

## JEE (ADVANCED)-2024

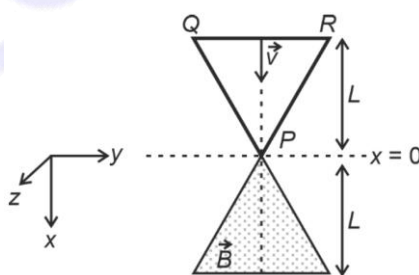
## PAPER-2

## PHYSICS

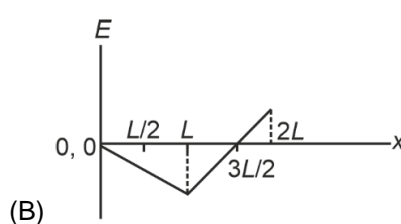
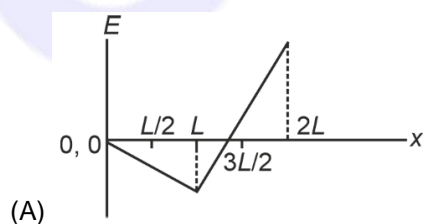
## SECTION 1 (Maximum Marks: 12)

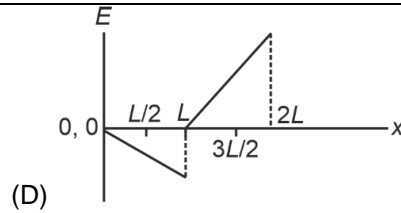
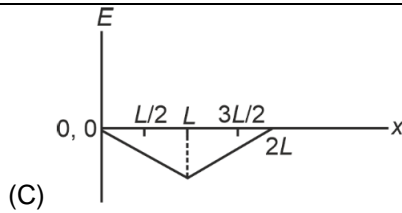
- This section contains **FOUR (04)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:  
 Full Marks : +3 If **ONLY** the correct option 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 region in the form of an equilateral triangle (in  $x-y$  plane) of height  $L$  has a uniform magnetic field  $\vec{B}$  pointing in the  $+z$ -direction. A conducting loop PQR, in the form of an equilateral triangle of the same height  $L$ , is placed in the  $x-y$  plane with its vertex  $P$  at  $x=0$  in the orientation shown in the figure. At  $t=0$ , the loop starts entering the region of the magnetic field with a uniform velocity  $\vec{v}$  along the  $+x$ -direction. The plane of the loop and its orientation remain unchanged throughout its motion.



Which of the following graph best depicts the variation of the induced emf ( $E$ ) in the loop as a function of the distance ( $x$ ) starting from  $x=0$ ?





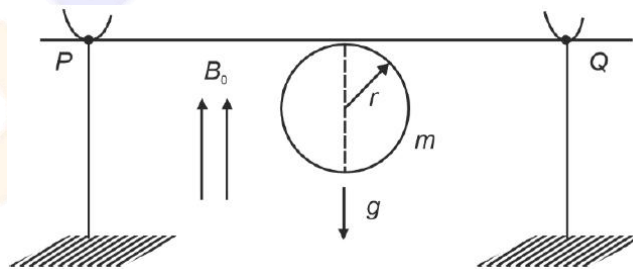
2. A particle of mass  $m$  is under the influence of the gravitational field of a body of mass  $M$  ( $\gg m$ ). The particle is moving in a circular orbit of radius  $r_0$  with time period  $T_0$  around the mass  $M$ . Then, the particle is subjected to an additional central force, corresponding to the potential energy  $V_c(r) = m\alpha / r^3$ , where  $\alpha$  is a positive constant of suitable dimensions and  $r$  is the distance from the center of the orbit. If the particle moves in the same circular orbit of radius  $r_0$  in the combined gravitational potential due to  $M$  and  $V_c(r)$ , but with a new time period  $T_1$ , then  $(T_1^2 - T_0^2) / T_1^2$  is given by [ $G$  is the gravitational constant.]

- (A)  $\frac{3\alpha}{GM r_0^2}$  (B)  $\frac{\alpha}{2GM r_0^2}$  (C)  $\frac{\alpha}{GM r_0^2}$  (D)  $\frac{2\alpha}{GM r_0^2}$

3. A metal target with atomic number  $Z = 46$  is bombarded with a high energy electron beam. The emission of X-rays from the target is analyzed. The ratio  $r$  of the wavelengths of the  $K_\alpha$ -line and the cut-off is found to be  $r = 2$ . If the same electron beam bombards another metal target with  $Z = 41$ , the value of  $r$  will be

- (A) 2.53 (B) 1.27 (C) 2.24 (D) 1.58

4. A thin stiff insulated metal wire is bent into a circular loop with its two ends extending tangentially from the same point of the loop. The wire loop has mass  $m$  and radius  $r$  and it is in a uniform vertical magnetic field  $B_0$ , as shown in the figure. Initially, it hangs vertically downwards, because of acceleration due to gravity  $g$ , on two conducting supports at  $P$  and  $Q$ . When a current  $I$  is passed through the loop, the loop turns about the line  $PQ$  by an angle  $\theta$  given by



- (A)  $\tan \theta = \pi r / B_0 / (mg)$  (B)  $\tan \theta = 2\pi r / B_0 / (mg)$   
(C)  $\tan \theta = \pi r / B_0 / (2mg)$  (D)  $\tan \theta = mg / (\pi r B_0)$

## SECTION 2 (Maximum Marks : 12)

- This section contains **THREE (03)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

*Full Marks* : +4 **ONLY** if (all) the correct option(s) is(are) chosen;

*Partial Marks* : +3 If all the four options are correct but **ONLY** three options are chosen;

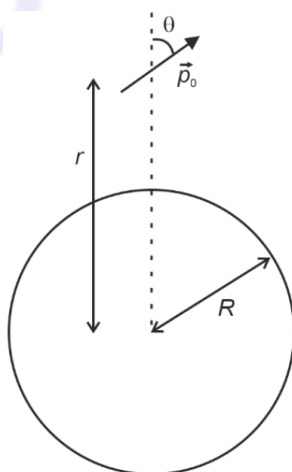
*Partial Marks* : +2 If three or more options are correct but **ONLY** two options are chosen, both of which are correct;

*Partial Marks* : +1 If two or more options are correct but **ONLY** one option is chosen and it is a correct option;

*Zero Marks* : 0 If unanswered;

*Negative Marks* : -2 In all other cases.

5. A small electric dipole  $\vec{p}_0$ , having a moment of inertia  $I$  about its center, is kept at a distance  $r$  from the center of a spherical shell of radius  $R$ . The surface charge density  $\sigma$  is uniformly distributed on the spherical shell. The dipole is initially oriented at a small angle  $\theta$  as shown in the figure. While staying at a distance  $r$ , the dipole is free to rotate about its center.



If released from rest, then which of the following statement(s) is (are) correct? [ $\epsilon_0$  is the permittivity of free space.]

- (A) The dipole will undergo small oscillations at any finite value of  $r$ .
- (B) The dipole will undergo small oscillations at any finite value of  $r > R$ .

(C) The dipole will undergo small oscillations with an angular frequency of  $\sqrt{\frac{2\sigma p_0}{\epsilon_0 I}}$  at  $r = 2R$

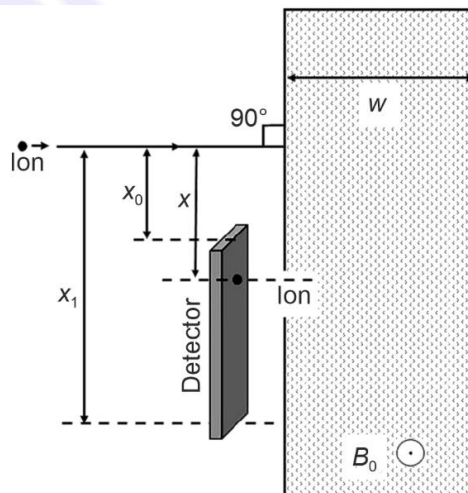
(D) The dipole will undergo small oscillations with an angular frequency of  $\sqrt{\frac{\sigma p_0}{100\epsilon_0 I}}$  at  $r = 10R$

6. A table tennis ball has radius  $(3/2) \times 10^{-2}$  m and mass  $(22/7) \times 10^{-3}$  kg. It is slowly pushed down into a swimming pool to a depth of  $d = 0.7$  m below the water surface and then released from rest. It emerges from the water surface at speed  $v$ , without getting wet, and rises up to a height  $H$ . Which of the following option(s) is (are) correct?

[Given:  $\pi = 22/7$ ,  $g = 10 \text{ ms}^{-2}$ , density of water  $= 1 \times 10^3 \text{ kg m}^{-3}$ , viscosity of water  $= 1 \times 10^{-3} \text{ Pa-s}$ .]

- (A) The work done in pushing the ball to the depth  $d$  is 0.077 J.
- (B) If we neglect the viscous force in water, then the speed  $v = 7 \text{ m/s}$ .
- (C) If we neglect the viscous force in water, then the height  $H = 1.4 \text{ m}$ .
- (D) The ratio of the magnitudes of the net force excluding the viscous force to the maximum viscous force in water is  $500/9$ .
7. A positive, singly ionized atom of mass number  $A_M$  is accelerated from rest by the voltage 192 V. Thereafter, it enters a rectangular region of width  $w$  with magnetic field  $\vec{B}_0 = 0.1\hat{k}$  Tesla, as shown in the figure. The ion finally hits a detector at the distance  $x$  below its starting trajectory.

[Given: Mass of neutron/proton  $= (5/3) \times 10^{-27} \text{ kg}$ , charge of the electron  $= 1.6 \times 10^{-19} \text{ C}$ .]

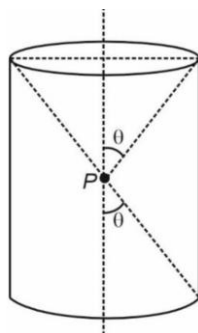


- (A) The value of  $x$  for  $\text{H}^+$  ion is 4 cm.
- (B) The value of  $x$  for an ion with  $A_M = 144$  is 48 cm.
- (C) For detecting ions with  $1 \leq A_M \leq 196$ , the minimum height  $(x_1 - x_0)$  of the detector is 55 cm.
- (D) The minimum width  $w$  of the region of the magnetic field for detecting ions with  $A_M = 196$  is 56 cm.

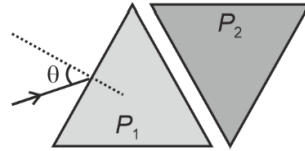
## SECTION 3 (Maximum Marks: 24)

- This section contains **SIX (06)** questions.
- The answer to each question is a **NON-NEGATIVE INTEGER**.
- For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:  
*Full Marks* : +4 If **ONLY** the correct integer is entered;  
*Zero Marks* : 0 In all other cases.

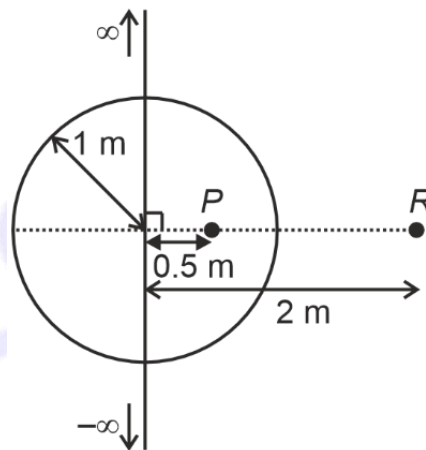
8. The dimensions of a cone are measured using a scale with a least count of 2 mm. The diameter of the base and the height are both measured to be 20.0 cm. The maximum percentage error in the determination of the volume is
9. A ball is thrown from the location  $(x_0, y_0) = (0, 0)$  of a horizontal playground with an initial speed  $v_0$  at an angle  $\theta_0$  from the  $+x$ -direction. The ball is to be hit by a stone, which is thrown at the same time from the location  $(x_1, y_1) = (L, 0)$ . The stone is thrown at an angle  $(180 - \theta_1)$  from the  $+x$ -direction with a suitable initial speed. For a fixed  $v_0$ , when  $(\theta_0, \theta_1) = (45^\circ, 45^\circ)$ , the stone hits the ball after time  $T_1$ , and when  $(\theta_0, \theta_1) = (60^\circ, 30^\circ)$ , it hits the ball after time  $T_2$ . In such a case,  $(T_1 / T_2)^2$  is \_\_\_\_.
10. A charge is kept at the central point  $P$  of a cylindrical region. The two edges subtend a half-angle  $\theta$  at  $P$ , as shown in the figure. When  $\theta = 30^\circ$ , then the electric flux through the curved surface of the cylinder is  $\Phi$ . If  $\theta = 60^\circ$ , then the electric flux through the curved surface becomes  $\Phi / \sqrt{n}$ , where the value of  $n$  is \_\_\_\_.



11. Two equilateral-triangular prisms  $P_1$  and  $P_2$  are kept with their sides parallel to each other, in vacuum, as shown in the figure. A light ray enters prism  $P_1$  at an angle of incidence  $\theta$  such that the outgoing ray undergoes minimum deviation in prism  $P_2$ . If the respective refractive indices of  $P_1$  and  $P_2$  are  $\sqrt{\frac{3}{2}}$  and  $\sqrt{3}$ ,  $\theta = \sin^{-1} \left[ \sqrt{\frac{3}{2}} \sin \left( \frac{\pi}{\beta} \right) \right]$ , where the value of  $\beta$  is \_\_\_\_\_.



12. An infinitely long thin wire, having a uniform charge density per unit length of  $5\text{ nC/m}$ , is passing through a spherical shell of radius  $1\text{ m}$ , as shown in the figure. A  $10\text{ nC}$  charge is distributed uniformly over the spherical shell. If the configuration of the charges remains static, the magnitude of the potential difference between points  $P$  and  $R$ , in Volt, is. [Given: In SI units  $\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ ,  $\ln 2 = 0.7$ . Ignore the area pierced by the wire.]



13. A spherical soap bubble inside an air chamber at pressure  $P_0 = 10^5\text{ Pa}$  has a certain radius so that the excess pressure inside the bubble is  $\Delta P = 144\text{ Pa}$ . Now, the chamber pressure is reduced to  $8P_0/27$  so that the bubble radius and its excess pressure change. In this process, all the temperatures remain unchanged. Assume air to be an ideal gas and the excess pressure  $\Delta P$  in both the cases to be much smaller than the chamber pressure. The new excess pressure  $\Delta P$  in Pa is

#### SECTION 4 (Maximum Marks: 12)

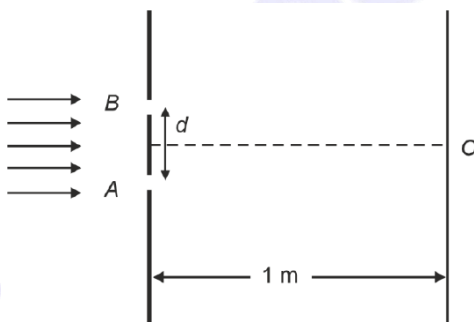
- This section contains **TWO (02)** paragraphs.
- Based on each paragraph, there are **TWO (02)** questions.



- The answer to each question is a **NUMERICAL VALUE**.
- For each question, enter the correct numerical value of the answer using the mouse and the onscreen virtual numeric keypad in the place designated to enter the answer.
- If the numerical value has more than two decimal places, **truncate/round-off** the value to **TWO** decimal places.
- Answer to each question will be evaluated according to the following marking scheme:  
*Full Marks* : +3 If ONLY the correct numerical value is entered in the designated place;  
*Zero Marks* : 0 In all other cases.

**PARAGRAPH I (14 to 15)**

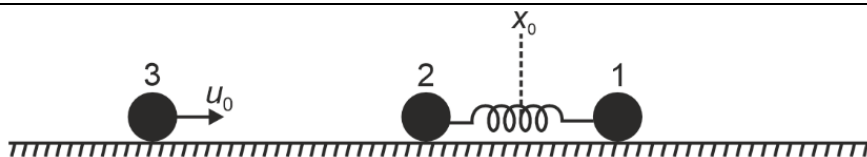
In a Young's double slit experiment, each of the two slits  $A$  and  $B$ , as shown in the figure, are oscillating about their fixed center and with a mean separation of  $0.8\text{ mm}$ . The distance between the slits at time  $t$  is given by  $d = (0.8 + 0.04 \sin \omega t)\text{ mm}$ , where  $\omega = 0.08\text{ rad s}^{-1}$ . The distance of the screen from the slits is  $1\text{ m}$  and the wavelength of the light used to illuminate the slits is  $6000\text{ \AA}$ . The interference pattern on the screen changes with time, while the central bright fringe (zeroth fringe) remains fixed at point  $O$ .



- The 8<sup>th</sup> bright fringe above the point  $O$  oscillates with time between two extreme positions. The separation between these two extreme positions, in micrometer ( $\mu\text{m}$ ), is
- The maximum speed in  $\mu\text{m/s}$  at which the 8<sup>th</sup> bright fringe will move is.

**PARAGRAPH II (16 to 17)**

Two particles, 1 and 2, each of mass  $m$ , are connected by a massless spring, and are on a horizontal frictionless plane, as shown in the figure. Initially, the two particles, with their center of mass at  $x_0$ , are oscillating with amplitude  $a$  and angular frequency  $\omega$ . Thus, their positions at time  $t$  are given by  $x_1(t) = (x_0 + d) + a \sin \omega t$  and  $x_2(t) = (x_0 - d) - a \sin \omega t$ , respectively, where  $d > 2a$ . Particle 3 of mass  $m$  moves towards this system with speed  $u_0 = a\omega/2$ , and undergoes instantaneous elastic collision with particle 2, at time  $t_0$ . Finally, particles 1 and 2 acquire a center of mass speed  $v_{\text{cm}}$  and oscillate with amplitude  $b$  and the same angular frequency  $\omega$ .



16. If the collision occurs at time  $t_0 = 0$ , the value of  $v_{cm} / (a\omega)$  will be
17. If the collision occurs at time  $t_0 = \pi / (2\omega)$ , then the value of  $4b^2 / a^2$  will be

## ANSWER KEY

1. (A) 2. (A) 3. (A) 4. (A) 5. (B, D) 6. (A, B, D)
7. (A, B) 8. 3 9. 2 10. 3 11. 12 12. 17 13. 96
14. 601.50 15. 24.00 16. 00.75 17. 04.25