Series: AP411

SESSION – 2

Subject Code: SPO

Roll No.: | | | | | | | | | | | | |

Candidates must write the Roll No on the title page of the Question Paper.

Physics | Level 4

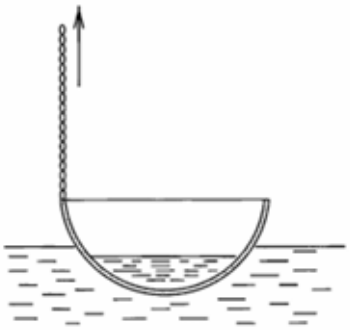
Time allowed: 1.5 hours Maximum Marks: 150

Instructions for Candidates:

1. Please verify that this question paper contains **12** printed pages and Ensure that the paper contains a total of **50** questions.
2. Use of mobile phones, smartphones, ipads during examination is **STRICTLY PROHIBITED**.
3. On the OMR sheet, enter all required information carefully in the space provided **ONLY IN BLOCK CAPITALS** and by properly darkening the corresponding bubbles. Incomplete, incorrect, or careless entries may lead to disqualification.
4. Use only a **BLUE or BLACK BALL POINT PEN** for writing entries and filling bubbles. Pencils or other pens are not permitted.
5. **Marking Scheme:** Each question has four alternatives, only one of which is correct. Select the correct option and darken the respective bubble.
   – Each correct answer carries **3 marks**.
   – Each incorrect answer attracts a penalty of **1 mark**.
   – No marks are awarded for unanswered questions.
6. Use only the space provided in the question paper for rough work.
7. Candidates must remain in the examination hall until the exam is officially over. Early exit is not allowed.
8. Do not make stray marks, symbols, or extra writing on the OMR sheet. Fill only the designated bubbles neatly.
9. Since OMR sheets are machine evaluated, changes in entries are **strictly not allowed**.
10. Avoid scratching, overwriting, or erasing, as these may result in wrong evaluation.
11. **DO NOT write anything on the back side** of the OMR sheet.

Multiple Choice Questions

1. Corn soup is prepared in a hemispherical metal bowl of diameter 40 cm. The bowl is placed into the water of a lake to cool down and floats with 10 cm of its depth immersed. A point on the rim of the bowl is pulled upwards through 10 cm by a chain fastened to it. Does water flow into the bowl?



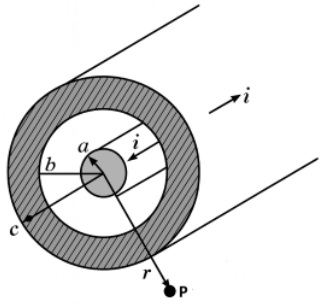
(A) Yes, water flows into the bowl.

(B) No, water does not flow into the bowl.

(C) Water may or may not flow, depending on the soup's density.

(D) The bowl sinks deeper and tilts, so the situation is indeterminate.

2. A coaxial cable having radii a, b, and c carries equal and opposite currents of magnitude i on the inner and outer conductors. What is the magnitude of the magnetic induction at point P outside the cable at a distance r from the axis?



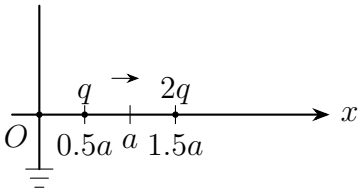
(A) Zero

(B) $\dfrac{\mu_0 i r}{2\pi a^2}$

(C) $\dfrac{\mu_0 i}{2\pi r}$

(D) $\dfrac{\mu_0 i}{2\pi r}\dfrac{c^2 - r^2}{c^2 - b^2}$

3. Two point charges of magnitudes q and $2q$ are placed on the x-axis at positions $x = 0.5a$ and $x = 1.5a$, respectively, as illustrated. An infinite grounded conducting plane is present at $x = 0$. Determine the magnitude of the net electrostatic force acting on the charge q.



(A) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{q^2}{a^2}$

(B) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{2q^2}{a^2}$

(C) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{3q^2}{a^2}$

(D) $\dfrac{1}{4\pi\varepsilon_0}\dfrac{7q^2}{2a^2}$

4. A thin soap film, having a refractive index greater than that of air, is stretched

over a circular wire frame and held vertically. When the film is illuminated by white light and observed in reflection, colorful interference fringes are seen in the lower region, while the upper portion appears dark.

Which of the following statements correctly explain this observation?

I. The upper region of the film absorbs all incident light, and no reflection occurs.

II. The thickness of the upper region of the film is much smaller than the wavelength of visible light.

III. Light reflected from the front surface of the film undergoes a phase shift of $180°$.

IV. Light reflected from the back surface of the film does not experience any phase shift.

(A) II and III only

(B) II, III, and IV

(C) III and IV only

(D) I, II, and III

5. A solid cylinder rolls on a horizontal surface with a constant velocity, without slipping. At the instant when a point on the rim of the cylinder comes into contact with the surface, what is the direction of its acceleration?

(A) Forward

(B) Backward

(C) Upward

(D) Downward

6. In a double-slit interference experiment, the separation between the slit centers is d, and each slit has a width w. For normally incident light, an interference maximum on the distant screen will be absent when:

(A) $d = \sqrt{2}\,w$

(B) $d = \sqrt{3}\,w$

(C) $2d = 3w$

(D) $3d = 2w$

7. Which of the following types of bonding is responsible for holding atoms together in solid argon?

(A) Ionic bonding only

(B) Covalent bonding only

(C) Partly covalent and partly ionic bonding

(D) van der Waals bonding

8. In underground laboratories, only certain types of cosmic rays penetrate deep enough to reach detectors. The two kinds of cosmic rays that most frequently reach such detectors are:

(A) Protons and electrons

(B) Iron nuclei and neutrons

(C) Muons and neutrinos

(D) Positrons and electrons

9. If the ground-state binding energy of a hydrogen atom is $E_0 = 13.6$ eV, what is the binding energy of a positronium system (electron–positron pair) in the $n = 2$ state?

(A) $8E_0$

(B) $\dfrac{E_0}{8}$

(C) $4E_0$

(D) $\dfrac{E_0}{4}$

10. A uniform cylinder of moment of inertia 4 kg·m^2 rotates about a fixed axis at an initial angular speed of 80 rad/s. If a constant torque slows it down to 40 rad/s, what is the total kinetic energy lost by the cylinder?

    (A) 800 J

    (B) 4000 J

    (C) 9600 J

    (D) 9200 J

11. A ball is dropped from a height h. After rebounding from the floor, its speed becomes 80% of its speed just before impact. To what height will it rise after the bounce?

    (A) $0.80h$

    (B) $0.75h$

    (C) $0.64h$

    (D) $0.60h$

12. A measurement of energy E must always satisfy which of the following relationships?

    (A) $E \leq \dfrac{\pi^2\hbar^2}{8ma^2}$

    (B) $E \geq \dfrac{\pi^2\hbar^2}{2ma^2}$

    (C) $E = \dfrac{\pi^2\hbar^2}{8ma^2}$

    (D) $E = \dfrac{n^2\pi^2\hbar^2}{8ma^2}$

13. If ν is the frequency and h is Planck's constant, the ground-state energy of a one-dimensional quantum harmonic oscillator is:

    (A) 0

    (B) $\dfrac{1}{3}h\nu$

    (C) $\dfrac{1}{2}h\nu$

    (D) $\dfrac{3}{2}h\nu$

14. The ground state of a helium atom corresponds to which spin multiplicity?

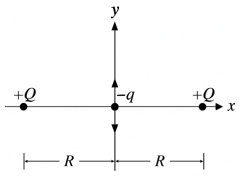
    (A) Singlet

    (B) Doublet

    (C) Triplet

    (D) Quartet

15. Two identical positive charges $+Q$ are fixed along the x-axis, separated by a distance $2R$. A small particle of mass m and charge $-q$ is placed midway between them. Determine the angular frequency ω of small oscillations of the particle along the y-axis.



    (A) $\dfrac{Qq}{4\pi\varepsilon_0 mR^2}$

    (B) $\dfrac{Qq}{2\pi\varepsilon_0 mR^3}$

    (C) $\left(\dfrac{Qq}{4\pi\varepsilon_0 mR^2}\right)^{1/2}$

    (D) $\left(\dfrac{Qq}{2\pi\varepsilon_0 mR^2}\right)^{1/2}$

16. The electronic configuration $1s^2 2p^3 p$ corresponds to three electrons. Which of the following represents the maximum possible total angular momentum quantum number?

    (A) $\dfrac{7}{2}$

    (B) 3

    (C) $\dfrac{5}{2}$

    (D) 2

17. An electron oscillates along the x-axis, emitting electromagnetic radiation. Which one of the following statements about the emitted radiation is **not true**?

    (A) The total power radiated in all directions is proportional to the square of the electron's acceleration.

    (B) The total power radiated in all directions is proportional to the square of the electron's charge.

    (C) At large distances, the power crossing a unit area decreases as the inverse square of the distance from the electron.

    (D) At large distances, the radiated intensity is maximum along the $\pm x$-directions.

18. A free electron with rest mass $m_e = 0.5$ MeV$/c^2$ has a total energy of 1.5 MeV. The momentum p of the electron, expressed in MeV$/c$, is approximately:

    (A) 0.86

    (B) 1.0

    (C) 1.4

    (D) 1.5

19. A particle of mass M moves in a circular orbit of radius r under the influence of an attractive force $F = \dfrac{K}{r^3}$, where K is a constant. If the potential energy is zero at infinity, the total energy of the particle in the orbit is:

    (A) $-\dfrac{K}{r^2}$

    (B) $-\dfrac{K}{2r^2}$

    (C) 0

    (D) $\dfrac{K}{2r^2}$

20. A parallel-plate capacitor is connected to a battery that maintains a potential difference V_0 across the plates. The charge on the positive plate is Q_0, the electric field between the plates is E_0, and the displacement vector has magnitude D_0. When a dielectric is inserted between the plates and the battery is then disconnected, which of the following relationships correctly describes the final state (denoted by subscript f)?

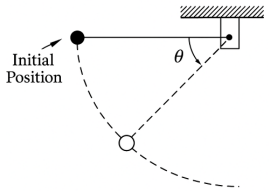
    (A) $V_f < V_0$

    (B) $Q_f = Q_0$

    (C) $E_f > E_0$

    (D) $D_f > D_0$

21. A small mass is tied to a light inextensible string that wraps around a fixed vertical post, as shown. The mass is released from rest when the string is horizontal. At a general position where the string makes an angle θ with the horizontal, the magnitude of the mass's total acceleration is:



    (A) $2g\cos\theta$

    (B) $2g\sin\theta$

    (C) $g\sqrt{3\cos^2\theta + 1}$

    (D) $g\sqrt{3\sin^2\theta + 1}$

22. A particle of mass m executes simple harmonic motion with period T_0. A linear damping force $f = -b\,v$ is then applied, yet the motion remains oscillatory. With the damping present, the period becomes

    (A) larger than T_0

(B) smaller than T_0

(C) independent of b

(D) proportional to b

23. In the hydrogen spectrum, find the ratio of the *longest* wavelength in the Lyman series ($n_f = 1$) to the *longest* wavelength in the Balmer series ($n_f = 2$).

(A) $\dfrac{5}{27}$

(B) $\dfrac{1}{3}$

(C) $\dfrac{4}{9}$

(D) $\dfrac{3}{2}$

24. Two identical copper blocks (1.0 kg each) are placed in a perfectly insulated container. Initially, one is at $T_1 = 0°$C and the other at $T_2 = 100°$C. After contact, they reach a common temperature T_f. How much heat is exchanged between the blocks? (Take copper's specific heat as 0.1 kcal kg^{-1} K^{-1}.)

(A) 50 kcal

(B) 25 kcal

(C) 10 kcal

(D) 5 kcal

25. A circular hoop of mass 3 kg and radius 0.20 m hangs from a small nail (about a point on its rim) and is displaced slightly. The period of small oscillations of this physical pendulum is (use $T = 2\pi\sqrt{I/(mgd)}$ with d the distance from pivot to CM)

(A) 0.63 s

(B) 1.0 s

(C) 1.3 s

(D) 1.8 s

26. A sphere of mass m is released from rest in a large tank of viscous fluid. Besides gravity mg, it experiences a retarding force $b\,v$ (with constant b and speed v). Neglect buoyancy. Which statement is correct?

(A) Its kinetic energy rises to a maximum and then falls to zero due to drag.

(B) Its speed increases monotonically to a terminal speed depending on both b and m.

(C) Its speed increases to a maximum, then decreases to a smaller steady value.

(D) Its speed increases monotonically to a terminal speed depending on b only.

27. Light originates at the bottom of a pool of water ($n = 1.33$). At what minimum angle of incidence at the water–air interface will total internal reflection occur?

(A) $0°$

(B) $50°$

(C) $75°$

(D) $90°$

28. A man of mass m jumps horizontally from a boat that was initially at rest. Immediately after the jump the boat (mass M) moves to the right with speed v. How much work did the man do during the leap (total KE gained by man + boat)?

(A) $\dfrac{1}{2}mv^2$

(B) $\dfrac{1}{2}(M+m)v^2$

(C) $\dfrac{1}{2}\left(M + \dfrac{M^2}{m}\right)v^2$

(D) $\dfrac{1}{2}\left(\dfrac{Mm}{M+m}\right)v^2$

29. In an n-type semiconductor, which statement best describes the role of donor impurities?

    (A) They accept electrons from valence-band states into levels just below the valence band.

    (B) They accept electrons from the conduction band into levels just below the conduction band.

    (C) They donate electrons to valence-band states from donor levels just above the valence band.

    (D) They donate electrons to the conduction band from donor levels just below the conduction band.

30. For an ideal diatomic gas in thermal equilibrium, the ratio of the molar heat capacity at constant volume in the high-temperature limit to that in the very low-temperature limit is

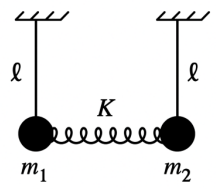
    (A) 1

    (B) $\frac{5}{3}$

    (C) 2

    (D) $\frac{7}{3}$

31. Two simple pendulums are coupled by a light horizontal spring as shown. Both pendulums have the same length ℓ, but their bobs have different masses m_1 and m_2. The separation between the bobs equals the spring's natural length; the spring constant is K. What is the *highest* normal–mode angular frequency of the system?



    (A) $\sqrt{\frac{K}{m_1+m_2}}$

    (B) $\sqrt{\frac{K}{m_1}+\frac{K}{m_2}}$

    (C) $\sqrt{\frac{g}{\ell}+\frac{K}{m_1+m_2}}$

    (D) $\sqrt{\frac{2g}{\ell}+\frac{K}{m_1+m_2}}$

32. Two identical balls A and B are projected from the top of a building. Ball A is thrown upward with velocity v, while ball B is thrown downward with the same velocity v. Which of the following statements is correct?

    (A) The velocity of A is greater than that of B when they reach the ground.

    (B) The velocity of B is greater than that of A when they reach the ground.

    (C) Both A and B strike the ground with the same velocity.

    (D) None of these.

33. For a particle in one–dimensional motion, match the entries of Column I with those of Column II:

Column I	**Column II**
(P) Zero speed but non–zero acceleration.	(1) Body that is about to fall.
(Q) Zero speed and non–zero velocity.	(2) Extreme position of an oscillating body.
(R) Constant speed but non–zero acceleration.	(3) Possible.
(S) Positive acceleration while speeding up.	(4) Not possible.

(A) (P→4), (Q→2), (R→1), (S→3)

(B) (P→2), (Q→1), (R→3), (S→4)

(C) (P→1,2,3), (Q→3), (R→4), (S→1,3)

(D) (P→2), (Q→4), (R→1), (S→3)

34. Rain falls vertically with speed V_r, while a man walks on level ground with speed V_m. If the man holds his umbrella making an angle θ with the vertical to shield himself, then the magnitude of the relative velocity of rain with respect to the man is:

(A) $V_{rm} = \sqrt{V_r^2 + V_m^2 + 2V_rV_m\cos\theta}$

(B) $V_{rm} = \sqrt{V_r^2 + V_m^2 - 2V_rV_m\cos\theta}$

(C) $V_{rm} = \sqrt{V_r^2 + V_m^2}$

(D) $V_{rm} = \sqrt{V_r^2 - V_m^2}$

35. A projectile is launched with a fixed speed on an inclined plane. If the *maximum horizontal range along the plane* is x times the *maximum vertical height above the plane*, find x.

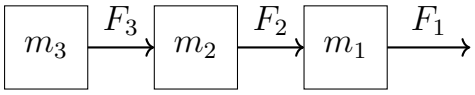
(A) 2

(B) 4

(C) 3

(D) $\frac{1}{2}$

36. For the system on a surface shown in the figure, find the expression for the contact force F_3 acting on mass m_3.



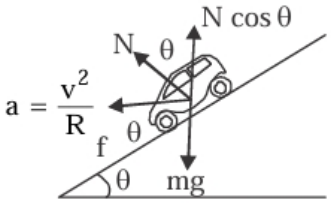
(A) $F_3 = F_1 + F_2$

(B) $F_3 = \dfrac{m_3F}{F_1 + F_2 + F_3}$

(C) $F_3 = \dfrac{m_3F}{m_1 + m_2 + m_3}$

(D) $F_3 = \dfrac{m_3F}{m_1 + m_2}$

37. The motion of a car on a banked road of angle θ is shown. Let N be the normal reaction and f the frictional force on the tyres. The centripetal-force balance along the horizontal (toward the centre of the circular path of radius R) is:



(A) $N\sin\theta + f\cos\theta = \dfrac{mv^2}{R}$

(B) $f = \dfrac{mv^2}{R}$

(C) $N\cos\theta + f = \dfrac{mv^2}{R}$

(D) $N\sin\theta + f = \dfrac{mv^2}{R}$

38. A small block of mass 200 g is placed at the top of an inclined plane of length 10 m and height 3.2 m. Match the quantities in Column I with their corresponding values in Column II.

Column I	**Column II**
(P) Work done in lifting the block from the ground to the top of the incline.	(1) 6.4 J
(Q) Work done in sliding the block up the incline.	(2) 7.2 J
(R) Speed of the block when dropped vertically from the top of the incline.	(3) 4 m/s
(S) Speed of the block when sliding down the incline.	(4) 8 m/s

(a) (P→2), (Q→3), (R→1), (S→4)

(b) (P→1), (Q→1), (R→3), (S→3)

(c) (P→4), (Q→3), (R→2), (S→2)

(d) (P→1), (Q→3), (R→1), (S→2)

39. An electron and a proton interact through mutual electromagnetic forces. When calculating the change in the total kinetic energy of the system, the magnetic force between them is ignored because:

(A) The magnetic forces are equal and opposite, producing no net effect.

(B) Magnetic forces do no work on either particle.

(C) The magnetic forces perform equal and opposite but nonzero work.

(D) The magnetic forces are negligible compared with electric forces.

40. Before a rubber ball rebounds from the floor, it remains in contact with the surface for a short time. Which of the following statements correctly describes this interval?

(A) Conservation of energy does not hold during this interval.

(B) Conservation of energy holds during this interval.

(C) As the ball compresses, its kinetic energy is converted into elastic potential energy.

(D) None of these.

41. A stick is thrown into the air and lands on the ground at some distance from the thrower. The path followed by its centre of mass will be parabolic:

(A) In all cases.

(B) Only if the stick is uniform.

(C) Only if the stick translates without rotation.

(D) Only if the centre of mass lies within the stick and not outside it.

42. Two air bubbles present in water:

(A) attract each other

(B) repel each other

(C) neither attract nor repel

(D) none of these

43. Two wires of equal length are made of the same material. Wire A has a diameter twice that of wire B. If identical weights are suspended from their free ends, the increase in length will be:

(A) Four times greater for wire A than for wire B

(B) Twice as great for wire A as for wire B

(C) Half as great for wire A as for wire B

(D) One–fourth as great for wire A as for wire B

44. Consider the following statements and select the true one(s):

I. When two soap bubbles of different sizes are connected by a capillary tube, the smaller bubble shrinks and the larger bubble expands until equilibrium is reached.

II. Raindrops fall to the ground with the same constant speed.

III. A hydrogen-filled balloon eventually stops rising after reaching a particular height in the atmosphere.

(A) I only

(B) II only

(C) III only

(D) I and III

45. A beaker is completely filled with water at 4°C. If the temperature of the water is first increased by a few degrees above 4°C and then decreased by a few degrees below 4°C, one will observe that:

(A) The water level remains constant in both cases.

(B) In the first case, the water level falls, while in the second case, it rises.

(C) In the second case, the water overflows, while in the first case, the level falls.

(D) The water overflows in both cases.

46. A block of ice floats on a liquid of density 1.2 in a beaker. What happens to the level of the liquid when the ice melts completely?

(A) It remains the same

(B) It rises

(C) It falls

(D) Either (b) or (c)

47. Choose the correct statements from the following:

I. Free expansion of a gas is an irreversible process.

II. The combustion of a petrol–air mixture ignited by a spark is an irreversible process.

III. The leakage of gas from a kitchen cylinder cannot reverse on its own.

IV. The transfer of heat from a hotter region to a colder region of a liquid is an irreversible process.

(A) I, II and IV

(B) III and IV

(C) II, III and IV

(D) I, II, III and IV

48. An infinitely long conducting cylinder is placed parallel to a uniform magnetic field $\mathbf{B}$ directed along the positive z–axis. The direction of the induced current, as viewed looking along the $+z$–axis, will be:

(A) Zero

(B) Anticlockwise

(C) Clockwise

(D) Along the direction of the magnetic field

49. The de Broglie wavelength (λ) of an electron (e), proton (p), neutron (n) and α-particle (α) — each having the same energy of 1 MeV — will follow which of the following sequences in increasing order of wavelength?

(A) $\lambda_e,\ \lambda_p,\ \lambda_n,\ \lambda_\alpha$

(B) $\lambda_e,\ \lambda_n,\ \lambda_p,\ \lambda_\alpha$

(C) $\lambda_\alpha,\ \lambda_n,\ \lambda_p,\ \lambda_e$

(D) $\lambda_p,\ \lambda_e,\ \lambda_\alpha,\ \lambda_n$

50. The trajectory of an α–particle in the Geiger–Marsden experiment can be explained using:

I. Coulomb's law

II. Newton's law

III. Gauss's law

IV. Faraday's law

(A) I and II

(B) I and III

(C) I and IV

(D) I, II and IV

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