 3Y}\text{ N/m}^2$$

7. Option (1) is correct.



$$X_{com} = \frac{2m \times 0 + m.d}{2m + m} = \frac{d}{3}$$

Now, applying force balance equation



$$F_c = F_g$$

$$\Rightarrow \quad \frac{(2m)v^2}{X_{com}} = \frac{G(2m)\cdot m}{d^2}$$

$$\Rightarrow \quad \frac{2m\left(\omega \frac{d}{3}\right)^2}{\left(\frac{d}{3}\right)} = \frac{2Gm^2}{d^2}$$

$$\Rightarrow \quad \omega^2 = \frac{\frac{2Gm^2}{d^2}}{2m\frac{d}{3}}$$

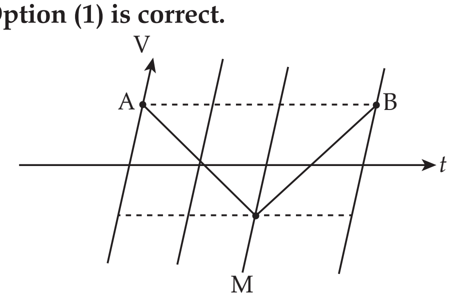
$$\Rightarrow \quad \omega = \sqrt{\frac{2Gm^2}{d^2 \cdot 2} \times \frac{3}{md}}$$

$$\Rightarrow \quad \omega = \sqrt{\frac{3Gm}{d^3}}$$

$$\Rightarrow \quad \frac{2\pi}{T} = \sqrt{\frac{3Gm}{d^3}}$$

$$\Rightarrow \quad T = 2\pi\sqrt{\frac{d^3}{3Gm}}$$

8. Option (1) is correct.



$$\Rightarrow \quad a = \frac{dv}{dt}$$

So, a can be positive and negative.

If a is positive, then

$$v = mt + c$$

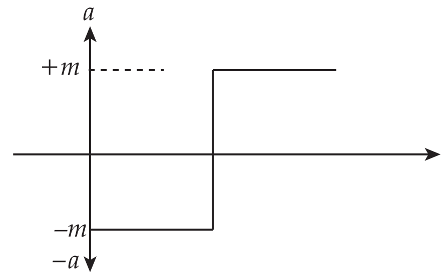
If a is negative, then

$$\Rightarrow \quad v = -mt + c$$

So, $\frac{dv}{dt} = m$ for $a > 0$

and $\frac{dv}{dt} = -m$ for $a < 0$

Hence,



9. Option (4) is correct.

Linear momentum of photon

$$p = \frac{h}{\lambda}$$

Energy of a photon

$$E = \frac{hc}{\lambda}$$

So, Two photons having equal linear momenta have equal wavelengths and if we will decrease the wavelength, then momentum and energy of the photon will increase.

Hence, statement (I) is true and statement (II) is false.

10. Option (4) is correct.

Given,

$$i = \alpha_0 t + \beta t^2$$

$$\Rightarrow \quad \frac{dQ}{dt} = \alpha_0 t + \beta t^2$$

$$\Rightarrow \quad dQ = (\alpha_0 t + \beta t^2)\, dt$$

Now, integrating both sides with respect to their limits.

$$\int_0^Q dQ = \int_0^t \left(\alpha_0 t + \beta t^2\right) dt$$

$$\Rightarrow \quad Q = \left[\frac{\alpha_0 t^2}{2} + \frac{\beta t^3}{3}\right]_0^t$$

$$\Rightarrow \quad Q = \frac{\alpha_0 t^2}{2} + \frac{\beta t^3}{3}$$

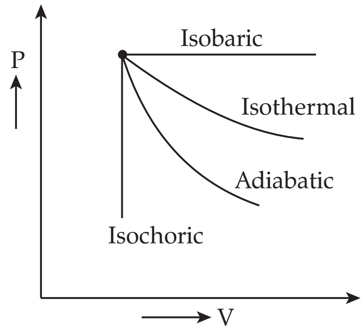
Now, substituting the given values,

$$Q = \frac{20 \times 15^2}{2} + \frac{8 \times 15^3}{3}$$

$$Q = \left(2250 + \frac{225 \times 15 \times 8}{3}\right) C$$

$$\Rightarrow \quad Q = (2250 + 9000)\ C = 11250\ C$$

11. Option (2) is correct.



Hence, from the above diagram, we can conclude that,

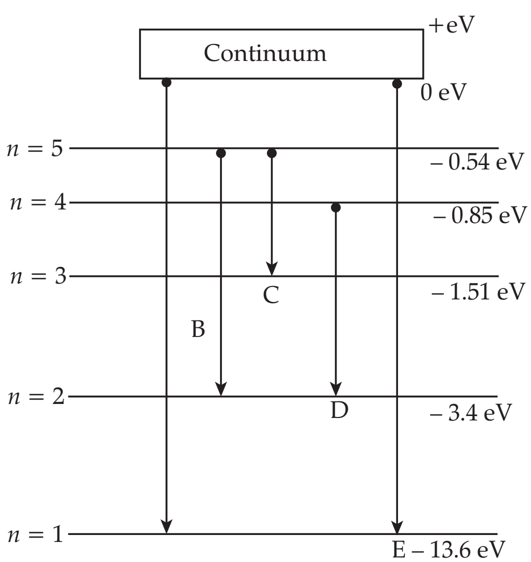
Isothermal – Temperature constant

Isobaric – Pressure is constant

Isochoric – Volume is constant

Adiabatic – $\Delta Q = 0$, Heat content is constant

12. Option (1) is correct.



<u>For transition A,</u>

$$n_1 > 5$$
$$n_2 = 1$$

Hence, it is the series limit of lyman series.

<u>For the transition of B,</u>

$$n_1 = 5$$
$$n_2 = 2$$

Hence, it represents the third member of balmer series.

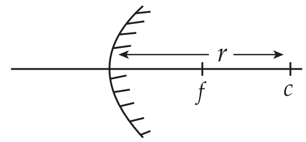
<u>For the transition C,</u>

$$n_1 = 5$$
$$n_2 = 3$$

Hence, it represents the second member of paschen series.

13. Option (3) is correct.

For spherical convex mirror

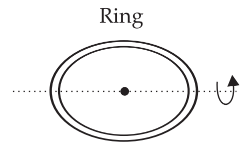


$$f = +\frac{r}{2}$$

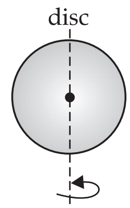
14. Option (4) is correct.

Let the masses of 4 bodies are M and radius = R

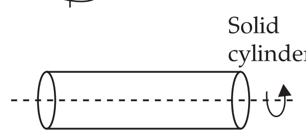
$$I_1 = \frac{1}{2}MR^2$$



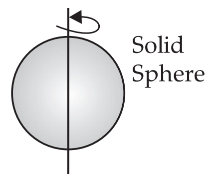
$$I_2 = \frac{1}{2}MR^2$$



$$I_3 = \frac{1}{2}MR^2$$



$$I_4 = \frac{2}{5}MR^2$$



So, $I_1 = I_2 = I_3 > I_4$

15. Option (3) is correct.

Given,

$$W = \alpha\beta^2 e^{-\frac{x^2}{\alpha kT}}$$

We know that exponents are dimensionless quantities

So, $$\frac{x^2}{\alpha kT} = [M^0L^0T^0]$$

$$\Rightarrow \quad \frac{[L^2]}{\alpha[ML^2T^{-2}K^{-1}][K]} = [M^0L^0T^0]$$

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

Dimension of work = $[ML^2T^{-2}]$

$$\Rightarrow \quad \alpha\beta^2 = [ML^2T^{-2}]$$

$$\Rightarrow \quad \beta^2[M^{-1}T^2] = [ML^2T^{-2}]$$

$$\Rightarrow \quad \beta^2 = \frac{[ML^2T^{-2}]}{[M^{-1}T^2]}$$

$$\Rightarrow \quad \beta^2 = [M^2 T^{-4} L^2]$$
$$\beta = [MT^{-2} L]$$
$$\beta = [M L T^{-2}]$$

16. Option (1) is correct.

Given,

Emitter current (I_E) = 4 mA

Collector current (I_C) = 3.5 mA

β = ?

$$I_B = I_E - I_C = (4 - 3.5)\text{mA} = 0.5 \text{ mA}$$

$$\beta = \frac{I_C}{I_B} = \frac{3.5}{0.5} = 7$$

17. Option (1) is correct.

Given,

Let the width of the slit be ω

So, $\omega_1 = 3\omega_2$

Since, $A \propto \omega$

Ratio of maximum to minimum intensity

$$\frac{I_{max}}{I_{min}} = ?$$

$$I = A_1^2 + A_2^2 + 2A_1A_2 \cos\phi$$

For maximum intensity $\cos\phi = 1$

For minimum intensity $\cos\phi = -1$

So, $I_{max} = (A_1 + A_2)^2$

$I_{min} = (A_1 - A_2)^2$

Since, $A_1 = A$ and $A_2 = 3A$

So, $\frac{A_1}{A_2} = \frac{\omega_1}{\omega_2}$

Hence, $$\frac{I_{max}}{I_{min}} = \frac{(A+3A)^2}{(A-3A)^2}$$

$$\Rightarrow \frac{I_{max}}{I_{min}} = \frac{(4A)^2}{(-2A)^2}$$

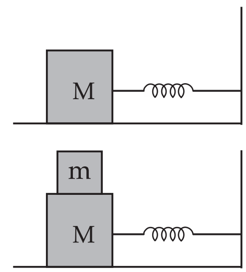
$$\Rightarrow \frac{I_{max}}{I_{min}} = \frac{16}{4} = \frac{4}{1}$$

Hence $$\frac{I_{max}}{I_{min}} = \frac{4}{1}$$

18. Option (1) is correct.

As per the condition, there is are no impulsive forces, so momentum always be conserve.

$$MA\left(\frac{2\pi}{T_1}\right) = (m+M)A_1\left(\frac{2\pi}{T_2}\right) \quad ...(i)$$



$$T_1 = 2\pi\sqrt{\frac{M}{K}}$$

$$T_2 = 2\pi\sqrt{\frac{M+m}{K}}$$

Now, substituting the value of T_1 and T_2 in equation (i).

$$MA\left(\frac{2\pi}{2\pi\sqrt{\frac{M}{K}}}\right) = (m+M)A_1\left(\frac{2\pi}{2\pi\sqrt{\frac{M+m}{K}}}\right)$$

$$\Rightarrow \quad A_1 = \frac{MA\sqrt{\frac{K}{M}}}{(m+M)\sqrt{\frac{K}{M+m}}}$$

$$\Rightarrow \quad A_1 = A\sqrt{\frac{M}{M+m}}$$

19. Option (3) is correct.

For the reduction of the problem, we can replace –Q charge at origin by +Q and –2Q.

Now, the electric field due to +Q charge of the corners at the centre of the cube will be zero.

Hence, the net electric field at the centre due to –2Q charge of the origin will work.

$$\vec{E} = \frac{kq\vec{r}}{r^3} = \frac{1(-2Q)\frac{a}{2}(\hat{x}+\hat{y}+\hat{z})}{4\pi\varepsilon_0\left(\frac{a}{2}\sqrt{3}\right)^3}$$

$$\vec{E} = \frac{-2Q(\hat{x}+\hat{y}+\hat{z})}{3\sqrt{3}\pi a^2\varepsilon_0}$$

20. Option (3) is correct.

Length of metal sheet of cube = a

Room temperature = T

Coefficient of liner expansion of metal sheet = α

Increase in temperature = ΔT

New temperature = $T + \Delta T$

Now, $\Delta V = V \cdot \gamma \cdot \Delta T$

$\Rightarrow \quad \Delta V = a^3 \cdot \gamma \cdot \Delta T$

$\Rightarrow \quad \Delta V = a^3 (3\alpha) \cdot \Delta T \qquad (\because \gamma = 3\alpha)$

$\Rightarrow \quad \Delta V = 3a^3 \alpha \Delta T$

Section B

21. Correct answer is [2000].

Inductance (L) = 2×10^{-4} H

Resistance (R) = 6.28 Ω

Frequency of oscillation (*f*) = 10 MHz

Quality factor (Q) = ?

$\Rightarrow \quad Q = \frac{X_L}{R}$

$\Rightarrow \quad Q = \frac{\omega L}{R}$

$\Rightarrow \quad Q = \frac{2\pi f L}{R} = \frac{2\pi \times 10 \times 10^6 \times 2 \times 10^{-4}}{6.28}$

$\Rightarrow \quad Q = 2000$

Hence, the value of quality factor for resonator be 2000.

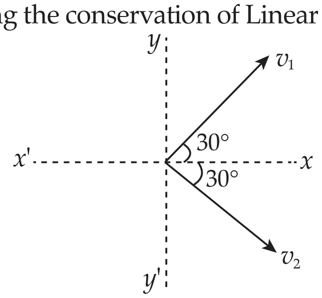
22. Correct answer is [1].

As per question, the balls are identical, so, $m_1 = m_2 = m$

Initial speed of first ball $u_1 = 9$ m/s

Initial speed of second ball $u_2 = 0$

Applying the conservation of Linear Momentum



Momentum along y – axis

$$0 = mv_1 \sin 30° - mv_2 \sin 30°$$

$$v_1 = v_2 \Rightarrow v_1 : v_2 = 1 : 1$$

Momentum along x – axis

$$mu_1 + 0 = mv_1 \cos 30° + mv_2 \cos 30°$$

or, $9 = v_1 \times \frac{\sqrt{3}}{2} + v_1 \times \frac{\sqrt{3}}{2}$

or, $\quad v_1 = v_2 = 3\sqrt{3}$

$\Rightarrow v_1 : v_2 = 1 : 1$

Hence, the ratio of velocities of ball after collision is $x : y = 1 : 1$, where $x = 1$.

23. Correct answer is [25].

$v_m = 20 \sin 2\pi(1500t)$;

$v_c = 80 \sin 2\pi\,(100{,}000t)$

Percent modulation = ?

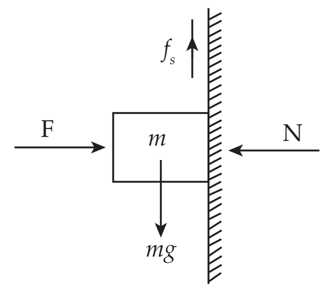
$$\text{Modulation index} = \frac{A_m}{A_c} = \frac{20}{80} = \frac{1}{4}$$

Hence, value of percent modulation index

$$= \frac{1}{4} \times 100 = 25\ \%$$

24. Correct answer is [25].

Applying force balance equation in vertical and horizontal direction.



Force balance in vertical direction

$f_s = mg \qquad$ ...(i)

$F = N \qquad$ ...(ii)

From equation (i) and (ii)

$$f_s = \mu N = mg$$

$$N = \frac{mg}{\mu} = \frac{0.5 \times 10}{0.2}$$

$$F = N = 25\text{ N}$$

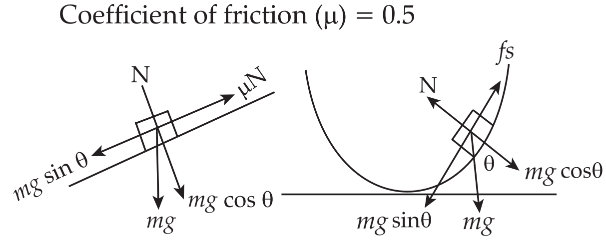
Hence, the magnitude of horizontal force be 25 N

25. Correct answer is [25].

Given, equation of vertical cross – section

$$y = \frac{x^2}{4}$$

Coefficient of friction (μ) = 0.5



Now, applying the force balance equation,

$$mg \sin\theta = \mu N = f_s$$

$\Rightarrow \quad mg \sin\theta = \mu\, mg \cos\theta$

$\Rightarrow \quad \tan\theta = \mu \qquad$ ...(i)

Now, $y = \frac{x^2}{4}$

$$\tan\theta = \frac{dy}{dx} = \frac{2x}{4} = \frac{x}{2}$$

From equation (i)

$\Rightarrow \tan\theta = \mu = \frac{x}{2}$

$\Rightarrow x = 2\mu = 2\times 0.5$

$\Rightarrow x = 1$

Hence, $y = \frac{x^2}{4}$

$$y = \frac{1}{4}$$

$$y = 0.25 \text{ m}$$

or $y = 25$ cm

26. Correct answer is [15].

Given,

Frequency of electromagnetic wave (f) = 5 GHz

$$\mu_r = 2$$
$$\varepsilon_r = 2$$

Velocity of wave, $v = \frac{c}{n}$

Since, $n = \sqrt{\mu_r \varepsilon_r}$

$$n = \sqrt{2\times 2} = 2$$

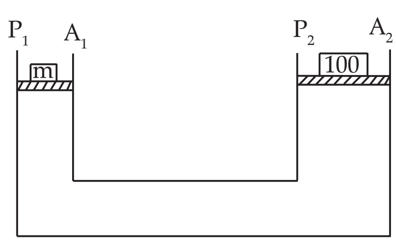
Now, $v = \frac{c}{n} = \frac{3\times 10^8}{2}$

$$v = 1.5\times 10^8 \text{ m/s}$$
$$v = 15\times 10^7 \text{ m/s}$$

Hence, the velocity in this medium is 15×10^7 m/s

So, $x = 15$

27. Correct answer is [25600].



Let pressure be P_1 and P_2 and area be A_1 and A_2

So, $P_1 = P_2$

$\Rightarrow \frac{F_1}{A_1} = \frac{F_2}{A_2}$

Case I

$\Rightarrow \frac{mg}{A_1} = \frac{100g}{A_2}$ ...(i)

Case II

$$A_1' = \frac{A_1}{16}$$
$$A_2' = 16A_2$$

Now, $\frac{mg16}{A_1} = \frac{Mg}{16A_2}$ ...(ii)

From (i) and (ii), we get

$$\frac{16\times 100g}{A_2} = \frac{Mg}{16A_2}$$

$$M = 25{,}600 \text{ kg}$$

28. Correct answer is [440].

Given,

Primary voltage (V_p) = 220 V

Secondary voltage (V_s) = 12 V

Number of turns in secondary coil (N_s) = 24

Number of turns in primary coil (N_p) = ?

For the transformer ratio

$$\frac{N_p}{N_s} = \frac{V_p}{V_s}$$

$$N_p = \frac{V_p}{V_s}\times N_s$$

$$N_p = \frac{220\times 24}{12} = 440$$

29. Correct answer is [75].

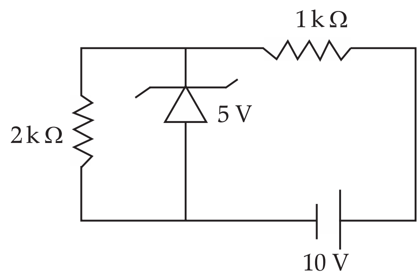
Given,

$$I_0 = 100 \text{ Lumens}$$
$$\theta = 30°$$
$$I = I_0\cos^2\theta$$

So, $I = 100\cos^2(30°)$

$$= 100\times\left(\frac{\sqrt{3}}{2}\right)^2$$
$$= 25\times 3$$
$$= 75 \text{ Lumens.}$$

30. Correct answer is [25].



For the zener diode, after 5 V, change in current will be zero.

$$i = \frac{5}{2 \times 10^3} \text{ A}$$

$$i = 2.5 \times 10^{-3} \text{ A}$$

$$i = 25 \times 10^{-4} \text{A}$$

❒❒❒