අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2026
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2026
General Certificate of Education (Adv. Level) Examination, 2026

භෞතික විද්‍යාව I
பௌதிகவியல் I
Physics I

01 E I

පැය දෙකයි
இரண்டு மணித்தியாலம்
Two hours

Instructions:

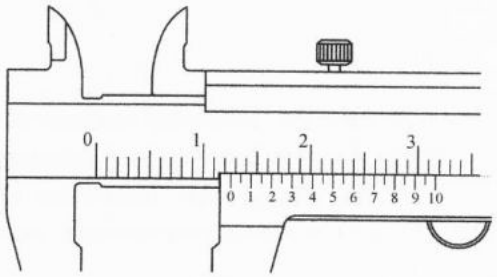
- ✻ *This question paper consists of* **50** *questions in* **10** *pages.*
- ✻ *Answer* ***all*** *the questions.*
- ✻ *Write your* ***Index Number*** *in the space provided in the answer sheet.*
- ✻ *Read the instructions given on the back of the answer sheet carefully.*
- ✻ *In each of the questions* **1** *to* **50**, *pick one of the alternatives from* (1), (2), (3), (4), (5) *which is* ***correct*** *or* ***most appropriate*** *and* ***mark your response on the answer sheet with a cross*** (×) ***in accordance with the instructions given on the back of the answer sheet.***

Use of calculators is not allowed.

($g = 10\ \text{m s}^{-2}$)

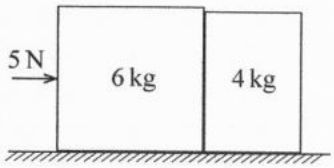
1. Which of the following pairs **does not** have similar dimensions?
(1) stress and pressure
(2) momentum and impulse
(3) force and surface tension
(4) speed and velocity
(5) work and energy

2. The diagram shows a reading of a certain length taken using a Vernier caliper. What are the measured length and the least count of the instrument, respectively? The Vernier caliper has no zero error.



(1) 1·206 cm and 0·001 cm
(2) 1·206 cm and 0·005 cm
(3) 1·260 cm and 0·001 cm
(4) 1·260 cm and 0·005 cm
(5) 1·260 cm and 0·010 cm

3. As shown in the figure, two blocks of mass 4 kg and 6 kg are placed in contact with each other on a frictionless horizontal surface. If a horizontal force of 5 N is applied on the heavier mass so that the system moves together, what is the magnitude of the force acting on the lighter mass?



(1) 1 N
(2) 2 N
(3) 3 N
(4) 4 N
(5) 5 N

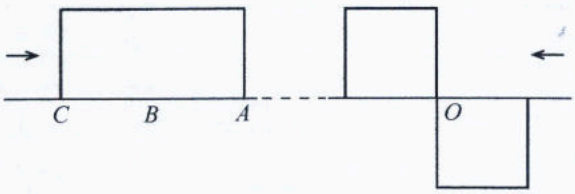
4. Speed of sound in air
(1) is independent of temperature.
(2) increases with increasing pressure.
(3) decreases with increasing pressure.
(4) decreases with increasing humidity.
(5) increases with increasing humidity.

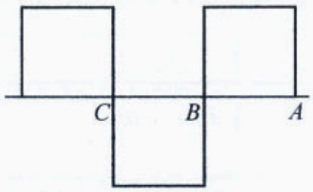
5. The total energy of a particle undergoing simple harmonic motion is directly proportional to its
(1) velocity.
(2) square of the velocity.
(3) amplitude.
(4) square of the amplitude.
(5) frequency.

6. How many types of quarks exist?
(1) 2
(2) 3
(3) 4
(4) 5
(5) 6

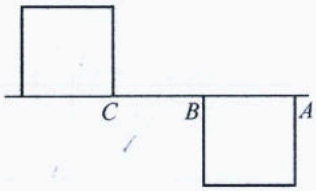
[See page two

7. The two waveforms shown in the figure are travelling in opposite directions in a medium along the same plane. What is the shape of the resultant waveform when point O reaches point C?





(1)



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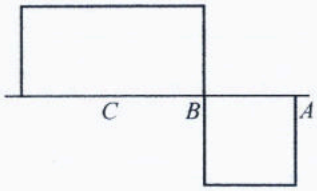

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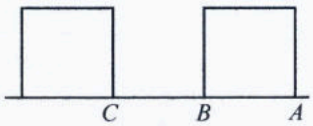

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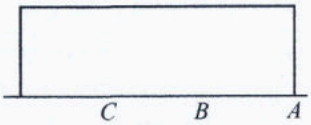

(5)

8. Which of the following is the suitable device for most accurate measurement of an e.m.f. of a cell?
   (1) Meter Bridge
   (2) Non-ideal voltmeter
   (3) Galvanometer
   (4) Ammeter
   (5) Potentiometer

9. A uniform solid sphere starts from rest and rolls along an inclined plane without slipping. The moment of inertia I of a uniform solid sphere of mass M and radius R rotating about an axis through the centre is $I = \frac{2}{5}MR^2$. What is the ratio $\frac{\text{translational kinetic energy of the sphere}}{\text{rotational kinetic energy of the sphere}}$?

   (1) $\frac{2}{5}$ (2) $\frac{1}{2}$ (3) 1 (4) $\frac{5}{2}$ (5) 4

10. Consider the following statements about electric equipotential surfaces.
    (A) The electric field intensity is always constant over an equipotential surface.
    (B) The electric field lines and equipotential surfaces are always mutually perpendicular.
    (C) No two equipotential surfaces intersect with each other.

    Of the above statements,
    (1) only (A) is true.
    (2) only (A) and (B) are true.
    (3) only (A) and (C) are true.
    (4) only (B) and (C) are true.
    (5) all (A), (B) and (C) are true.

11. A monochromatic ray of light is incident on a glass block at an incident angle of 60°. If the partially reflected and refracted rays are perpendicular to each other, what is the refractive index of glass?

    (1) 1·3 (2) 1·4 (3) 1·5 (4) $\sqrt{3}$ (5) 1·8

12. How much water should be filled in a cylindrical container 21 cm in height so that it appears half filled when viewed from the top of the container? The refractive index of water is $\frac{4}{3}$.

    (1) 16·0 cm (2) 14·0 cm (3) 12·0 cm (4) 10·0 cm (5) 8·0 cm

13. If the mass of a radioactive sample is increased, the activity and the decay constant of the sample are respectively
    (1) increases, remains the same.
    (2) decreases, increases.
    (3) decreases, remains the same.
    (4) increases, decreases.
    (5) increases, increases.

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14. A child holding two weights in his hands is sitting on a chair with folded hands on a platform rotating about its central axis. The rotational kinetic energy of the system is K. If the child stretches his arms so that the moment of inertia of the system doubles, what is the rotational kinetic energy of the system?

(1) $4K$ (2) $2K$ (3) K (4) $\frac{K}{2}$ (5) $\frac{K}{4}$

15. An electric generator in a construction site produces a sound intensity level of 50 dB at a certain point. Due to the operation of another equipment, the sound intensity at that point becomes 100 times of the original value. What is the new sound intensity level at that point?

(1) 50 dB (2) 60 dB (3) 70 dB (4) 80 dB (5) 150 dB

16. A compound microscope and an astronomical telescope are in normal adjustment positions. If the focal length of both objective lenses is increased, what will happen to the magnifying power of the microscope and the telescope, respectively?

(1) Increases, decreases
(2) Decreases, increases
(3) Remains the same, increases
(4) Increases, increases
(5) Decreases, decreases

17. An inflated helium air balloon has a volume of 500 m^3. What is the largest mass that can be raised upwards by the balloon? Neglect the mass of the material of the balloon. The densities of air and helium are 1·28 kg m^{-3} and 0·18 kg m^{-3}, respectively.

(1) 400 kg (2) 550 kg (3) 600 kg (4) 700 kg (5) 750 kg

18. An ideal gas expands from a lower volume to a higher volume by different thermodynamic processes. Consider the following statements.

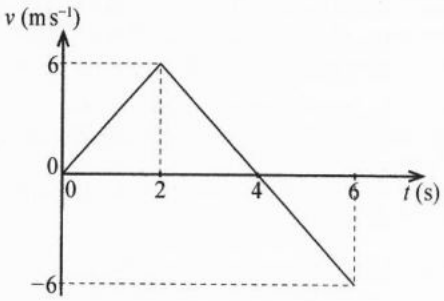
(A) The amount of work done by the gas is maximum when the expansion is isobaric.
(B) The heat absorbed by the gas is maximum when the expansion is adiabatic.
(C) The change in internal energy of the gas is maximum when the expansion is isothermal.

Of the above statements,

(1) only (A) is true.
(2) only (A) and (B) are true.
(3) only (A) and (C) are true.
(4) only (B) and (C) are true.
(5) all (A), (B) and (C) are true.

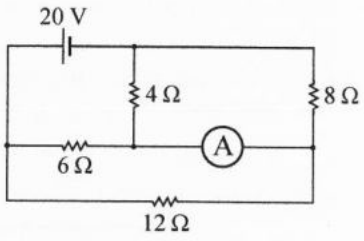
19. The velocity (v) - time (t) graph of a particle is shown in the figure. What is the net displacement of the particle?

(1) 18 m
(2) 12 m
(3) 6 m
(4) 3 m
(5) 0



20. What is the reading of the ammeter shown in the circuit?

(1) 0
(2) 1 A
(3) 2 A
(4) 3 A
(5) 4 A



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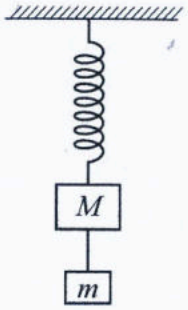
21. A mass M is suspended from a rigid support by a light vertical spring, as shown in the figure. A second mass m is attached to M by a light string ($M > m$). When the system is in equilibrium, the string is instantly cut.



Consider the following statements.

(A) Immediately after the string is cut, the tension in the spring becomes Mg.

(B) Immediately after the string is cut, the mass M accelerates upwards with a magnitude of less than g.

(C) Finally the mass M will begin to perform a simple harmonic motion about its new equilibrium position.

Of the above statements,

(1) only (A) is true.
(2) only (A) and (B) are true.
(3) only (A) and (C) are true.
(4) only (B) and (C) are true.
(5) all (A), (B) and (C) are true.

22. A toy boat floats in a cylindrical water container. The boat carries two blocks A and B of equal mass. The densities of the materials of A and B are $600\,kg\,m^{-3}$ and $1200\,kg\,m^{-3}$, respectively. The height of the water level in the container is h.

Consider the following two cases.

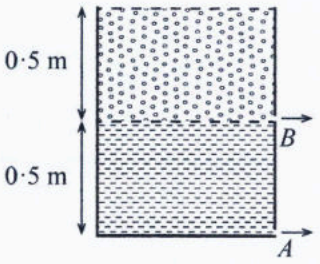
Case I : Block A is removed from the boat and when it is placed on the water surface, it floats, while B remains in the boat.

Case II: Block B is removed from the boat and when it is placed on the water surface, it sinks, while A remains in the boat.

Which of the following statements is true regarding the height of the water level in the container?

(1) It becomes higher than h in case I and lower than h in case II.
(2) It becomes higher than h in both cases I and II.
(3) It remains at h in case I and lower than h in case II.
(4) It remains at h in both cases I and II.
(5) It remains at h in case I and higher than h in case II.

23. A tank having a large cross-sectional area contains two immiscible liquids as shown in the figure. Water of density $1000\,kg\,m^{-3}$ fills the lower half of the tank to a height of 0·5 m, while an oil of density $500\,kg\,m^{-3}$ fills the upper half to a height of 0·5 m. The tank is open to the atmosphere. Two small outlets A and B are fitted to the tank in such a way that outlet A is at the bottom of the tank and outlet B is just above the oil–water interface. Water flows out through outlet A at speed v_A, while oil flows out through outlet B at speed v_B. What is the ratio $\frac{v_A}{v_B}$ at this instant? Assume that liquids are non-viscous.



(1) $\sqrt{\frac{7}{2}}$ (2) $\sqrt{\frac{5}{2}}$ (3) $\sqrt{\frac{3}{2}}$ (4) $\sqrt{\frac{2}{3}}$ (5) $\sqrt{\frac{1}{2}}$

24. Two sealed cylinders of equal volume are kept at the same temperature. One cylinder contains argon gas while the other contains neon gas. Relative atomic mass of argon is higher than that of neon. Assume both gases behave ideally.

Consider the following statements.

(A) The mean translational kinetic energy of the gas atoms in both cylinders is the same.

(B) The root mean square speed of argon atoms is greater than that of neon atoms.

(C) If number of gas atoms in both cylinders are the same, the gas pressures inside the cylinders are equal.

Of the above statements,

(1) only (A) is true.
(2) only (A) and (B) are true.
(3) only (A) and (C) are true.
(4) only (B) and (C) are true.
(5) all (A), (B) and (C) are true.

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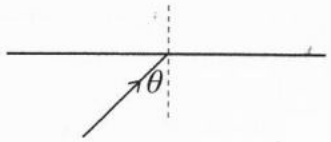
25. A monochromatic ray of light is incident on the interface of two transparent media with an incident angle θ as shown in the figure. When θ is slightly increased the ray undergoes total internal reflection. What is the angle between the two outgoing rays in the above two situations?



(1) $90° - 2\theta$ (2) $90° - \theta$ (3) $180° - 2\theta$ (4) $180° - \theta$ (5) 2θ

26. Consider the following statements.

(A) A body can be accelerating while travelling at constant speed.

(B) A body can have acceleration even at an instant when its velocity is zero.

(C) A body can be accelerating in the direction opposite to its velocity.

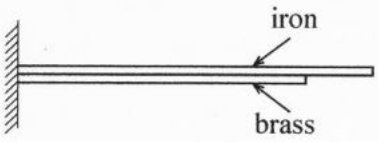
Of the above statements,

(1) only (A) is true. (2) only (A) and (B) are true.
(3) only (A) and (C) are true. (4) only (B) and (C) are true.
(5) all (A), (B) and (C) are true.

27. Starting from rest a small spherical ball of radius r falls freely under gravity through a height h in air before entering a tank of water. Neglect air resistance. The ball enters water with a velocity v without any energy loss. After entering the water, if the velocity of the ball remains constant at v until it reaches the bottom of the tank, h is proportional to

(1) r (2) r^2 (3) r^3 (4) r^4 (5) r^5

28. The figure shows a bimetallic strip made of iron and brass. Left ends of the each strip are fixed together and the other ends are free. The difference between their lengths is 10 cm. If this difference is to remain constant with increase in temperature, what should be the length of the brass strip? Linear expansivities of iron and brass are $1{\cdot}2 \times 10^{-5}\,K^{-1}$ and $1{\cdot}8 \times 10^{-5}\,K^{-1}$, respectively.

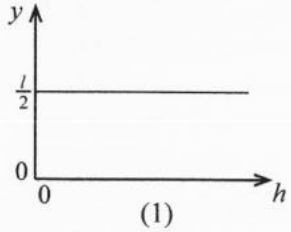


(1) 5 cm (2) 10 cm (3) 15 cm (4) 20 cm (5) 25 cm

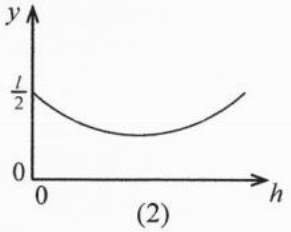
29. The output of an S – R flip-flop is at $Q = 1$. After setting inputs simultaneously to $S = 1$, $R = 1$ briefly, both inputs are set to 0. Which of the following conclusions is true about the output state of the flip-flop now?

(1) It certainly sets to $Q = 1$.
(2) It certainly sets to $Q = 0$.
(3) Its output state is unpredictable.
(4) Q certainly follows the sequence $Q = 1 \rightarrow Q = 0 \rightarrow Q = 0$.
(5) Q certainly follows the sequence $Q = 1 \rightarrow Q = 1 \rightarrow Q = 1$.

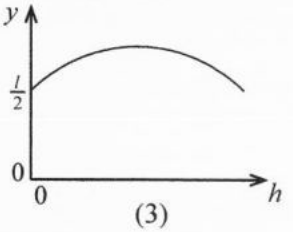
30. A uniform vertical cylindrical container of height l has a base only which is of negligible mass. Initially the cylinder is empty and water is poured into the cylinder gradually at a constant rate. Which of the following graphs best represents the variation of the height (y) of the centre of gravity of the system measured from the base of the cylinder with the height (h) of water?



(1)



(2)



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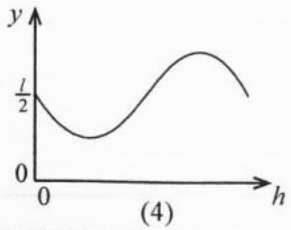
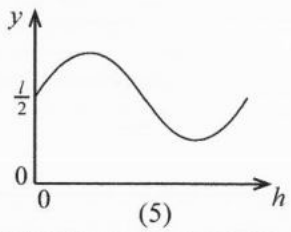


(4)



(5)

[See page six

31. A calorimeter of heat capacity $50\,J\,K^{-1}$ contains a liquid of mass 0·25 kg. A 10 W immersion heater is placed in the liquid. The immersion heater is switched on and after some time the temperature of the liquid reaches a steady value. The heater is now switched off and it is observed that the initial rate of fall of temperature of the liquid is $1{\cdot}0 \times 10^{-2}\,K\,s^{-1}$. What is the specific heat capacity of the liquid?

(1) $3000\,J\,kg^{-1}\,K^{-1}$ (2) $3500\,J\,kg^{-1}\,K^{-1}$ (3) $3800\,J\,kg^{-1}\,K^{-1}$
(4) $4000\,J\,kg^{-1}\,K^{-1}$ (5) $4500\,J\,kg^{-1}\,K^{-1}$

32. Figure (1) shows a child pulling himself up at a constant speed while standing on a movable platform hung on a frictionless pulley. Figure (2) shows the child on the platform pulled at a constant speed by another child standing on the ground. Assume that the ropes are massless and inextensible.

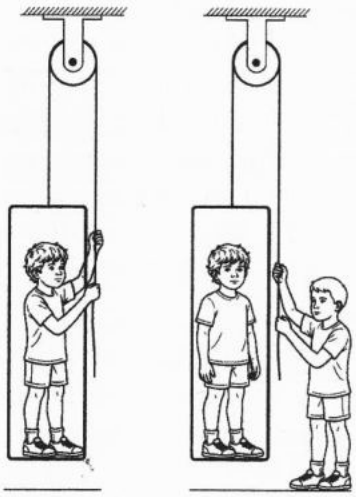


Figure (1) Figure (2)

Consider the following statements.

(A) The force applied by the child in figure (1) is half of the force applied by the child on the ground in figure (2).

(B) To move up by the same height, the work done by the child in figure (1) is less than the work done by the child on the ground in figure (2).

(C) The reaction forces from the platform acting on the child standing on the platform are equal in both situations.

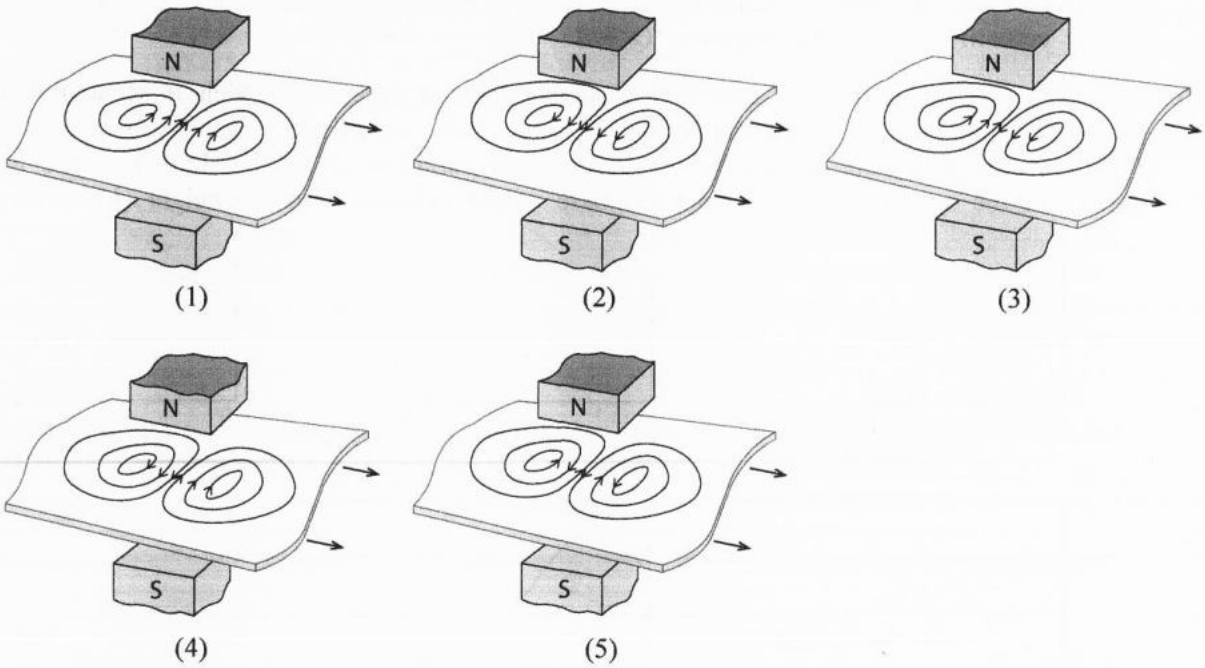
Of the above statements,

(1) only (A) is true. (2) only (A) and (B) are true.
(3) only (A) and (C) are true. (4) only (B) and (C) are true.
(5) all (A), (B) and (C) are true.

33. A star system consists of three collinear stars of equal mass M. The two companion stars move around the central star in a circular orbit of radius R. What is the linear speed of a companion star relative to the central star?

(1) $\frac{1}{2}\sqrt{\frac{GM}{R}}$ (2) $\frac{1}{\sqrt{2}}\sqrt{\frac{GM}{R}}$ (3) $\frac{\sqrt{3}}{2}\sqrt{\frac{GM}{R}}$ (4) $\sqrt{\frac{GM}{R}}$ (5) $\frac{\sqrt{5}}{2}\sqrt{\frac{GM}{R}}$

34. A thin conducting plate is pulled out horizontally across a uniform magnetic field acting vertically downwards as shown in the figure. Which of the following diagrams accurately represents the direction of the eddy currents induced in the plate?

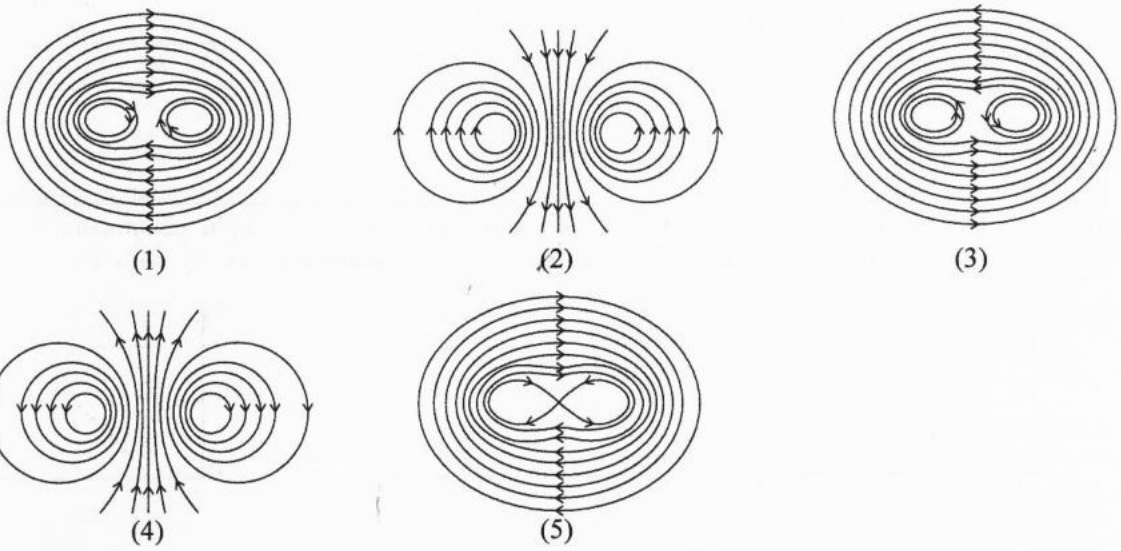


(1) (2) (3)

(4) (5)

[See page seven

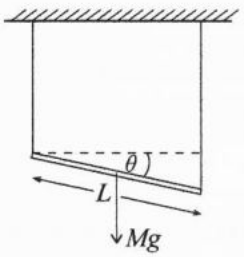
35. Two parallel wires of infinite length carry equal currents along same direction into the plane of the page. Which of the following diagrams best represents the pattern of the resulting magnetic field lines?



(1) (2) (3)

(4) (5)

36. A heavy uniform rod of mass M and length L is suspended from a rigid ceiling by two vertical wires attached to each end of the rod. The un-stretched length and the cross-sectional area of the wires are l and A, respectively. One wire is made of copper and the other is made of brass. The Young's moduli of copper and brass are E_C and E_B, $(E_C > E_B)$ respectively. What is the angle θ, (in radians) shown in the figure that the rod makes with the horizontal? (Hint: For a small angle θ measured in radians $\sin\theta = \theta$)



(1) $\frac{Mgl}{4AL}\left(\frac{1}{E_B}-\frac{1}{E_C}\right)$ (2) $\frac{Mgl}{2AL}\left(\frac{1}{E_B}-\frac{1}{E_C}\right)$ (3) $\frac{Mgl}{AL}\left(\frac{1}{E_B}-\frac{1}{E_C}\right)$

(4) $\frac{MgL}{2Al}\left(\frac{1}{E_B}-\frac{1}{E_C}\right)$ (5) $\frac{MgL}{Al}\left(\frac{1}{E_B}-\frac{1}{E_C}\right)$

37. A circuit with an ideal diode in series with a resistance R is shown in figure (1). A supply voltage in the form of a square wave with amplitude V_0 is applied between the terminals A and B as shown in figure (2). What is the value of average power dissipated across the resistance R over one cycle?

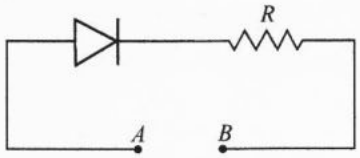


Figure (1)

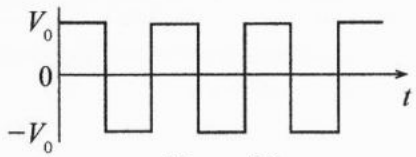
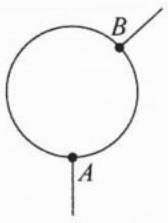


Figure (2)

(1) 0 (2) $\frac{V_0^2}{4R}$ (3) $\frac{V_0^2}{2R}$ (4) $\frac{V_0^2}{R}$ (5) $\frac{2V_0^2}{R}$

38. A uniform wire of diameter 1·0 mm is bent to form a circular loop, as shown in the figure. The radius of the circular loop is 10 cm. The resistivity of the material of the wire is $3{\cdot}0 \times 10^{-4}\,\Omega$m. Two conducting wires are connected at points A and B to the loop, such that the point B can slide around the loop. What is the maximum resistance that can exist between points A and B?



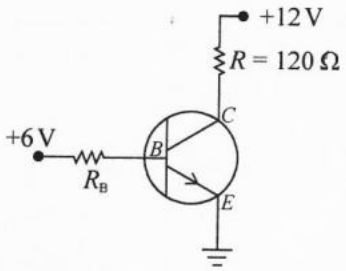
(1) 30 Ω (2) 40 Ω (3) 50 Ω

(4) 60 Ω (5) 80 Ω

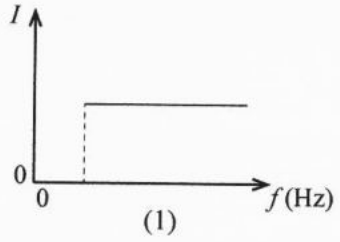
[See page eight

39. The transistor shown in figure has current gain $\beta = 20$, $V_{BE} = 0{\cdot}5\,V$, and V_{CE} (saturation) $= 0\,V$. What is the minimum value of R_B needed for the transistor to operate in saturation mode?

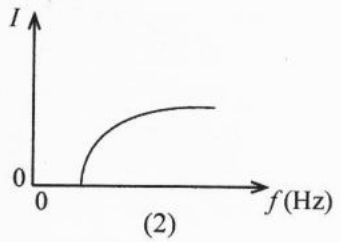
(1) $120\,\Omega$ (2) $240\,\Omega$
(3) $540\,\Omega$ (4) $1{\cdot}0\,k\Omega$
(5) $1{\cdot}1\,k\Omega$



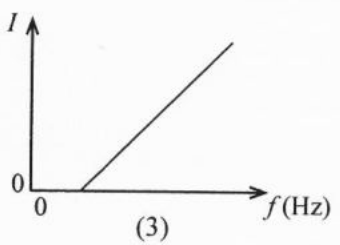
40. In a photo-electric experimental setup the cathode is illuminated by a light source. The frequency (f) of the incident light is increased while keeping the intensity of the light beam constant. Which of the following graphs best represents the variation of the photo-current (I) with f?



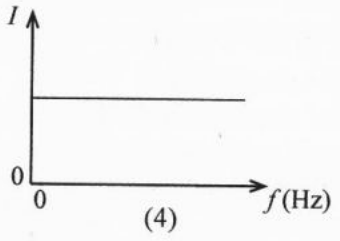
(1)



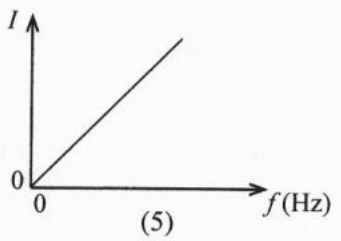
(2)



(3)



(4)

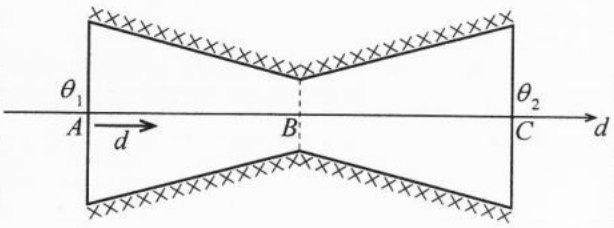


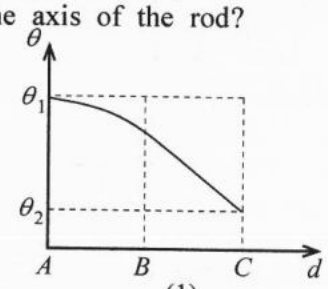
(5)

41. A uniform steel wire rigidly fixed at both ends is subjected to a tension of 750 N. The length of the wire is 0·4 m and has a mass of 0·3 g. What is the highest harmonic produced by this wire that could be heard by a person who is capable of hearing frequencies up to 10 000 Hz?

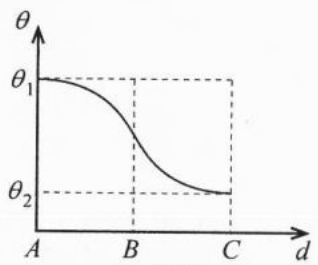
(1) 4 (2) 5 (3) 6 (4) 7 (5) 8

42. A combined metal rod consists of a gradually decreasing cross-section part AB and a gradually increasing cross-section part BC as shown in the figure. The rod is fully lagged and the ends are maintained at temperatures θ_1 and θ_2 ($\theta_1 > \theta_2$) respectively. At the steady state which of the following graphs best represents the variation of temperature θ of the rod with distance d along the axis of the rod?

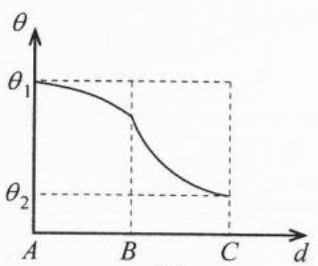




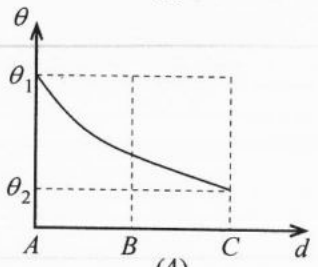
(1)



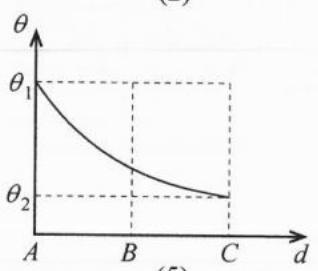
(2)



(3)



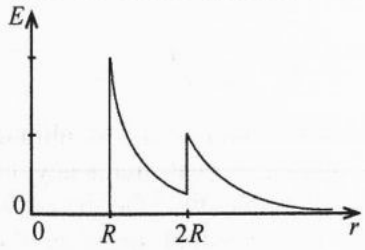
(4)



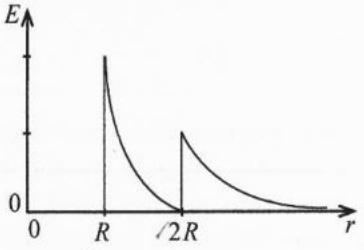
(5)

[See page nine

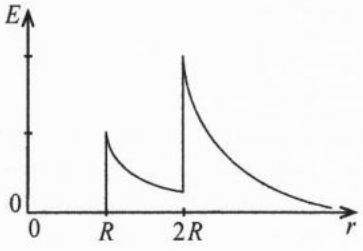
43. A solid conducting sphere with radius R carrying a charge $+Q$ is concentric with a **very thin** insulating shell of radius $2R$ carrying charge $+Q$. The charge is distributed uniformly over the insulating shell. Which of the following graphs best represents the variation of electric field intensity E with the radial distance r from the common center?



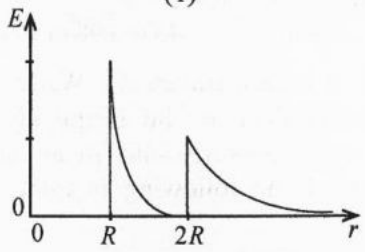
(1)



(2)



(3)



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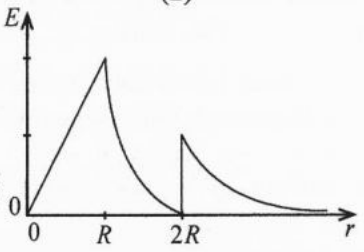
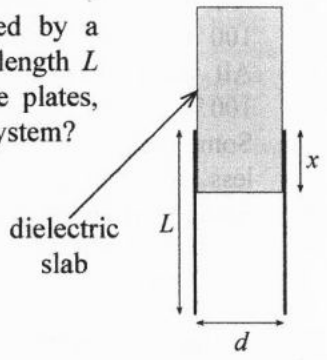


(5)

44. Two square conducting plates with sides of length L are separated by a distance d. A dielectric slab with dielectric constant k with sides of length L and thickness d is inserted a distance x into the space between the plates, as shown in the figure. What is the effective capacitance of the system?



(1) $\frac{\varepsilon_0 L}{d}\left[L+(k-1)x\right]$

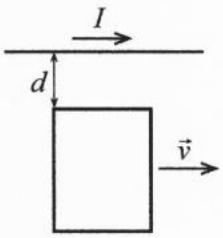
(2) $\frac{\varepsilon_0 L}{d}\left[L+kx\right]$

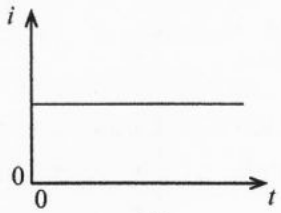
(3) $\frac{\varepsilon_0 k(L-x)x}{d}$

(4) $\frac{\varepsilon_0 kLx}{d}$

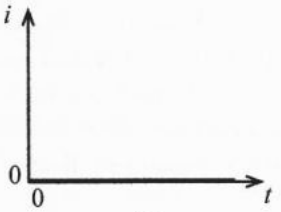
(5) $\frac{2\varepsilon_0 L}{d}\left[L+(k-1)x\right]$

45. An infinitely long straight wire carries a constant current I. A rectangular conducting loop starts moving at constant velocity v as shown in the figure at time $t = 0$, keeping separation d constant. The wire and the loop lie on the same plane. Which of the following graphs best represents the variation of the current (i) induced in the loop with time t?

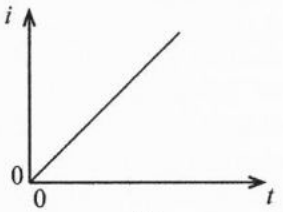




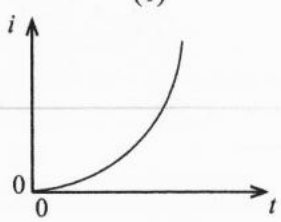
(1)



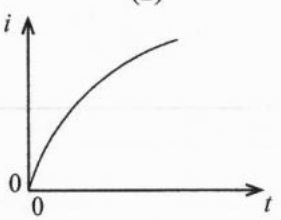
(2)



(3)



(4)



(5)

[See page ten

46. When the radius of a soap bubble is increased from r to $2r$ isothermally by blowing air, the surface energy of the bubble increases by E_1. When two identical soap bubbles each of radius r made from the same soap solution coalesce to form a single bubble, the surface energy decreases by E_2. What is the magnitude of the ratio of $\frac{E_1}{E_2}$?

(1) $\frac{3}{2-2^{\frac{2}{3}}}$ (2) $\frac{4}{2-2^{\frac{2}{3}}}$ (3) $\frac{3}{2-2^{\frac{1}{3}}}$ (4) $\frac{4}{2-2^{\frac{1}{3}}}$ (5) $\frac{3}{2^{\frac{2}{3}}}$

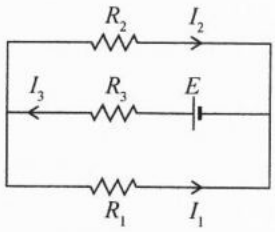
47. An airplane with two non-identical engines flies over a stationary observer at a low altitude along a horizontal straight path with constant speed. As the plane flies the beat frequency heard by the observer from the two engines changes from 8 Hz to 2 Hz. Assume that the speed at which the plane moves towards and away from the observer is equal to the actual speed of the plane. What is the speed of the airplane? (The speed of sound in air is $330\,m\,s^{-1}$)

(1) $100\,m\,s^{-1}$ (2) $125\,m\,s^{-1}$ (3) $150\,m\,s^{-1}$ (4) $195\,m\,s^{-1}$ (5) $198\,m\,s^{-1}$

48. A hot copper container with its copper lid of total mass M is at a temperature θ_1. Water of mass m at temperature θ_2 ($\theta_2 < \theta_1$) is poured into the container, and then the lid is quickly closed. A student assumes that a fraction x (in terms of mass) of water converts into steam and does a calculation to find x. If the student finds that $x > 1$, which of the following is true? Assume that there is no heat loss to the surroundings.

(1) All water has converted into steam and the final temperature of the system is equal to 100 °C.
(2) All water has converted into steam and the final temperature of the system is greater than 100 °C.
(3) All water has converted into steam and the final temperature of the system is less than 100 °C.
(4) Some portion of water has converted into steam and the final temperature of the system is less than 100 °C.
(5) Some portion of water has converted into steam and the final temperature of the system is equal to 100 °C.

49. Consider the given circuit. Here $R_2 > R_1 >> R_3$. Which of the following inequalities is correct?

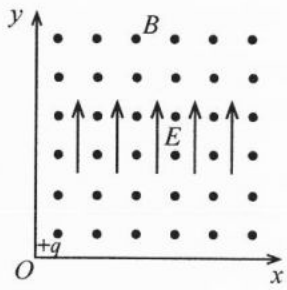


(1) $I_3 > 2I_1$ (2) $I_3 < 2I_2$

(3) $I_3 > 2I_2\frac{R_2}{R_1}$ (4) $I_3 > \frac{R_3(I_1+I_2)}{R_3+R_1}$

(5) $I_3 > \frac{R_2}{R_1}(I_1+I_2)$

50. A uniform electric field of intensity E acts in +y direction and a uniform magnetic field of flux density B is directed out of the plane of the page as shown in the figure. A particle with mass m and charge $+q$ is released from rest at point O. What is the speed of the charged particle at a vertical height y measured from the horizontal? (Neglect gravitational forces)



(1) $\sqrt{\frac{qEy}{2m}}$ (2) $\sqrt{\frac{qEy}{m}}$ (3) $\sqrt{\frac{2qEy}{m}}$

(4) $\sqrt{\frac{q(E+B)y}{m}}$ (5) $\sqrt{\frac{2q(E+B)y}{m}}$

* * *

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අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2026
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2026
General Certificate of Education (Adv. Level) Examination, 2026

භෞතික විද්‍යාව II
பௌதிகவியல் II
Physics II

01 E II

පැය තුනයි
மூன்று மணித்தியாலம்
Three hours

අමතර කියවීම් කාලය - මිනිත්තු 10 යි
மேலதிக வாசிப்பு நேரம் - 10 நிமிடங்கள்
Additional Reading Time - 10 minutes

Use additional reading time to go through the question paper, select the questions you will answer and decide which of them you will prioritise.

Index No. : .....

Important:

- *This question paper consists of* **16** *pages.*
- *This question paper comprises of* ***two*** *parts, Part* **A** *and Part* **B.** *The time allotted for* ***both parts*** *is* ***three hours.***
- *Use of calculators is* ***not*** *allowed.*

PART A — Structured Essay:
(pages 2 - 8)

Answer ***all*** *the questions on this paper itself. Write your answers in the space provided for each question. Note that the space provided is sufficient for your answers and that extensive answers are not expected.*

PART B — Essay:
(pages 9 - 16)

This part contains ***six*** *questions, of which,* ***four*** *are to be answered. Use the papers supplied for this purpose.*

- *At the end of the time allotted for this paper, tie the* ***two parts together*** *so that* ***Part*** **A** *is* ***on top*** *of* ***Part*** **B** *before handing them over to the Supervisor.*
- *You are permitted to remove* ***only Part*** **B** *of the question paper from the Examination Hall.*

For Examiners' Use Only

For paper II		
Part	**Question Nos.**	**Marks Awarded**
A	**1**	
	2	
	3	
	4	
B	**5**	
	6	
	7	
	8	
	9 (A)	
	9 (B)	
	10 (A)	
	10 (B)	
Total	In numbers	
	In words	

Code Numbers

Marking Examiner 1	
Marking Examiner 2	
Marks checked by	
Supervised by	

[see page two

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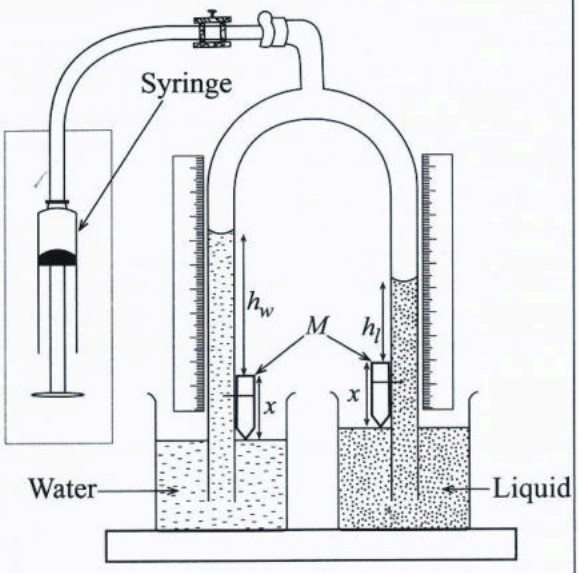
PART A — Structured Essay

Answer ***all four*** *questions on this* ***paper itself.***

($g = 10\ m\ s^{-2}$)

1. An experimental setup used in a school laboratory to find out the density of a liquid is shown in the figure.



(*a*) What is the name of the apparatus shown in the figure?

.....

(*b*) (i) Name the items marked as *M*.

.....

(ii) What is the purpose of having them?

.....

.....

.....

(iii) Before taking any set of readings these items have to be adjusted. What is this adjustment?

.....

.....

(*c*) Give **two** advantages of using a syringe to draw up liquid columns compared to oral suction.

(i) Experimental advantage: .....

.....

(ii) Health and safety related advantage: .....

.....

(*d*) In the apparatus shown above, the two glass tubes with scales have to be vertical. What is the reason for this?

.....

.....

(*e*) (i) The densities of water and the liquid are d_w and d_l respectively. The length of each *M* is x and the air pressure inside the tubes is P. If h_w and h_l represent the heights of the water column and the liquid column respectively as measured from the top ends of respective *M*, write down the equation relating P, h_w, h_l, d_w, d_l and x.

.....

.....

(ii) Rearrange the above equation, to determine d_l by plotting a suitable straight line graph keeping h_w as the independent variable.

.....

.....

.....

[see page three

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(iii) Hence, write down expressions for the gradient and intercept of the graph.

Gradient: .....

Intercept: .....

(iv) If the gradient of the drawn straight line is 0·80, determine d_l. (d_w= 1000 kg m^{-3})

.....

.....

(v) Why is it inappropriate to use the intercept over the gradient to determine d_l?

.....

(*f*) (i) You are provided with three glass tubes *A*, *B* and *C*. The internal diameters of *A*, *B* and *C* tubes are 15 mm, 6 mm and 0·5 mm respectively. Which glass tube would you select to make the apparatus shown in the above figure?

Tube:.....

(ii) Give reasons as to why you **do not select the other two tubes**.

Tube..... Reason: .....

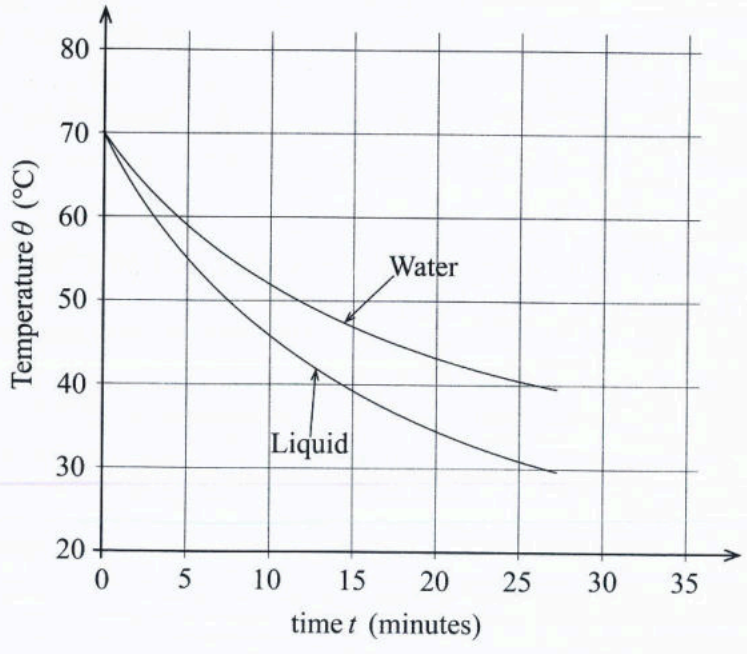
.....

Tube..... Reason: .....

.....

2. An experiment is conducted in the school laboratory to determine the specific heat capacity of an unknown liquid (*L*) using the method of cooling. First, a copper calorimeter is filled up to 1 cm from the top of the calorimeter with a known volume of water, heated to 70 °C and allowed to cool in an environment at a constant room temperature of 25 °C. The experiment is then repeated under the exact environmental conditions using the same volume of liquid *L*.

The cooling curves (temperature θ *vs.* time *t*) obtained from the two experiments are drawn on the same grid, as shown below.



[see page four

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(*a*) Write down an equation for Newton's law of cooling and identify all the symbols used.

.....

.....

.....

.....

(*b*) (i) Why is it essential to use the same calorimeter in both occasions in the experiment?

.....

.....

(ii) Why must the volumes of water and liquid be equal?

.....

.....

(*c*) In this experiment, an electric fan can be used to supply a constant air flow around the calorimeter. Give a reason for this.

.....

.....

(*d*) Constant stirring is essential while taking temperature measurements. What is the reason for this?

.....

(*e*) The mass of water used is $m_W = 0{\cdot}25\,\text{kg}$ and the mass of liquid is $m_L = 0{\cdot}20\,\text{kg}$. The copper calorimeter with the stirrer has a mass of $0{\cdot}05\,\text{kg}$ and the specific heat capacities of copper and water are $400\,\text{J kg}^{-1}\,\text{K}^{-1}$ and $4200\,\text{J kg}^{-1}\,\text{K}^{-1}$ respectively.

(i) At the temperature of 55 °C, the rate of cooling of water is measured to be $0{\cdot}60\,^{\circ}\text{C min}^{-1}$. Calculate the rate of loss of heat $\frac{dQ}{dt}$ from the system to the surroundings at this temperature.

.....

.....

.....

.....

(ii) At the same temperature, the rate of cooling of liquid L is $1{\cdot}50\,^{\circ}\text{C min}^{-1}$. Calculate the specific heat capacity C_L of the liquid.

.....

.....

.....

.....

[*see page five*

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(*f*) A student used a small plane mirror to construct the tangent to a cooling curve at 55 °C (mirror method). Write down the steps of the procedure that he has to adopt.

(i) Related to placing the mirror:

.....

.....

.....

(ii) Related to drawing the appropriate lines:

(1) .....

.....

(2) .....

.....

(*g*) Starting the experiment with initial temperature exceeding 70 °C is not desirable. Give a reason for this?

.....

3. Figure (1) (A) shows an alternative experimental setup that can be used to find the velocity of sound in air using a resonance tube with one end closed and a tuning fork. The principle of this setup is similar to the principle of the setup normally used in school laboratory. The water level in the tube can be lowered using the attached tap and it can be raised by adding water to the tube.

(*a*) (i) Name the other essential item that you need to perform this experiment apart from the tuning fork.

.....

(ii) Draw the tuning fork at the appropriate place and its orientation in the figure (1)(A).

(*b*) Draw the standing wave patterns for the first mode of vibration (fundamental) and the second mode of vibration in the respective figures by considering the end correction of the tube.

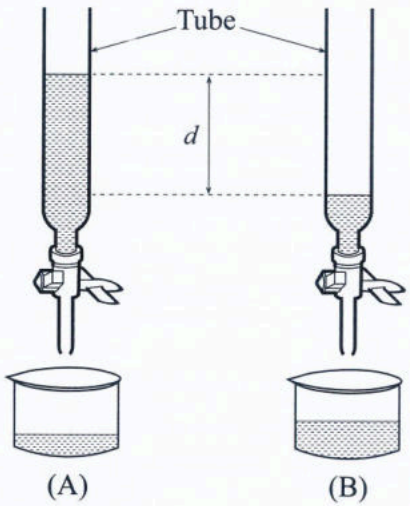


Figure (1)

(*c*) At which position of the tube the pressure variation of air is maximum? Underline the correct answer.

At the closed end / at the open end

(*d*) (i) Derive an equation for the velocity v of sound in air in terms of the tuning fork frequency f, and the difference in resonance lengths d, shown in above figure (1).

.....

.....

.....

.....

[see page six

Do not write in this column

(ii) If $f = 512\,\text{Hz}$ and $d = 34\,\text{cm}$, calculate the velocity v of sound in air.

.....

.....

(iii) What happens to the end correction when the internal diameter of the tube is increased? Underline the correct answer.

Increases / decreases / does not change

(*e*) You are provided with a **set of tuning forks** and a bottle [see figure (2)] containing an air cavity of volume V, opened to the atmosphere through a narrow tube of cross-sectional area A and length L with the end correction. Volume V is reduced by **adding water**. When the air in the tube is disturbed by a vibrating tuning fork, the system produces resonance at a characteristic frequency f given by the following equation. Here v is the velocity of sound in air.

$$f = \frac{v}{2\pi}\sqrt{\frac{A}{VL}}$$

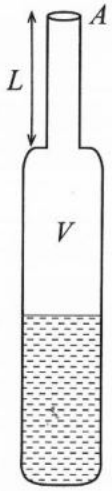


Figure (2)

(i) What happens to f for a larger L value? Underline the correct answer.
Increases / decreases / does not change.

(ii) Which tuning fork do you select first to start the experiment? Underline the correct answer.

Highest frequency tuning fork / lowest frequency tuning fork

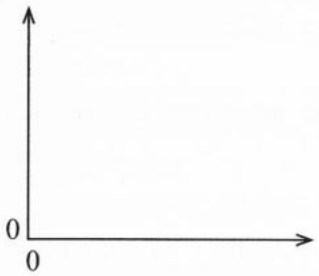
(iii) Rearrange the equation in (*e*) above and subject V to plot a straight line graph.

.....

.....

.....

(iv) Labelling the axes, draw the expected graph on the following diagram corresponding to the equation in (*e*) (iii) above.



(v) Hence, write down an equation for the velocity v of sound in air in terms of the gradient of the graph m, A and L.

.....

.....

[see page seven

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4. A student is asked to determine the e.m.f. E and the internal resistance r of a dry cell. A dry cell, a rheostat (0 – 100 Ω), a resistor with resistance R and connecting wires are provided to him.

(a) Figure (1) shows a circuit used to determine E and r of the dry cell.

Select the most suitable apparatus from the pairs given below for each labelled box in the circuit. Underline the correct answers.

A : galvanometer / digital voltmeter

B : milliammeter / voltmeter

C : plug key / tap key

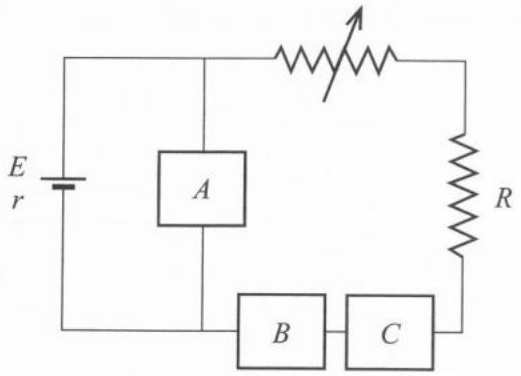

Figure (1)

(b) (i) Why is a fixed resistor included in the circuit in addition to the rheostat?

.....

(ii) Two resistors with values of 10 Ω and 1000 Ω are available for R. Which resistance is more suitable to use? Give a reason based on the range of current readings.

Resistance: .....

Reason: .....

.....

(c) (i) Identify the terminals that should be connected to the circuit in the rheostat shown in figure (2). Underline the correct answer.

X and Y / X and Z

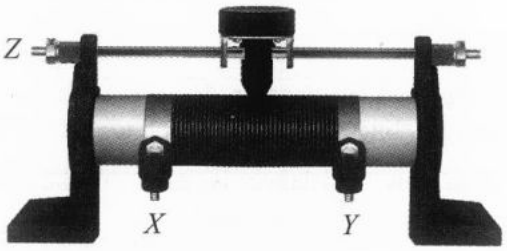

Figure (2)

(ii) Before the key is closed for the first reading, which of the following positions should the slider of the rheostat shown in (c) (i) above has to be placed for the safety of the circuit? Underline the correct answer.

Slider close to X / Slider close to Y

(d) What is the reason for selecting the appropriate key mentioned in (a) above?

.....

(e) (i) When the current through the dry cell is I, the potential difference across the terminals of the dry cell is V. Write down an equation for the e.m.f. E of the dry cell in terms of V, I, and the internal resistance r of the dry cell.

.....

(ii) Rearrange the equation in (e) (i) above, in order to plot a straight line graph.

.....

[see page eight

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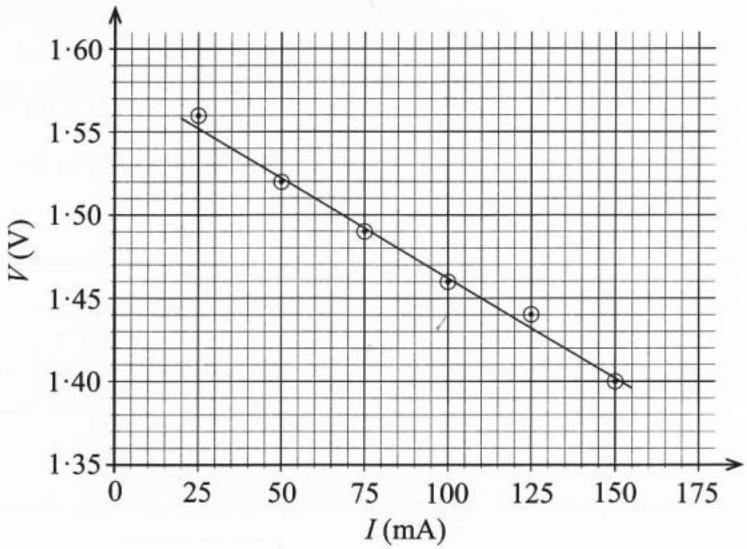
(*f*) In the experiment, the following graph was obtained.



(i) Using the most suitable two points, calculate the gradient of the graph.

.....

.....

.....

(ii) Hence determine the internal resistance r of the dry cell.

.....

(iii) By extending the straight line, determine the value of E to the nearest second decimal place.

.....

(iv) The above dry cell is replaced by another dry cell with lower E value and higher r value. Sketch the straight line that you expect to get on the given grid above.

(*g*) If a voltmeter with unknown low resistance is used in the circuit, how would the determined values of E and r above are affected?

(i) Value of E : will get a higher value / will get a lower value / not affected. Underline the correct answer.

(ii) Value of r : will get a higher value / will get a lower value / not affected. Underline the correct answer.

* *

[*see page nine*

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கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2026
General Certificate of Education (Adv. Level) Examination, 2026

භෞතික විද්‍යාව II
பௌதிகவியல் II
Physics II

PART B — Essay

01 E II

*Answer **four** questions only.*
($g = 10\,m\,s^{-2}$)

5. Read the following passage and answer the questions.

A hydroelectric power station uses the gravitational potential energy of water collected in reservoirs situated in high altitudes to generate electricity. When electricity is needed, controlled gates open to allow this stored water to descend through a thick steel pipe (penstock) as shown in figure (1). Due to gravity, the falling water builds immense water pressure as it nears the end of its journey.

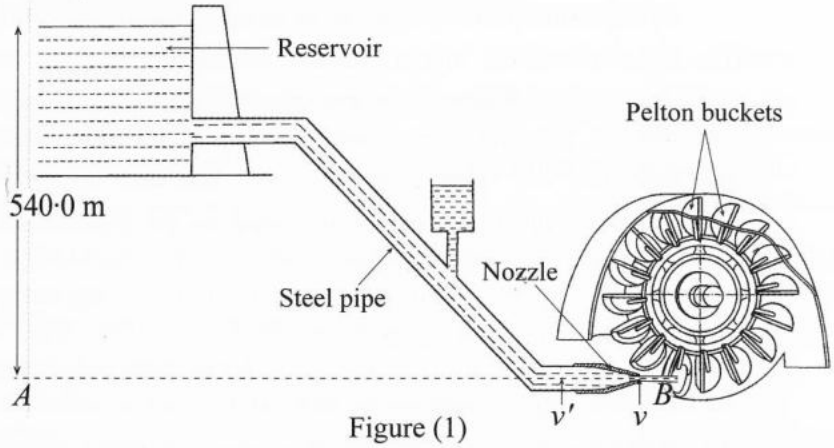

Figure (1)

At the lower end of the steel pipe, this large volume of water is allowed to flow through a nozzle. The nozzle creates a very high-velocity jet of water that provides the mechanical force needed to rotate a turbine. This turbine is known as Pelton turbine named after L. A. Pelton who invented it in 1880. This consists of a wheel, which is a circular disc and on the periphery of it, a number of Pelton buckets are mounted with equal spacing between them. Each bucket consists of two semi-ellipsoidal shaped cups (see figure 2).

Water striking a bucket forces the wheel to rotate at high speed, converting the water's kinetic energy into mechanical rotational energy. This rotating wheel is connected to a central shaft that turns a large electrical generator. The generator has powerful magnets which rotate inside stationary ring of copper coils. This process, through electromagnetic induction, creates electrical current and sends across the national transmission grid. Unlike fossil-fuel stations, hydroelectric power stations generate no direct greenhouse gases, other toxic gases like carbon monoxide and sulfur dioxide, particulate matter and ash. (Figures are not drawn to scale)

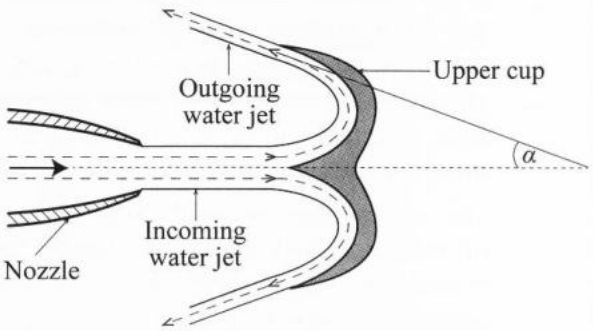

Figure (2)

(*a*) Why is it essential to store water in high altitude reservoirs in a hydroelectric power station?

(*b*) What is the shape of the cups of a bucket mounted on the periphery of the turning wheel?

(*c*) State in order the **four** energy types involved in the energy transformation of a hydroelectric power station.

(*d*) What is the principle behind generating electricity from rotating magnets inside fixed copper coils?

(*e*) Why is electricity generation from hydropower very much suitable over burning fossil fuels?

(*f*) (i) In a hydroelectric power station the water level in the reservoir is at a vertical height of 540·0 m above the horizontal level *AB* shown in figure (1). The reservoir is open to atmospheric pressure *P* and the pressure of water just before it enters the nozzle is 54·875*P*. Assuming that the surface area of the reservoir is large and the water flow is steady and water is non-viscous, calculate the speed of water *v'* before it enters the nozzle. Atmospheric pressure $P = 10^5$ Pa, Density of water = $10^3\,kg\,m^{-3}$.

(ii) If the ratio $\frac{\text{Internal cross-sectional area of penstock}}{\text{Internal cross-sectional area of the nozzle outlet}} = 20$, determine the velocity *v* of horizontal water jet ejecting from the nozzle at *B*. Assume that water is incompressible.

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(iii) Calculate the rate of mass flow m of water leaving from the nozzle. Internal diameter of the nozzle outlet is 20 cm. Take $\pi = 3$.

(*g*) (i) When the water jet with velocity v calculated in (*f*) (ii) above strikes a bucket, it acquires a horizontal velocity u. Write down an equation for the velocity v_r of the incoming water jet relative to the bucket in terms of v and u ($v > u$)

(ii) As shown in figure (2), when the water jet strikes the center of the bucket, it divides into two equal streams. Write down an equation for the horizontal component of the velocity v_e of the outgoing water stream relative to the upper cup when it leaves the upper cup in terms of v_r and α. Assume that the relative speed of the water jet is unchanged throughout the flow.

(iii) The rate of mass flow of water incident on the upper cup will be $\frac{m}{2}$ [m calculated in (*f*) (iii) above]. Show that the horizontal force F acting on the upper cup due to the rate of change of momentum of water stream is given by $F = \frac{m}{2} v_r (1+\cos\alpha)$ once the steady state is achieved.

(iv) Write down the total horizontal force F' acting on the bucket in terms of F.

(*h*) (i) If the mean diameter of the wheel with buckets is 1·5 m and it rotates with 720 revolutions per minute, determine u mentioned in (*g*) (i) above. Take $\pi = 3$.

(ii) Calculate the value of F'. $\alpha = 20°$ and take $\cos 20° = 0{\cdot}95$.

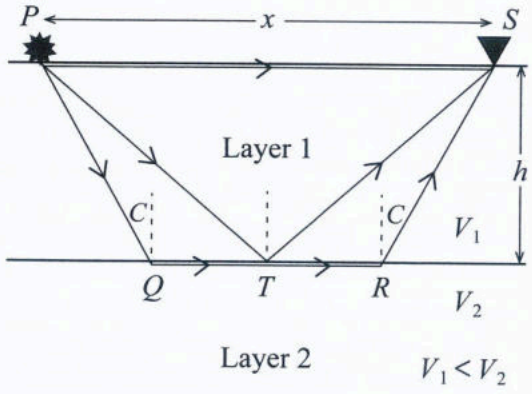
(iii) Calculate the input power imparted to the wheel. Give your answer to the nearest MW.

6. (*a*) Consider two media, medium 1 and medium 2, separated by a horizontal interface. A wave travels through medium 1 and refracts into medium 2. The angle of incidence in medium 1 is i and the angle of refraction in medium 2 is r. The wave velocities in media 1 and 2 are V_1 and V_2 respectively. Snell's laws can be applied to any type of wave refraction.

(i) Write down an equation for the refractive index ($_1n_2$) of medium 2 relative to medium 1 in terms of i and r.

(ii) Write down an equation for the refractive index $_1n_2$ in terms of V_1 and V_2.

(*b*) The earth's crust can be modelled as parallel sedimentary layers, each with a characteristic wave velocity V. Low-frequency sound waves generated at point P near the earth surface undergo reflection and refraction at the layer boundaries before being detected by receivers placed on the surface. The wave velocities and subsurface layer structure can be determined by analysing the arrival times of these waves.



The waves propagating through the earth obey the laws of reflection and refraction (Snell's laws) at the layer boundaries. Furthermore, the wave velocity within each layer is assumed to be constant and independent of direction.

In such exploration, three possible ray paths of the generated waves arriving at the receiver are shown in the diagram. The first wave (direct wave) travels directly from the source P to the receiver S through layer 1 with velocity V_1. The second wave (reflected wave) travels from the source P to the receiver S after being reflected at point T on the boundary between layers 1 and 2 with velocity V_1. The third wave (head wave), travels from the source P through layer 1 with velocity V_1, undergoes critical refraction at point Q with the incident angle equal to the critical angle C, and then propagates along the interface in layer 2 with velocity V_2. It is subsequently critically refracted back into layer 1 at point R at the same critical angle C and finally arrives at the receiver S as shown in the diagram.

(i) The wave generated at point P travelling through layer 1 along a straight line arrives at the receiver S after 0·25 s. The receiver is positioned $x = 1000$ m away from the source as shown in the diagram. Calculate the wave velocity V_1 in layer 1.

(ii) If the frequency of the above waves is 50 Hz, determine the wavelength λ of the waves travelling in layer 1.

[see page eleven

(*c*) The wave travelling from the source *P* is reflected at the boundary between layer 1 and layer 2 at *T* and returns to the receiver *S* after 0·40 s.

(i) Using the wave velocity V_1 of the wave calculated in (*b*) (i) above and the arrival time of the reflected wave, calculate the total distance *PTS* travelled by the reflected wave.

(ii) Hence, using the geometry of the reflected wave path, calculate the thickness *h* of layer 1 (Take $\sqrt{39} = 6.25$).

(*d*) Consider *PQRS* wave path as shown in the diagram.

(i) Using the condition for critical refraction at point *Q* in the diagram, write an equation for the critical angle *C*, in terms of the wave velocity V_1 in layer 1, and the wave velocity V_2 in layer 2.

(ii) If the total travel time of the critically refracted wave (head wave) from the source *P* to the receiver *S*, traveling via the path *PQRS*, is T_H, show that

$$T_H = \frac{x}{V_2} + \frac{2h}{V_1 \cos C}\left(1 - \frac{V_1^2}{V_2^2}\right)$$ Take $\tan C = \frac{\sin C}{\cos C}$. Hint: $T_H = \frac{PQ}{V_1} + \frac{QR}{V_2} + \frac{RS}{V_1}$

where, *x* is the distance between the source and the receiver and *h* is the thickness of layer 1.

(iii) Two receivers placed at two different horizontal distances from the source detect critically refracted waves generated from the source. At a horizontal distance of $x_1 = 1000$ m the arrival time of head wave is $t_1 = 0{\cdot}39$ s. At a horizontal distance of $x_2 = 1600$ m the arrival time of head wave is $t_2 = 0{\cdot}51$ s. The travel time of head wave obtained in the equation (*d*) (ii) above can be rewritten as $T_H = \frac{x}{V_2} + A$, where, *A* is a constant and *x* is the horizontal distance from the source to the receiver. Determine the wave velocity V_2 in the layer 2.

(iv) Using the equation in (*a*) (ii) above, determine ${}_1n_2$.

7. (*a*) An industrial laboratory tests a lubricant fluid before it is used in a hydraulic system. Its coefficient of viscosity can be measured using the modified parallel-plate viscometer shown in figure (1).

The viscometer consists of a smooth square upper plate of side length *L* placed above a larger smooth fixed plate. The plates are separated by a small uniform gap *h*, which is completely filled with the test fluid. The upper plate is connected by a light inextensible string passing over a frictionless pulley to a hanging mass *M*.

As the upper plate moves, the displacement of point *A* on the plate is continuously measured using a displacement sensor. After a short time, the upper plate **attains a constant velocity**. During this steady motion, point *A* is observed to move a distance *s* in a time interval *t*.

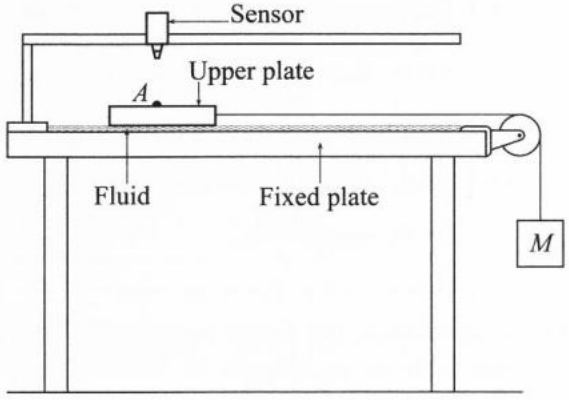


Figure (1)

(i) Considering the steady motion obtain an equation for the coefficient of viscosity of the fluid η in terms of *M*, *L*, *s*, *t* and *h*.

(ii) In the experiment, the viscometer is operated using a mass of $M = 0{\cdot}50$ kg. During steady motion, point *A* on the upper plate moves a distance of 0·20 m in 8·0 s. $L = 0{\cdot}10$ m and $h = 0{\cdot}10$ mm. Calculate the coefficient of viscosity η of the fluid.

(*b*) Figure (2) shows a sectional view of a coaxial-cylinder rotating viscometer, commonly used in industrial laboratories to measure the coefficient of viscosity. The outer cylinder rotates while the inner cylinder is suspended by a torsion rod. The viscous force exerted by the fluid produces a torque on the inner cylinder, causing the torsion rod to twist by an angle θ.

(i) If the torsional constant of the rod is *C*, write down an equation for the restoring torque τ of the rod in terms of *C* and the angular deflection θ in radians.

(ii) The viscous force acting on the inner cylinder is 10·0 N. If the radius of the inner cylinder is 5·0 cm and the angular deflection of the torsion rod is 0·20 rad, calculate the torsional constant *C* of the rod.

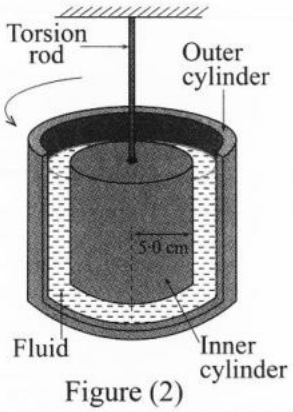


Figure (2)

[see page twelve

(*c*) A viscous fluid can be used to detect the variation of the diameters of very small metal spheres made of same material, as shown in figure (3). Here a small steel sphere is released at rest inside a vertical transparent tube filled with the fluid. After attaining terminal velocity, the sphere moves downward and activates a switch at the bottom of the tube. The time taken to activate the switch will be different for spheres of different diameters.

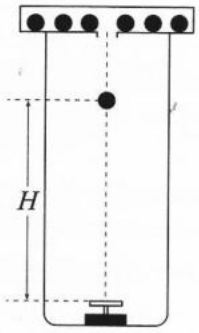


Figure (3)

(i) Derive an equation for the terminal velocity v_t of the steel sphere in terms of its radius r, density of the material of the sphere ρ_s, density of the fluid ρ_f, and coefficient of viscosity η.

(ii) Write down an equation for the time T taken by the sphere in terms of v_t and H if it travels a vertical height H after reaching terminal velocity.

(iii) I. A steel sphere made of material of density $8000\,kg\,m^{-3}$ and radius $5{\cdot}0\,mm$ is released in a fluid of coefficient of viscosity $1{\cdot}0\,Pa\,s$ and density $800\,kg\,m^{-3}$. After reaching terminal velocity, the sphere travels a distance of $0{\cdot}50\,m$ before activating the switch. Calculate the time taken by the sphere to activate the switch after reaching the terminal velocity.

II. Two spheres, A and B made of the same material with sphere B having a smaller radius than A, are released at rest inside the tube at the same time. Which sphere will activate the switch first?

(iv) During the experiment, if the temperature of the fluid increases, explain how this affects the time calculated in (*c*) (iii) above.

8. Artemis II mission took place from April 1 to April 10 in 2026. It was the first crewed flight of the Orion spacecraft around the moon and back, making history by flying further than any humans have before. Instead of directly launching from the ground to the moon, the spacecraft orbits (known as parking orbit) around the earth first, then fired its engines to achieve the precise velocity required to enter a trajectory heading towards the moon.

(*a*) Consider the Orion spacecraft of mass m orbiting around the earth with speed v_o in a circular orbit with radius r from the center of the earth. Assume that the earth is a solid uniform sphere of mass M and the spacecraft is a point object. The universal gravitation constant is G.

(i) Derive an equation for the orbital speed v_o of the spacecraft in terms of M, r and G.

(ii) Show that the orbital period T of the spacecraft is given by, $T = 2\pi\sqrt{\dfrac{r^3}{MG}}$.

(iii) Derive an equation for the total mechanical energy E of the spacecraft in terms of M, m, r and G.

(iv) Show that the escape velocity v_e of the spacecraft from the circular orbit with radius r is given by $v_e = \sqrt{\dfrac{2GM}{r}}$.

(v) Hence, write down an equation for v_e in terms of v_o.

(*b*) Even though the Orion spacecraft's parking orbit is elliptical, assume that it stayed in a circular parking orbit at an altitude of 400 km from the earth surface. Radius of the earth $R = 6{\cdot}6\times10^6\,m$. Mass of the earth $M = 6{\cdot}0\times10^{24}\,kg$. Take $G = 7{\cdot}0\times10^{-11}\,N\,m^2\,kg^{-2}$.

(i) Using the equation derived in (*a*) (i) above, calculate the orbital speed v_o of the Orion spacecraft orbiting along the parking orbit. Take $\sqrt{60} = 7{\cdot}75$.

(ii) Using the equation derived in (*a*) (iii) above, calculate the total mechanical energy E of the spacecraft. Mass of the spacecraft $m = 3{\cdot}3\times10^4\,kg$.

(iii) Using conservation of mechanical energy, show that the minimum launching speed v_L on the earth that the spacecraft should have in order to arrive at the parking orbit is given by $v_L = \sqrt{GM\left(\dfrac{2}{R}-\dfrac{1}{r}\right)}$.

(iv) Calculate the value of v_L. Take $\sqrt{\dfrac{740}{11}} = 8{\cdot}2$.

(v) Using the relationship in (*a*) (v) above, calculate the escape velocity v_e of spacecraft from the parking orbit. Take $\sqrt{2} = 1{\cdot}4$.

(vi) Using the equation given in (*a*) (ii) above, calculate the orbital period T of the spacecraft Take $\pi = 3$ and $\dfrac{42}{\sqrt{60}} = 5{\cdot}4$.

(vii) How many orbits per day will it complete?

(viii) The actual time for the Orion spacecraft to go around the parking orbit with the orbital speed calculated in (*b*) (i) above took one day. Give the reason for this?

[*see page thirteen*

9. Answer either part (A) or Part (B) only.

Part (A)

An induction cooker shown in figure (1) is a fast, without flames and efficient heating device that uses an alternating magnetic field to generate heat directly within electrically conductive materials. It works by creating eddy currents through electromagnetic induction. A metal pot is placed on top of an induction cooker.

Figure (2) shows the uniform circular conducting bottom of the pot. It is a thin disk of radius l and thickness h. The induction cooker produces a magnetic field of flux density B which is directed into the plane of the disk and it vary with time t at a constant rate of $\frac{\Delta B}{\Delta t}$.

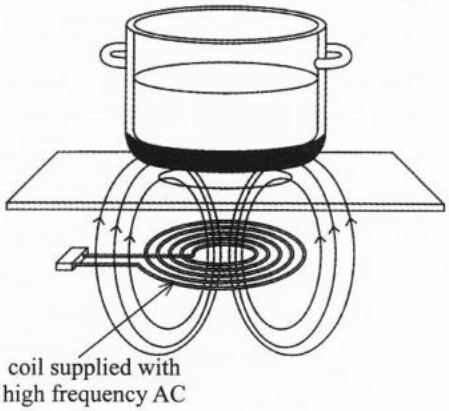


Figure (1)

Consider a small circular strip of radius r, width Δr and thickness h situated on the disk as shown in figure (2).

(*a*) (i) Write down an equation for the magnitude of induced e.m.f. ε in the loop of radius r in terms of r and $\frac{\Delta B}{\Delta t}$.

(ii) The resistivity of the conducting material of the disk is ρ. Write down an equation for the resistance R of the circular strip of radius r, width Δr and thickness h in terms of ρ, r, Δr and h. Take the length of the circular strip as the circumference of the loop of radius r.

(iii) Hence, derive an equation for the current ΔI induced in the strip in terms of ρ, r, Δr, h and $\frac{\Delta B}{\Delta t}$. Assume that the e.m.f. induced in the strip is constant throughout the strip and is equal to the expression obtained in (a) (i) above.

(iv) Derive an equation for the rate of heat generated ΔP in the strip in terms of ρ, r, Δr, h and $\frac{\Delta B}{\Delta t}$.

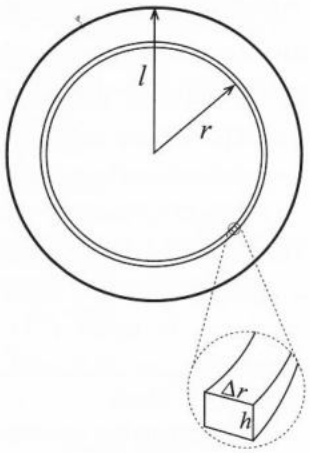


Figure (2)

(v) The rate of heat generated P in the whole disk is given by $P = \frac{\pi l^4 h}{8\rho}\left(\frac{\Delta B}{\Delta t}\right)^2$. The bottom of the pot is made of cast iron and it has following specifications of $l = 0{\cdot}1\,\text{m}$, $h = 2{\cdot}0\times10^{-4}\,\text{m}$ and $\rho = 8\times10^{-7}\,\Omega\text{ m}$. The induction cooker coil produces $\frac{\Delta B}{\Delta t} = 4000\,\text{T s}^{-1}$. Calculate the total rate of heat generated P in the bottom of the pot. Take $\pi = 3$.

(*b*) Standard household power runs at 50 Hz. Induction cookers increase this up to a frequency range of 20 kHz to 50 kHz. What is the reason for this?

(*c*) Can clay pots be used with induction cookers? Give reasons for your answer.

(*d*) To cook a certain food 1·8 kW h of heat is needed. How much energy (in kW h) must be drawn from the main supply in order to cook this food using

(i) an induction-cooker with efficiency 90% **and**

(ii) an electric hot-plate with efficiency 60%.

[*see page fourteen*

Part (B)

A factory uses an electric motor to drive a machine. During operation, the motor may become overheated if it is overloaded or if its cooling system fails. A temperature sensor is attached to the motor casing. The sensor produces a small voltage that depends on the temperature of the motor.

When the motor is operating at normal temperature, the sensor output voltage is 0·04 V. When the motor temperature rises above the safe limit, the sensor output voltage will be 0·41 V and will **increase further with temperature**.

A certain digital circuit requires logic LOW and logic HIGH voltage levels corresponding to normal operating temperature and overheating, respectively.

(*a*) Why 0·41 V **cannot be** directly used to produce logic HIGH voltage level as the input to a digital circuit?

(*b*) The sensor output is connected to the non-inverting input (V_{in}) of an operational amplifier as shown in figure (1) having:

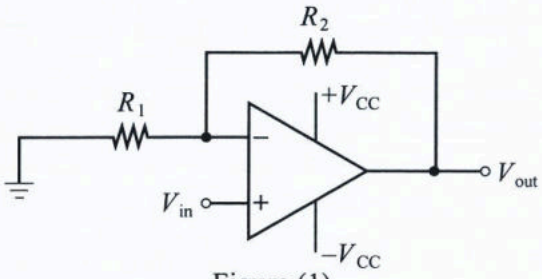


Figure (1)

Input resistance $R_1 = 2\ k\Omega$

Feedback resistance $R_2 = 18\ k\Omega$

Consider that the op-amp is ideal and the supply voltage $+V_{CC} = +10\,V$ and $-V_{CC} = -10\,V$.

(i) Using golden rules, derive an equation for the voltage gain of the amplifier.

(ii) Calculate the voltage gain of the amplifier.

(iii) Determine the amplifier output voltage when the sensor output is 0·04 V.

(iv) Determine the amplifier output voltage when the sensor output is 0·41 V.

(v) The sensor output rises to 1·5 V due to a fault in the sensor circuit. Calculate the expected amplifier output voltage using the expression in (*b*) (i) above, and explain why the actual output voltage **cannot be** equal to this value.

(*c*) The amplified output obtained from (*b*) above, is connected to the non-inverting input (V_+) of an op-amp comparator as shown in figure (2).

Here $+V_{CC} = +5\,V$ and $-V_{CC} = 0\,V$. Assume that the op-amp is ideal.

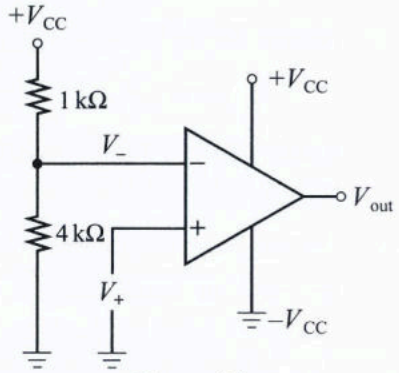


Figure (2)

(i) Calculate the inverting input voltage V_- of the circuit.

(ii) Determine the output voltages of the comparator for the following situations:

I. The motor is operating at normal temperature.

II. The motor temperature is above the safe limit.

(*d*) The output of the comparator from (*c*) above is fed to a 5 V buzzer which sounds when supplied with a 5 V input. The buzzer would respond only to the present output state of the comparator. Therefore, after an overheating event, the buzzer stops sounding when the motor temperature returns to the normal range, even though the motor has not yet been checked by an operator. An S-R flip-flop is used to solve this issue. A push button is provided for the operator, and pressing it produces a 5 V signal.

(i) State which signal should be connected to the SET input of the flip-flop.

(ii) State which signal should be connected to the RESET input of the flip-flop.

(iii) Which output of the flip flop should be connected to the buzzer?

(*e*) The operator wants to make the reset operation safer. The flip-flop should reset **only** when

I. the motor temperature has returned **below the safe limit, and**

II. the reset push button is pressed.

Let:

C = comparator output and P = reset push button output

(i) Write a logic expression for the RESET input of the flip-flop.

(ii) Copy the given flip-flop block diagram shown in figure (3) to your answer sheet. Draw a suitable logic circuit on the block diagram, using C, P and only two appropriate logic gates.

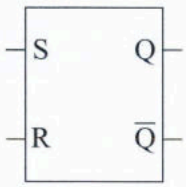


Figure (3)

[*see page fifteen*

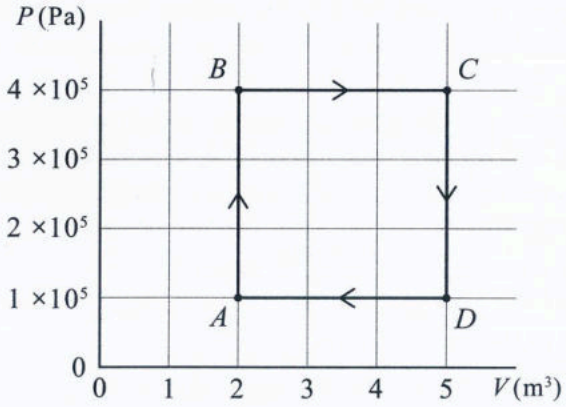
10. Answer either part (A) or Part (B) only.

Part (A)

(a) (i) Starting from Charles's law and pressure law, derive the ideal gas equation $PV = nRT$ for n number of moles. Other symbols have their usual meanings.

(ii) The first law of thermodynamics for a closed system is $\Delta Q = \Delta U + \Delta W$. Identify each term in the above equation.

(*b*) A solar thermal power plant uses mirrors to concentrate solar radiation onto a receiver. The receiver transfers this accumulated thermal energy to a fixed mass of an ideal gas contained in an engine where a cylinder fitted with a frictionless movable piston. Thermal energy supplied causes the gas to expand and perform useful work. During the cooling stage, thermal energy is transferred from the gas to the surrounding water, allowing the gas to return to its initial state. The back and forth motion of the piston is used to drive an electrical generator. The figure shows the pressure (P) - volume (V) diagram for one complete cycle for such an engine working under idealized conditions. Let P_A, P_B and P_C, V_A, V_B and V_C and T_A, T_B and T_C be pressures, volumes and absolute temperatures at points A, B and C, respectively.



(i) Identify the thermodynamic processes represented by $A \rightarrow B$ and $B \rightarrow C$.

(ii) State whether $C \rightarrow D$ and $D \rightarrow A$ processes are cooling or heating process.

(iii) Calculate the ratio $\frac{T_C}{T_A}$.

(*c*) In the process $A \rightarrow B$, the heat absorbed by the gas ΔQ_{AB} is given by $\Delta Q_{AB} = n\frac{3}{2}R(T_B - T_A)$. Here n is the number of moles of the ideal gas used.

(i) Show that ΔQ_{AB} can be written as, $\Delta Q_{AB} = \frac{3}{2}V_A(P_B - P_A)$.

(ii) Hence, calculate ΔQ_{AB}.

(iii) What is the increase in the internal energy ΔU_{AB} of the gas?

(*d*) In the process $B \rightarrow C$, the heat absorbed by the gas ΔQ_{BC} is given by $\Delta Q_{BC} = n\frac{5}{2}R(T_C - T_B)$.

(i) Derive an equation for ΔQ_{BC} in terms of P_B, V_C and V_B.

(ii) Hence, calculate ΔQ_{BC}.

(iii) During the process $B \rightarrow C$, calculate the work done by the gas, ΔW_{BC}.

(iv) Hence, calculate the increase in the internal energy ΔU_{BC} of the gas.

(*e*) (i) Calculate the net work done by the gas ΔW_{net} during one complete cycle.

(ii) Hence, calculate the thermal efficiency η of the complete cycle. Give your answer to the nearest integer as a percentage.

(iii) Due to solar irradiation the power plant receives 10 000 W of thermal power. What is the mechanical power produced by the plant?

(*f*) After several months of operation, dust accumulates on the reflecting mirrors of the solar thermal power plant. What changes would you expect in the P - V diagram given above?

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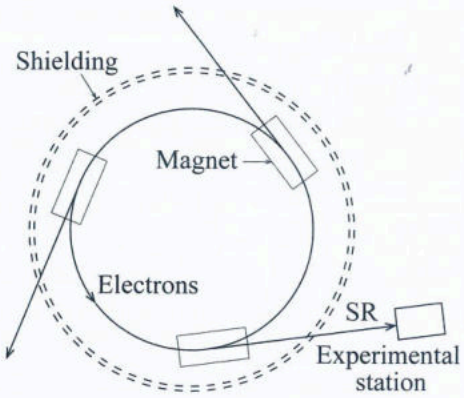
Part (B)

A synchrotron is a special research facility in which electrons are accelerated to speeds close to the speed of light and stored in a circular storage ring. As the electrons are continuously deflected by magnetic fields, they emit intense electromagnetic radiation known as synchrotron radiation (SR). This radiation covers a wide range of wavelengths across the electromagnetic spectrum. The radiation produced is directed to experimental stations where it is used for research in materials science, physics, biology and nanotechnology. Since synchrotron radiation has a very high photon flux, strict radiation-safety procedures are followed. Figure shows a simplified arrangement of a synchrotron facility.



(Take $hc = 1240\ \text{eV nm}$ for calculations, where h is Planck's constant and c is the speed of light. Also, $1\ \text{eV} = 1{\cdot}6\times10^{-19}\ \text{J}$ and electron charge $= 1{\cdot}6\times10^{-19}\ \text{C}$)

(*a*) The storage ring contains $5{\cdot}0\times10^{12}$ electrons. Each electron completes $2{\cdot}0\times10^{6}$ revolutions per second. The motion of these electrons produces an electric current known as the beam current.

(i) Determine the total number of electrons passing a fixed point in the storage ring in one second.

(ii) Hence determine the beam current in the storage ring.

(*b*) Different experimental stations are designed to receive radiation with different wavelengths and photon energy ranges for various experimental applications. A synchrotron facility operates three experimental stations using electromagnetic radiation in the given wavelength ranges.

Experimental station	Wavelength Range
A	$1\times10^{-10}\,\text{m} - 1\times10^{-8}\,\text{m}$
B	$1\times10^{-8}\,\text{m} - 4\times10^{-7}\,\text{m}$
C	$7\times10^{-7}\,\text{m} - 1\times10^{-4}\,\text{m}$

Write down the name of the region of the electromagnetic spectrum corresponding to each of the wavelength range.

(*c*) In a synchrotron radiation experiment, a carbon nanomaterial is analyzed using X-ray photons. It is found that photons with an energy of 310 eV can remove electrons from inner shells of carbon atoms in the material. In the experiment, the X-ray beam used for the analysis has a power of 9·92 mW and is focused onto an area of $2{\cdot}0\times10^{-6}\,\text{m}^2$ on the sample surface.

(i) Determine the wavelength corresponding to this photon energy.

(ii) Determine the number of photons incident on the sample per second.

(iii) Determine the photon flux (number of photons incident per unit area per second) on the sample.

(*d*) In a conventional X-ray tube, high-energy electrons are accelerated towards an aluminium target. Characteristic X-rays are emitted when an electron from a higher energy level fills a vacancy in an inner shell of an aluminium atom. If the energies of the higher and lower levels for aluminium are E1 = −74 eV and E2 = −1624 eV, respectively, calculate the energy of the characteristic X-ray photon emitted.

(*e*) State **one** advantage of synchrotron X-ray radiation over characteristic X-rays.

(*f*) Synchrotron facilities are designated radiation-controlled areas. Radiation produced near the storage ring may travel towards an experimental station. Therefore, shielding materials are installed between the storage ring and experimental stations, and personnel working wear personal dosimeters.

The effective dose rate without shielding is 0·40 mSv day^{-1}. The shielding material reduces the effective dose rate to one-half of its existing value for every 2·0 cm thickness.

(i) Calculate the effective dose rate after passing through 4·0 cm thick shielding.

(ii) A researcher working at the experimental station receives this reduced effective dose rate. Calculate the total effective dose received during 8 hours per day for 99 working days.

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