JEE Advanced (2025)

PAPER 2

SECTION 1 (Maximum Marks: 12)

- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks	:	+3 **ONLY** if the option corresponding to the correct combination is chosen;
Zero Marks	:	0 If none of the options is chosen (i.e., the question is unanswered);
Negative Marks	:	−1 In all other cases.

1. A temperature difference can generate e.m.f. in some materials. Let S be the e.m.f. produced per unit temperature difference between the ends of a wire, σ the electrical conductivity and k, the thermal conductivity of the material of the wire. Taking M,L,T, I and K as dimensions of mass, length, time, current and temperature, respectively, the dimensional formula of the quantity $Z = \dfrac{S^2\sigma}{k}$ is:

(A) $[M^0L^0T^0I^0K^0]$
(B) $[M^0L^0T^0I^0K^{-1}]$
(C) $[M^1L^2T^{-2}I^{-1}K^{-1}]$
(D) $[M^1L^2T^{-4}I^{-1}K^{-1}]$

2. Two co-axial conducting cylinders of same length ℓ with radii $\sqrt{2}R$ and $2R$ are kept, as shown in Fig. 1. The charge on the inner cylinder is Q and the outer cylinder is grounded. The annular region between the cylinders is filled with a material of dielectric constant $k = 5$. Consider an imaginary plane of the same length ℓ at a distance R from the common axis of the cylinders. This plane is parallel to the axis of the cylinders. The cross-sectional view of this arrangement is shown in Fig. 2. Ignoring the edge effects, the flux of the electric field through the plane is (ε_0 is the permittivity of free space):
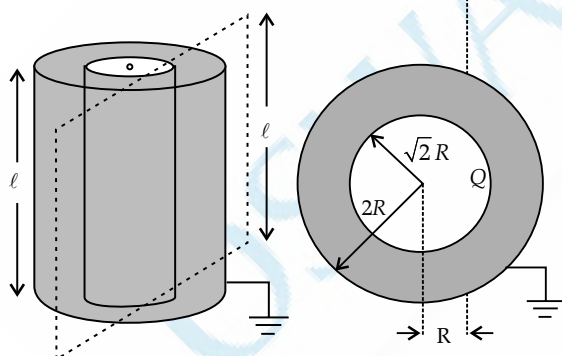

Fig. 1   Fig. 2

(A) $\dfrac{Q}{30\varepsilon_0}$
(B) $\dfrac{Q}{15\varepsilon_0}$
(C) $\dfrac{Q}{60\varepsilon_0}$
(D) $\dfrac{Q}{120\varepsilon_0}$

3. As shown in the figures, a uniform rod OO′ of length l is hinged at the point O and held in place vertically between the two walls using two massless springs of same spring constant. The springs are connected at the midpoint and at the top-end (O′) of the rod, as shown in Fig. 1, and the rod is made to oscillate by a small angular displacement. The frequency of oscillation of the rod is f_1. On the other hand, if both the springs are connected at the midpoint of the rod, as shown in Fig. 2, and the rod is made to oscillate by a small angular displacement, then the frequency of oscillation is f_2. Ignoring the gravity and assuming motion only in the plane of the diagram, the value of $\dfrac{f_1}{f_2}$ is:
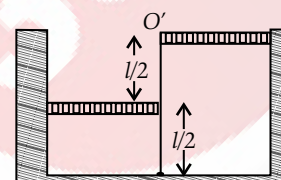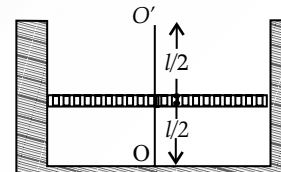

Fig. 1

Fig. 2

(A) 2
(B) $\sqrt{2}$
(C) $\sqrt{\dfrac{5}{2}}$
(D) $\sqrt{\dfrac{2}{5}}$

4. Consider a star of mass m_2 kg revolving in a circular orbit around another star of mass m_1 kg with $m_1 > m_2$. The heavier star slowly acquires mass from the lighter star at a constant rate of γ kg/s. In this transfer process, there is no other loss of mass. If the separation between the centres of the stars is r, then its relative rate of change $\dfrac{1}{r}\dfrac{dr}{dt}$ (in s^{-1}) is given by:

(A) $-\dfrac{3\gamma}{2m_2}$
(B) $-\dfrac{2\gamma}{m_2}$
(C) $-\dfrac{2\gamma}{m_1}$
(D) $-\dfrac{3\gamma}{2m_1}$

SECTION 2 (Maximum Marks: 16)

5. A positive point charge of 10^{-8} C is kept at a distance of 20 cm from the centre of a neutral conducting sphere of radius 10 cm. The sphere is then grounded and the charge on the sphere is measured. The grounding is then removed and subsequently the point charge is moved by a distance of 10 cm further away from the centre of the sphere along the radial direction. Taking $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ Nm^2/C^2 (where ε_0 is the permittivity of free space), which of the following statements is/are correct:

(A) Before the grounding, the electrostatic potential of the sphere is 450 V.

(B) Charge flowing from the sphere to the ground because of grounding is 5×10^{-9} C.

(C) After the grounding is removed, the charge on the sphere is -5×10^{-9} C.

(D) The final electrostatic potential of the sphere is 300 V.

6. Two identical concave mirrors each of focal length f are facing each other as shown in the schematic diagram. The focal length f is much larger than the size of the mirrors. A glass slab of thickness t and refractive index n_0 is kept at equidistant from the mirrors and perpendicular to their common principal axis. A monochromatic point of light source S is embedded at the centre of the slab on the principal axis, as shown in the schematic diagram. For the image to be formed on S itself, which of the following distances between the two mirrors is/are correct:
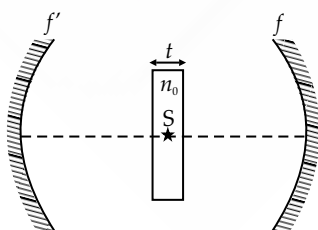

(A) $4f + \left(1 - \dfrac{1}{n_0}\right)t$

(B) $2f + \left(1 - \dfrac{1}{n_0}\right)t$

(C) $4f + (n_0 - t)t$

(D) $2f + (n_0 - t)t$

7. Six infinitely large and thin non-conducting sheets are fixed in configurations I and II. As shown in the figure, the sheets carry uniform surface charge densities which are indicated in terms of σ_0. The separation between any two consecutive sheets is 1 μm. The various regions between the sheets are denoted as 1, 2, 3, 4 and 5. If $\sigma_0 = 9$ μC/m^2, then which of the following statements is (are) correct:

(Take permittivity of free space $\varepsilon_0 = 9 \times 10^{-12}$ F/m)
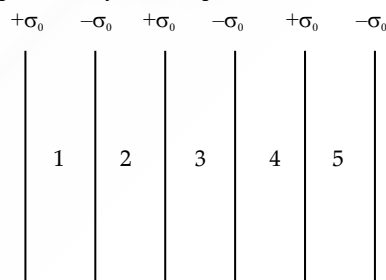
Configuration I
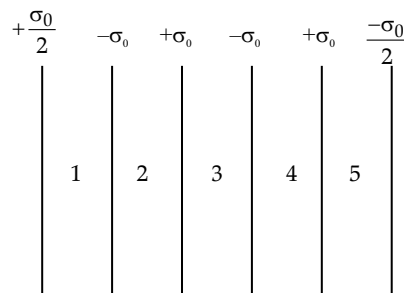
Configuration II

(A) In region 4 of the Configuration I, the magnitude of the electric field is zero.

(B) In region 3 of the Configuration II, the magnitude of the electric field is $\frac{\sigma_0}{\varepsilon_0}$.

(C) Potential difference between the first and the last sheets of the Configuration I is 5 V.

(D) Potential difference between the first and the last sheets of the Configuration II is zero.

8. The efficiency of a Carnot engine operating with a hot reservoir kept at a temperature of 1000 K is 0.4. It extracts 150 J of heat per cycle from the hot reservoir. The work extracted from this engine is being fully used to run a heat pump which has a coefficient of performance 10. The hot reservoir of the heat pump is at a temperature of 300 K. Which of the following statements is (are) correct:_____

(A) Work extracted from the Carnot engine in one cycle is 60 J.

(B) Temperature of the cold reservoir of the Carnot engine is 600 K.

(C) Temperature of the cold reservoir of the heat pump is 270 K.

**(D)** Heat supplied to the hot reservoir of the heat pump in one cycle is 540 J.

9. A conducting solid sphere of radius R and mass M carries a charge Q. The sphere is rotating about an axis passing through its centre with a uniform angular speed ω. The ratio of the magnitudes of the magnetic dipole moment to the angular momentum about the same axis is given as $\alpha\frac{Q}{2M}$. The value of α is:

10. A hydrogen atom, initially at rest in its ground state, absorbs a photon of frequency v_1 and ejects the electron with a kinetic energy of 10 eV. The electron then combines with a positron at rest to form a positronium atom in its ground state and simultaneously emits a photon of frequency v_2. The centre of mass of the resulting positronium atom moves with a kinetic energy of 5 eV. It is given that positron has the same mass as that of the electron and the positronium atom can be considered as a Bohr atom, in which the electron and the positron orbit around their centre of mass. Considering no other energy loss during the whole process, the difference between the two photon energies (in eV) is _____.

11. An ideal monatomic gas of n moles is taken through a cycle WXYZW consisting of consecutive adiabatic and isobaric quasi-static processes, as shown in the schematic V-T diagram. The volume of the gas at W, X and Y points are, 64 cm³, 125 cm³ and 250 cm³, respectively. If the absolute temperature of the gas T_W, at the point W is such that $nRT_W = 1$ J (R is the universal gas constant), then the amount of heat absorbed (in J) by the gas along the path XY is _____.
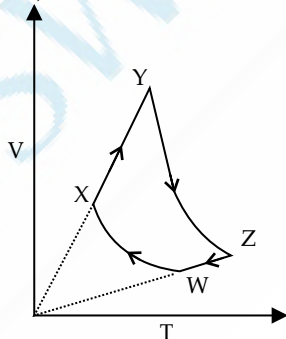
12. A geostationary satellite above the equator is orbiting around the earth at a fixed distance r_1 from the centre of the earth. A second satellite is orbiting in the equatorial plane in the opposite direction to the earth's rotation, at a distance r_2 from the centre of the earth, such that $r_1 = 1.21r_2$. The time period of the second satellite as measured from the geostationary satellite is $\frac{24}{p}$ hours. The value of p is _____.

13. The left and right compartments of a thermally isolated container of length L are separated by a thermally conducting, movable piston of area A. The left and right compartments are filled with $\frac{3}{2}$ and 1 moles of an ideal gas, respectively. In the left compartment the piston is attached by a spring with spring constant k and natural length $\frac{2L}{5}$. In thermodynamic equilibrium, the piston is at a distance $\frac{L}{2}$ from the left and right edges of the container as shown in the figure. Under the above conditions, if the pressure in the right compartment is $P = \frac{KL}{A\alpha}$, then the value of α is _____.
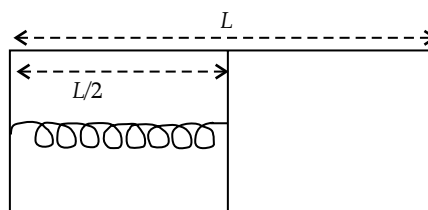
14. In a Young's double slit experiment, a combination of two glass wedges A and B, having refractive indices 1.7 and 1.5, respectively, are placed in front of the slits, as shown in the figure. The separation between the slits is $d = 2$ mm

and the shortest distance between the slits and the screen is $D = 2$ m. Thickness of the combination of the wedges is $t = 12$ μm. The value of l as shown in the figure is 1 mm. Neglect any refraction effect at the slanted interface of the wedges. Due to the combination of the wedges, the central maximum shifts with respect to O is _____ mm.
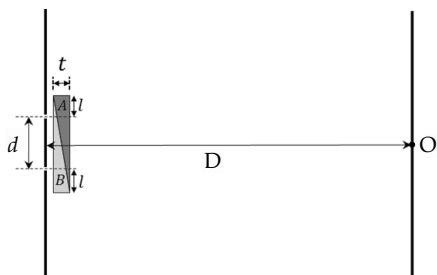
15. A projectile of mass 200 g is launched in a viscous medium at an angle 60° with the horizontal, with an initial velocity of 270 m/s. It experiences a viscous drag force $\vec{F} = -c\vec{v}$, where the drag coefficient $c = 0.1$ kg/s and $\vec{v}$ is the instantaneous velocity of the projectile. The projectile hits a vertical wall after 2 s. Taking $e = 2.7$, the horizontal distance of the wall from the point of projection (in m) is _____.

16. An audio transmitter (T) and a receiver (R) are hung vertically from two identical massless strings of length 8 m with their pivots well-separated along the x-axis. They are pulled from the equilibrium position in opposite directions along the x-axis by a small angular amplitude $\theta_0 = \cos^{-1}(0.9)$ and released simultaneously. If the natural frequency of the transmitter is 660 Hz and the speed of sound in air is 330 m/s, the maximum variation in the frequency (in Hz) as measured by the receiver (Take the acceleration due to gravity $g = 10$ m/s^2) is _____.
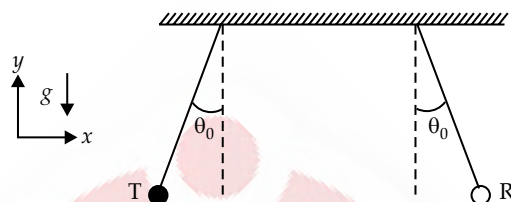
Answer Key

Q.No.	Answer key	Topic name	Chapter name
1	(B)	Dimensions	Units and Measurements
2	(C)	Electric Flux	Electrostatics
3	(C)	SHM	Oscillations
4	(B)	Angular Momentum	System of Particles and Rotational Motion
5	(A, B, C, D)	Electric Potential due a Conducting Sphere	Electrostatics
6	(A, B)	Image Formation by Mirror	Ray Optics
7	(A)	Application of Gauss Law	Electrostatics
8	(A, B, C)	Carnot Engine	Thermodynamics
9	[1.65 to 1.67]	Angular Momentum	System of Particles and Rotational Motion
10	[11.7 to 11.9]	Bohr's Model, Radioactive Emission	Atoms and Nuclei
11	[1.6]	Thermodynamic Process	Thermodynamics
12	[2.3 to 2.4]	Motion of Satellite	Gravitation
13	[0.2]	Pressure Exerted of Ideal Gas	Kinetic Theory of Gases
14	[1.2]	YDSE	Wave Optics
15	[170]	Projectile Motion	Motion in a Plane
16	[26 to 33]	Doppler Effect	Waves

ANSWERS WITH EXPLANATIONS

1. Correct option is (B).

$$S = \frac{\text{e.m.f.}}{\text{Temp}} = \frac{[M^1L^2T^{-3}A^{-1}]}{[K]} = [M^1L^2T^{-3}A^{-1}K^{-1}]$$

$$\sigma = \frac{1}{\rho} = \frac{L}{RA} = \frac{IL}{VA} = \frac{[M^0L^1A^1]}{[M^1L^2T^{-3}A^{-1}][L^2]}$$

$$= [M^{-1}L^{-3}T^3A^2]$$

K, thermal conductivity $K = \dfrac{QL}{A\Delta T\Delta t}$ where Q is heat.

$$K = \frac{[M^1L^2T^{-2}][L]}{[L^2][K][T]} = [M^1L^1T^{-3}K^{-1}]$$

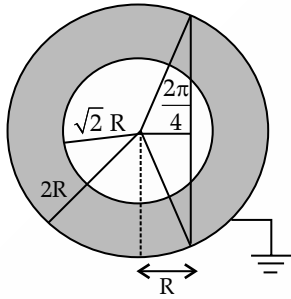Given, $\qquad Z = \dfrac{S^2\sigma}{K}$

$$= \frac{[M^2L^4T^{-6}A^{-2}K^{-2}][M^{-1}L^{-3}T^3A^2]}{[M^1L^1T^{-3}K^{-1}]}$$

$$= [M^0L^0T^0A^0K^{-1}] = [K^{-1}]$$

2. Correct option is (C).

Charge on inner cylinder Q,

$$Q_1 = \frac{Q}{2\pi}\times\frac{\pi}{2} = \frac{Q}{4}$$

Charge on outer cylinder $Q_2 = \dfrac{-Q}{2\pi}\times\dfrac{2\pi}{3} = \dfrac{-Q}{3}$

Total charge $Q' = Q_1 + Q_2 = \dfrac{Q}{4}+\left(-\dfrac{Q}{3}\right) = \dfrac{-Q}{12}$

As per Gauss's law $\phi = \dfrac{q_{in}}{\varepsilon_0 k}$ due to dielectric

$$|\phi| = \frac{Q'}{\varepsilon_0 k} = \left|\frac{\left(\frac{-Q}{12}\right)}{\varepsilon_0 5}\right| = +\frac{Q}{60\varepsilon_0}$$

3. Correct option is (C).

Case 1: Let the spring be displaced by a small angle θ, then the restoring forces will act in opposite direction.
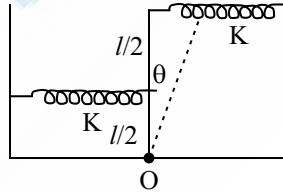

Torque about O

$$\tau_1 = F_1 x + F_2 x = I\alpha_1$$

$$\left(K\frac{l}{2}\theta\right)\frac{l}{2}+(Kl\theta)l = I\alpha_1$$

$$\alpha_1 = \omega_1^2\theta$$

$$I\alpha_1 = Kl^2\theta\left(\frac{1}{4}+1\right)$$

$$\alpha_1 = \left(\frac{Kl^2}{I}\cdot\frac{5}{4}\right)\theta \qquad \text{...(i)}$$
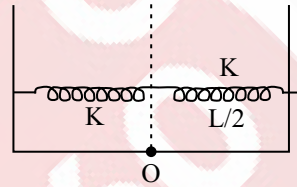
$$\alpha_1 = \omega_1^2\theta$$

Case 2: $\qquad \tau_2 = I\alpha_2 = 2\left(K\frac{l}{2}\theta\right)\cdot\frac{l}{2} = 2\frac{Kl^2\theta}{4}$

$$\alpha_2 = \left(\frac{Kl^2}{2I}\right)\theta \qquad \text{...(ii)}$$

$$\alpha_2 = \omega_2^2\theta$$

$$\frac{F_1}{F_2} = \frac{\omega_1}{\omega_2} = \frac{\sqrt{\frac{Kl^2}{I}\cdot\frac{5}{4}}}{\sqrt{\frac{Kl^2}{I}\cdot\frac{1}{2}}} = \frac{\sqrt{\frac{5}{4}}}{\sqrt{\frac{1}{2}}} = \sqrt{\frac{5}{2}}$$
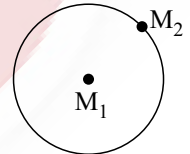

4. Correct option is (B).

Applying conservation of angular momentum

$$m_2 v_2 r = \text{const.} \qquad \text{...(i)}$$

Orbital velocity $\quad v_2 = \sqrt{\dfrac{Gm_1}{r}}$

$$\frac{Gm_1 m_2}{r^2} = \frac{m_2 v_2^2}{r} \Rightarrow v_2 = \sqrt{\frac{Gm_1}{r}}$$

Putting above value in Eq. (i),

$$m_2\sqrt{\frac{Gm_1}{r}}\cdot r = \text{const.}$$

Squaring both sides

$$m_2^2\frac{Gm_1}{r}\cdot r^2 = \text{const.}$$

$$m_2^2 Gm_1 r = \text{const.}$$

Differentiating above equation w.r.t. time, t,

$$Gm_1 m_2^2\frac{dr}{dt}+Gm_2^2 r\frac{dm_1}{dt}+Gm_1 r\cdot 2m_2\frac{dm_2}{dt} = 0$$

$$m_1 m_2\frac{dr}{dt}+m_2 r\frac{dm_1}{dt}+2m_1 r\frac{dm_2}{dt} = 0$$

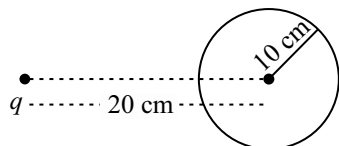Dividing the above equation by $m_1 m_2$, we get,

$$\frac{dr}{dt}+\frac{r}{m_1}\frac{dm_1}{dt}+\frac{2r}{m_2}\frac{dm_2}{dt} = 0$$

$$\frac{1}{r}\frac{dr}{dt} = -\underbrace{\frac{1}{m_1}\frac{dm_1}{dt}}-\frac{2r}{m_2}\frac{dm_2}{dt}$$

Negative as m_1 is too large.

$$\frac{1}{r}\frac{dr}{dt} = -\frac{2}{m_2}\frac{dm_2}{dt} = \frac{-2}{m_2}r$$

5. Correct options are (A, B, C).

Initially, the potential of sphere due to charge q

$$V = \frac{kq}{r} = \frac{9 \times 10^9 \times 10^{-8}}{20 \times 10^{-2}} = \frac{900}{2} = 450\text{V}$$

Option (A) is correct.

Now, as the sphere is grounded, the net voltage on it will be zero. Hence,

$$\frac{Kq}{r} + \frac{kQ}{R} = 0$$

$$\Rightarrow \quad Q = -q \times \frac{R}{r} = \frac{10^{-8} \times 10}{20} = -5 \times 10^{-9}\,C$$

Option (B) is correct.

When grounding is removed, the charge will get trapped on sphere, i.e., total charge will be conserved. i.e., $5 \times 10^{-9}\,C$

Option (C) is correct.
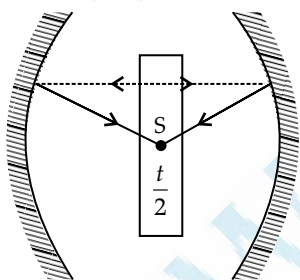
Now, $\quad V = \frac{Kq}{r'} + \frac{KQ}{R}$

$$= K\left(\frac{q}{r'} + \frac{Q}{R}\right)$$

$$= 9 \times 10^9 \left(\frac{10^{-8}}{30 \times 10^{-2}} - \frac{5 \times 10^{-9}}{10 \times 10^{-2}}\right)$$

$$= 900\left(\frac{1}{3} - \frac{1}{2}\right) = -150\ \text{V}$$

Option (D) is incorrect.

6. Correct options are (A, B).

$$\frac{t}{2n_o} + \frac{D}{2} - \frac{t}{2} = 2f$$

$$\frac{t}{n_o} + D - t = 4f$$

$$\Rightarrow \quad D = 4f + t - \frac{t}{n_o} = 4f + t\left(1 - \frac{1}{n_o}\right)$$

Also, when it strikes at 90°, its path

$$\frac{t}{2n_o} + \frac{D-t}{2} = f$$

$$\frac{t}{n_o} + D - t = 2f$$

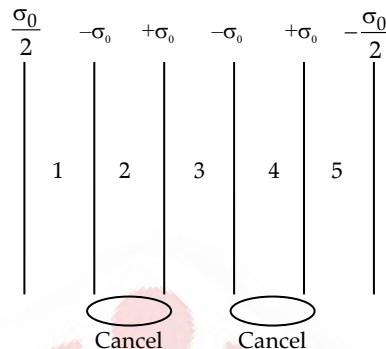$$D = 2f + t - \frac{t}{n_o} = 2f + t\left(1 - \frac{1}{n_o}\right)$$

7. Correct option is (A).

Electric field due to sheet, $E = \frac{\sigma}{2\varepsilon_0}$.

The net charge density around region 4 is zero. Hence, $E_4 = 0$.

Option (A) is correct.

For region 3 of the Configuration II,

$$E_3' = \frac{\frac{\sigma_0}{2}}{2\varepsilon_0}\hat{i} + \frac{\frac{\sigma_0}{2}}{2\varepsilon_0}\hat{i} = \frac{\sigma_0}{2\varepsilon_0}\hat{i}$$

Option (B) is incorrect.

$$\Delta V = E \cdot d$$
$$E = E_1 + E_2 + E_3 + E_4 + E_5$$

$$= \frac{\sigma}{\varepsilon_0} + 0 + \frac{\sigma}{\varepsilon_0} + 0 + \frac{\sigma}{\varepsilon_0}$$

$$\Delta V = \frac{3\sigma}{\varepsilon_0} \cdot d = \frac{3 \times 9 \times 10^{-6}}{9 \times 10^{-12}} \times 10^{-6} = 3\ \text{V}$$

Option (C) is incorrect.

For Configuration II, $E' = E_1 + E_2 + E_3 + E_4 + E_5$

$$= \frac{\sigma}{2\varepsilon_0} + 0 + \frac{\sigma}{2\varepsilon_0} + 0 + \frac{\sigma}{2\varepsilon_0} = \frac{3\sigma}{2\varepsilon_0}$$
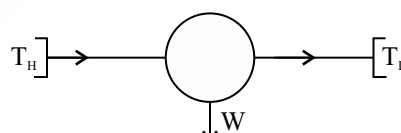
as $E' \neq 0$.

Voltage between first and last plate cannot be zero.

Option (D) is incorrect.

8. Correct options are (A, B, C).

For Carnot engine,

$$\eta = 1 - \frac{T_L}{T_H}$$

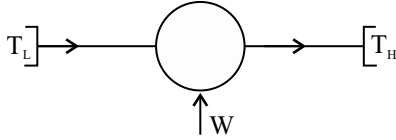
$$0.4 = 1 - \frac{T_L}{1000}$$

$$\frac{T_L}{1000} = 0.6$$

$$T_L = 600\ \text{K}$$

Now, $\quad \eta = \frac{\Delta W}{Q_1} = \frac{\Delta W}{150} = 0.4$

$$\Delta W = 0.4 \times 150 = 60\ \text{J}$$

For pump:

$$\beta = \frac{Q_1}{W}$$

$$10 = \frac{Q_1}{60} \Rightarrow Q_1 = 600\,\text{J}$$

$$\beta = \frac{T_H}{T_H - T_L} = \frac{300}{300 - T_L} = 10$$

$$30 = 300 - T_L$$
$$T_L = 270\,\text{K}$$

Therefore, option (A), (B) & (C) are correct.

9. Correct answer is [1.67].

As sphere is conducting, all the charges will be at outer surface, so it will behave like hollow sphere (in terms of charges):

$$M_{\text{conducting shell}} = Q\frac{\frac{2}{3}MR^2W}{2M} \qquad \text{...(i)}$$

$$L = \frac{2}{5}MR^2W \qquad \text{...(ii)}$$

On dividing Eq. (i) by Eq. (ii), we get,

$$\frac{\frac{2}{3}MR^2QW}{2M} = \frac{5}{6}\frac{Q}{M} \text{ or } \frac{5}{3}\frac{Q}{2M}$$

Comparing above value with $\alpha\frac{Q}{2M}$, we get

$$\alpha = \frac{5}{3} \text{ or } 1.67$$

10. Correct answer is [11.8].

$$KE = h\nu_1 - 13.6$$
$$10 = h\nu_1 - 13.6$$
$$h\nu_1 = 23.6\,\text{eV}$$

Then $e^- + e^+$ emit photon

$$E_0 = \frac{-13.6Z^2}{n^2}\frac{\mu}{M_c} = \frac{-13.6}{2} = -6.8 \text{ eV}$$

$$10 = -6.8 + 5 + h\nu_2$$
$$h\nu_2 = 11.8\,\text{eV}$$
$$\Delta h\nu = h\nu_1 - h\nu_2 = 23.6 - 11.8 = 11.8$$

11. Correct answer is [1.6].

Given, $\quad V_w = 64\,\text{cm}^3$
$$V_x = 125\,\text{cm}^3$$
$$V_y = 250\,\text{cm}^3$$

From $x \to y$ (in isobaric process),

$$Q = nC_P(\Delta T) = nC_P(T_y - T_x)$$
$$Q = nC_P(2T_x - T_x)$$
$$\text{[as } V_y = 2V_x \text{ and } P = \text{const.]}$$
$$= \frac{5}{2}nRT_x \qquad \text{...(i) so } T_y = 2T_x$$

For $X - W$ (adiabatic process),

$$T_WV_W^{\gamma-1} = T_xV_x^{\gamma-1} \qquad \gamma = \frac{5}{3}$$

$$T_WV_W^{2/3} = T_xV_x^{2/3}$$

$$T_x = T_W\left(\frac{V_W}{V_x}\right)^{\frac{2}{3}} = T_W\left(\frac{64}{125}\right)^{\frac{2}{3}} = \frac{16}{25}T_w \qquad \text{...(ii)}$$

From Eqs. (i) and (ii),

$$Q = \frac{5}{2}nR\cdot\frac{16}{25}T_W = \frac{8}{5}nRT_w$$

$$= \frac{8}{5}\times 1 \qquad \text{(Given, } nRT_w = 1\text{ J)}$$

$$= 1.6$$

12. Correct answer is [2.33].

As per Kepler's third law, $T^2 \propto r^3$

$$\left(\frac{T_1}{T_2}\right)^2 = \left(\frac{r_1}{r_2}\right)^3$$

$$\Rightarrow \left(\frac{T_1}{T_2}\right)^2 = \left(\frac{1.21r_2}{r_2}\right)^3 = (1.21)^3$$

$$\left(\frac{24}{T_2}\right)^2 = (1.21)^3 \qquad [\because T_1 = 24\text{ hr}]$$

$$\frac{24}{T_2} = (1.21)^{\frac{3}{2}}$$

$$T_2 = \frac{24}{(1.21)^{\frac{3}{2}}} = \frac{24}{1.331} = 18\text{ h}$$

$$T_{21} \text{ (in angular frame)} = \frac{2\pi}{\omega_1 + \omega_2}$$

$$T_{21} = \frac{2\pi}{\frac{2\pi}{T_1}+\frac{2\pi}{T_2}} = \frac{2\pi}{2\pi\left(\frac{T_2+T_2}{T_1T_2}\right)} = \frac{T_1T_2}{T_1+T_2}$$

$$T_{21} = \frac{24\times 18}{24 + 18} = \frac{24\times 18}{42} = \frac{24}{\frac{42}{18}}$$

Comparing with $\frac{24}{P}$, we get $P = \frac{42}{18} = 2.33$

13. Correct answer is [0.2].

In equation net pressure from both side will be equal.

$$P_1 = P_2 + \frac{K}{A}\left(\frac{L}{2} - \frac{2L}{5}\right)$$

$$P_1 = P_2 + \frac{KL}{10A}$$

Also, $\qquad \frac{P_1V_1}{n_1} = \frac{P_2V_2}{n_2}$

$$\left(P_2 + \frac{KL}{10A}\right)\cdot\frac{\frac{1}{3}}{2} = \frac{P_2}{1}$$

$\Rightarrow \qquad \dfrac{2}{3}P_2 + \dfrac{KL}{15A} = P_2$

$\Rightarrow \qquad \dfrac{KL}{15A} = \dfrac{P_2}{3}$

$\Rightarrow \qquad P_2 = \dfrac{KL}{A} \cdot \dfrac{1}{5}$

On comparison, we get $\alpha = \dfrac{1}{5}$ or 0.2

14. Correct answer is [1.2].

$\Delta x = S_2 P + \mu_B \times 9 + \mu_A \times 3 - (S_1 P + \mu_B \times 3 + \mu_A \times 9)$

$\Delta x_p = (S_2 P - S_1 P) + 6\,\mu_A - 6\mu_B = 0$

$= ((S_2 P - S_1 P) + 6\,(\mu_A - \mu_B) = d\sin\theta + 6\,(\mu_A - \mu_B)$

$0 = d\sin\theta + 6\,(17 - 1.5)$

$d\left(\dfrac{V}{3}\right) = -6 \times 0.2 = -1.2\,\mu_m$

$y = \dfrac{-1.2 \times 10^{-12} \times 2\ \text{m}}{2 \times 10^{-3}} = -1.2\ \text{mm}$

15. Correct answer is [170].

Given, $\qquad \vec{F} = c\vec{v}$, where $c = 0.1$ kg/s

$Ma_x = -cv_x$

$a_x = -\dfrac{c}{M}v_x$

$a_x = \dfrac{0.1}{0.2}v_x$

$\dfrac{dv_x}{dt} = -\dfrac{v_x}{2}$

Integrating both sides,

$\displaystyle\int_{u\cos\theta}^{v_x} \dfrac{dv_x}{v_x} = -\int_0^t \dfrac{dt}{2}$

$(\ln v_x)_{u\cos 60}^{v_x} = -\left(\dfrac{t}{2}\right)_0^t$

$(\ln v_x)_{\frac{270}{2}}^{v_x} = \dfrac{-t}{2}$

$v_x = \dfrac{270}{2}e^{\left(-\frac{t}{2}\right)}$

Now, $\qquad v_x = 135 e^{\left(-\frac{t}{2}\right)}$

$\dfrac{dx}{dt} = 135 e^{\left(-\frac{t}{2}\right)}$

$\displaystyle\int_0^x dx = \int_0^t 135 e^{\left(-\frac{t}{2}\right)} dt$

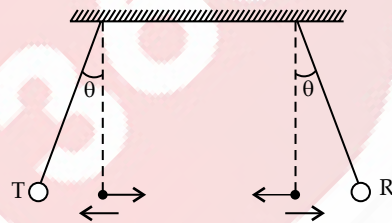$x = -135(e^{-\frac{t}{2}})_0^t \cdot 2$

$x = -270(e^{-\frac{t}{2}} - 1)$

$= -270(e^{-\frac{2}{2}} - 1)$

$= -270\left(\dfrac{1}{e} - 1\right)$

$= 270\left(1 - \dfrac{1}{e}\right)$

$= 270 \times 0.6296 = \sim 170$

16. Correct option is [32].

$v_{\max} = \sqrt{2gl(1 - \cos\theta)}$

$= \sqrt{2 \times 10 \times 8 \times (1 - 0.9)} = 4$ m/s

$f_{\max} = f_0\left(\dfrac{v + v_0}{v - v_0}\right) \qquad \Big| \qquad f_{\min} = f_0\left(\dfrac{v - v_0}{v + v_0}\right)$

$= 660\left(\dfrac{334}{326}\right) = 676.19 \qquad \Big| \qquad = 660 \times \dfrac{326}{334} = 644.19$

$\Delta f = f_{\max} - f_{\min}$

$= 676.19 - 644.19 = 32$ Hz