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இலங்கைப் பரீட்சைத் திணைக்களம்
Department of Examinations, Sri Lanka

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2022(2023)
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2022 (2023)
General Certificate of Education (Adv. Level) Examination, 2022 (2023)

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* **11** *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 one of the following pairs of quantities consists of a vector and a scalar, respectively?
(1) Mass, Velocity (2) Power, Speed
(3) Work, Distance (4) Force, Potential Energy
(5) Momentum, Torque

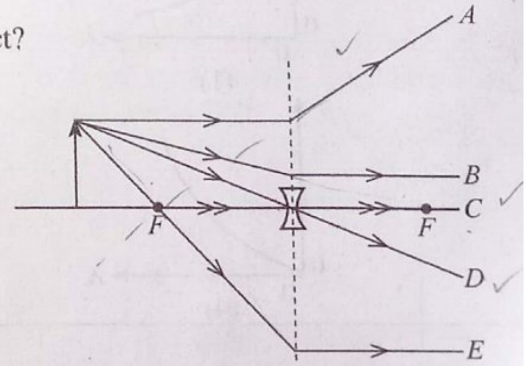
2. The magnitudes of two coplanar forces acting on a body are 11 N and 5 N. Which one of the following values could **not** be equal to the magnitude of the resultant force?
(1) 16 N (2) 9 N (3) 7 N (4) 6 N (5) 5 N

3. The quality of sound produced by a musical instrument depends on the
(1) frequency of sound. (2) amplitude of sound.
(3) intensity of sound. (4) wavelength of sound.
(5) existence of overtones in the sound.

4. A stationary magnetic field **does not** interact with any
(1) stationary electric charges. (2) moving electric charges.
(3) current carrying wires. (4) stationary permanent magnets.
(5) moving permanent magnets.

5. The back e.m.f. in an electric motor is maximum when the motor
(1) is not operating. (2) begins its operation.
(3) is increasing its speed. (4) is at its maximum speed.
(5) is decreasing its speed.

6. Which one of the rays drawn in the figure is **not** correct?
(1) *A* (2) *B* (3) *C*
(4) *D* (5) *E*



[See page t

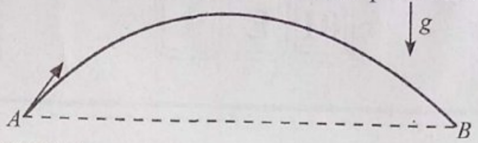
7. What is the charge of an $\bar{u}$ quark? (The elementary charge is e)

(1) 0 (2) $+\frac{1}{3}e$ (3) $+\frac{2}{3}e$ (4) $-\frac{2}{3}e$ (5) $-\frac{1}{3}e$

8. The surface temperature of the sun is 6000 K and it emits blackbody radiation at peak wavelength 500 nm. For a blackbody with a surface temperature of 10 000 K, what will be the value of peak wavelength of emitted radiation?

(1) 30 nm (2) 300 nm (3) 500 nm (4) 600 nm (5) 800 nm

9. The figure shows the path AB of a ball projected from point A. Neglect air resistance.



Consider the following statements.

(A) The velocity of the ball at the maximum height of the path is zero.
(B) The velocity of the ball at point B is equal to the velocity at point A.
(C) The kinetic energy of the ball at point B is equal to the kinetic energy at point A.

Of the above statements,

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

10. The Young's modulus of the material of a wire depends on

(A) the initial length of the wire.
(B) the cross-sectional area of the wire.
(C) the nature of the material of the wire.

Of the above statements,

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

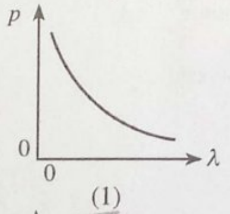
11. A uniform electric field of intensity $200\ \text{V m}^{-1}$ is applied in between a pair of parallel metallic plates. What should be the separation between the plates in order to produce a potential difference of 10 V?

(1) 20 mm (2) 30 mm (3) 50 mm (4) 20 m (5) 30 m

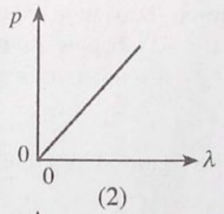
12. An alarm in a car at rest is emitting sound waves of frequency 510 Hz. A person on a motorcycle is travelling directly away from the car. What is his velocity if he hears the frequency of the alarm as 480 Hz? (Speed of sound in air is $340\ \text{m s}^{-1}$)

(1) $10\ \text{m s}^{-1}$ (2) $15\ \text{m s}^{-1}$ (3) $20\ \text{m s}^{-1}$ (4) $25\ \text{m s}^{-1}$ (5) $30\ \text{m s}^{-1}$

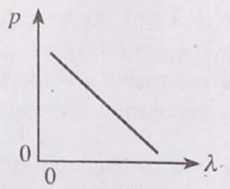
13. Which of the following graphs best represents the variation of momentum (p) of a particle with its de Broglie wavelength (λ)



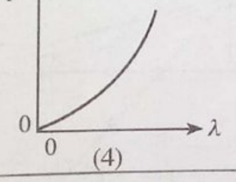
(1)



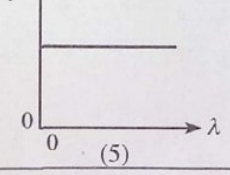
(2)



(3)



(4)



(5)

[See page three

14. A car has a grease nipple of length of 3×10^{-3} m and diameter 5×10^{-4} m. If the coefficient of viscosity of grease is 80 Pa s, what is the pressure difference needed to force a volume of 10^{-6} m^3 grease through the nipple in 10 s? [Take $(2 \cdot 5)^4 = 40$ and $\pi = 3$]

(1) $1 \cdot 6 \times 10^3$ Pa (2) $1 \cdot 6 \times 10^4$ Pa (3) $1 \cdot 6 \times 10^5$ Pa (4) $1 \cdot 6 \times 10^6$ Pa (5) $1 \cdot 6 \times 10^7$ Pa

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15. Consider the following statements made about absolute zero temperature.

(A) It is the temperature at which water freezes at atmospheric pressure.
(B) It is the temperature at which all gases become liquids.
(C) It is the temperature at which mean kinetic energy of an ideal gas becomes zero.

Of the above statements,

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

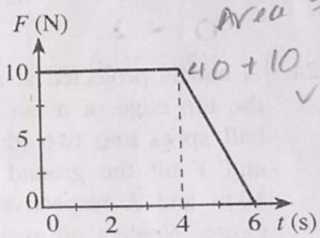
16. Which of the following can store one bit of data?

(1) AND gate (2) NOR gate (3) XOR gate (4) OR gate (5) Flip-flop

17. The period of oscillation of a simple pendulum of length l is T. Suppose a simple pendulum of length $2l$ is hung from the ceiling of an elevator. What will be the period of oscillations of this pendulum if the elevator accelerates vertically upward at $\frac{g}{2}$?

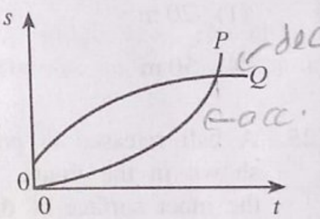
(1) $\frac{T}{4\sqrt{3}}$ (2) $\frac{T}{2\sqrt{3}}$ (3) $\frac{T}{\sqrt{3}}$ (4) $\frac{2T}{\sqrt{3}}$ (5) $\frac{4T}{\sqrt{3}}$

18. A body of mass 2 kg is initially at rest on a frictionless horizontal surface. Then a horizontal force F varying with time t as shown in the figure acts on the body during 6 s. What is the final velocity of the body?



(1) 20 m s^{-1} (2) 25 m s^{-1} (3) 30 m s^{-1}
(4) 40 m s^{-1} (5) 50 m s^{-1}

19. The figure shows the displacement (s) - time (t) graphs of two objects P and Q moving along a straight line. Consider the following statements.

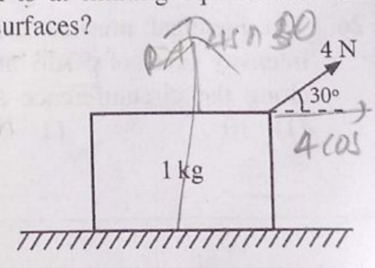


(A) Both objects have velocities in the same direction.
(B) Velocities of both objects increase with time.
(C) Both objects have the same velocity at the crossing point of the two graphs.

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.

20. A block of mass 1 kg is kept on a rough horizontal surface. The block is pulled by a force of 4 N inclined at 30° to the horizontal as shown in the figure. If the block is at limiting equilibrium what is the value of the coefficient of limiting friction between the two surfaces?



(1) $\frac{\sqrt{3}}{4}$ (2) $\frac{\sqrt{3}}{5}$ (3) $\frac{\sqrt{3}}{6}$

(4) $\frac{\sqrt{3}}{8}$ (5) $\frac{\sqrt{3}}{10}$

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21. Consider the following statements made regarding Tsunami waves.

(A) Wavelengths of waves in deep water are lower than that in shallow water.

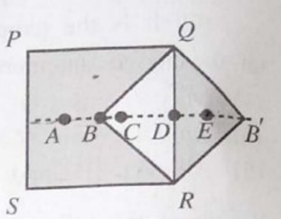
(B) Speeds of waves are higher in deep water than that in shallow water.

(C) Amplitudes of the waves in deep water are higher than that in shallow water.

Of the above statements,

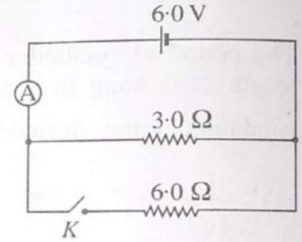
(1) Only (A) is true. (2) Only (B) is true.
(3) Only (A) and (C) are true. (4) Only (B) and (C) are true.
(5) All (A), (B) and (C) are true.

22. A triangular shaped portion QBR is removed from a uniform square sheet $PQRS$ and connected to form the composite sheet $PQB'RS$ as shown in the figure. The center of the gravity of the composite sheet is most likely to be at



(1) A (2) B (3) C
(4) D (5) E

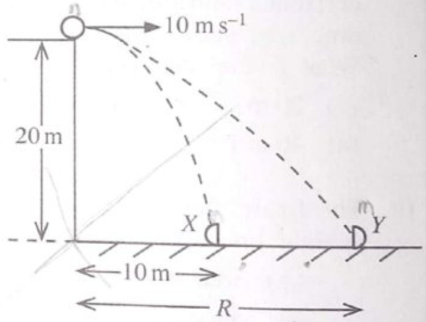
23. The diagram shows a circuit having a battery of e.m.f. 6·0 V, a 3·0 Ω resistor and a 6·0 Ω resistor connected in parallel. When the switch K is opened reading of the ideal ammeter is 1·5 A. What is the ammeter reading when the switch is closed?



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

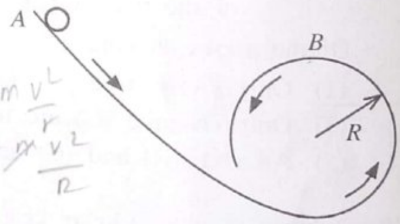
24. A ball is projected at a velocity of $10\ m\ s^{-1}$ horizontally from the top edge of a building of height 20 m. While falling, the ball splits into two identical pieces, X and Y. Then pieces X and Y hit the ground simultaneously at horizontal distances 10 m and R respectively from the building as shown in the figure. Neglect air resistance.

What is the distance R?



(1) 20 m (2) 30 m (3) 40 m
(4) 50 m (5) 60 m

25. A ball released at point A travels on a frictionless track as shown in the figure. Then the ball **just touches** point B on the inner surface of the circular part of the track of radius R. What is the velocity of the ball at point B?



(1) 0 (2) $\sqrt{gR}$ (3) $2\sqrt{gR}$
(4) $\sqrt{5gR}$ (5) $4\sqrt{gR}$

26. Ten identical musical instruments placed along the circumference of a circle produce a sound intensity level of 50 dB at the center of the circle. How many identical musical instruments placed along the circumference are needed to produce a sound intensity level of 60 dB at the center?

(1) 10 (2) 20 (3) 50 (4) 100 (5) 200

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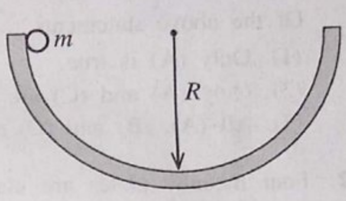
27. As shown in the figure, a sphere of mass m is released from the rim of a hemispherical bowl of radius R. The sphere finally stops due to friction at the bottom of the bowl after oscillating several times.

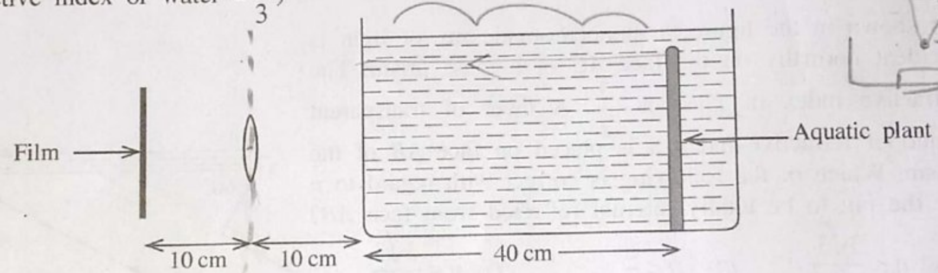
Which of the following is true regarding the work done by gravitational force and the normal reaction force acting on the sphere during the process?

	Work done by gravitational force	Work done by normal reaction force
(1)	0	0
(2)	$\frac{1}{2}mgR$	0
(3)	mgR	0
(4)	0	mgR
(5)	mgR	mgR



28. A person takes a picture of a aquatic plant in a container with thin glass walls using a convex lens. The container is filled with water. When the film, lens, and aquatic plant are positioned as shown in the figure, a clear image of the aquatic plant is recorded on the film.

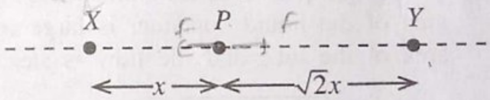
(Refractive index of water $= \frac{4}{3}$)



What is the focal length of the convex lens?

(1) 8·0 cm (2) $\frac{25}{3}$ cm (3) $\frac{110}{13}$ cm (4) 9·0 cm (5) $\frac{40}{3}$ cm

29. As shown in the figure, two point charges X and Y are fixed along a straight line. The charge of X is $+q$. When a negative point charge is placed at point P, it remains stationary. What is the charge of Y? Neglect all other forces acting on charges.



(1) $-\frac{1}{\sqrt{2}}q$ (2) $-\frac{1}{2}q$ (3) $+\frac{1}{2}q$

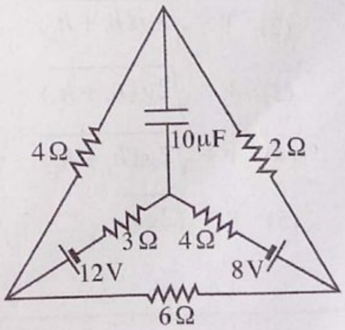
(4) $+\frac{1}{\sqrt{2}}q$ (5) $+2q$

30. The figure shows a circuit containing two batteries with negligible internal resistance, five resistors, and one capacitor.

What is the current flowing through the 3 Ω resistor after steady state of the circuit has achieved?

(1) 0·1 A (2) 0·2 A (3) 0·4 A

(4) 0·8 A (5) 1·0 A



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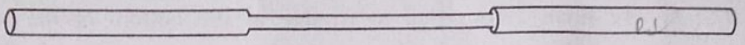
31. A current carrying metallic wire with different cross-sections is shown in the figure. Consider the following statements.



(A) The current in the wire is same everywhere.

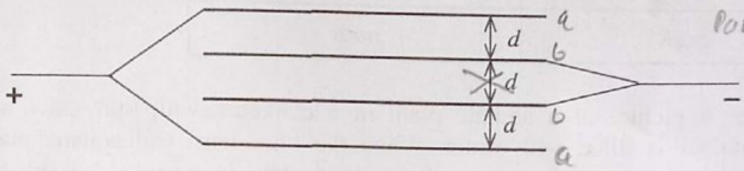
(B) The power dissipation of the wire is higher in the thin section than that in thick section.

(C) The drift velocity of electrons is higher in the thin section than that in thick section.

Of the above statements,

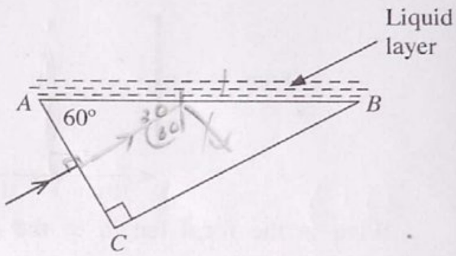
(1) Only (A) is true.
(2) Only (B) is true.
(3) Only (A) and (C) are true.
(4) Only (B) and (C) are true.
(5) All (A), (B) and (C) are true.

32. Four metallic plates are placed at a separation d from each other as shown in the figure. The overlapping area of each plate with the other is A. What is the equivalent capacitance of the system?



(1) $\frac{1}{3}\frac{\varepsilon_0 A}{d}$ (2) $\frac{1}{2}\frac{\varepsilon_0 A}{d}$ (3) $\frac{\varepsilon_0 A}{d}$ (4) $2\frac{\varepsilon_0 A}{d}$ (5) $3\frac{\varepsilon_0 A}{d}$

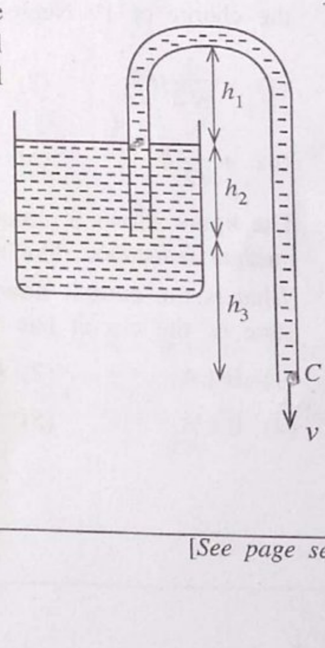
33. As shown in the figure, a monochromatic ray of light is incident normally on the face AC of a glass prism. The refractive index of glass is $\frac{3}{2}$. A layer of transparent liquid of refractive index n is placed on face AB of the prism. Which of the following is correct with regard to n for the ray to be totally internal reflected from face AB?



(1) $n<\frac{3\sqrt{3}}{8}$ (2) $n<\frac{3}{4}$ (3) $n<\frac{3\sqrt{3}}{4}$

(4) $n>\frac{3\sqrt{3}}{8}$ (5) $n>\frac{3\sqrt{3}}{4}$

34. Figure shows a siphon which is filled with a liquid. The respective heights are marked in the figure. What is the speed (v) of the emerging liquid from the siphon at C? Assume that the cross-sectional area of the liquid container is large compared to the cross-sectional area of the tube and the flow is steady and non-viscous.



(1) $v=\sqrt{2g(h_1+h_2+h_3)}$

(2) $v=\sqrt{2g(h_1+h_2)}$

(3) $v=\sqrt{2g(h_1+h_3)}$

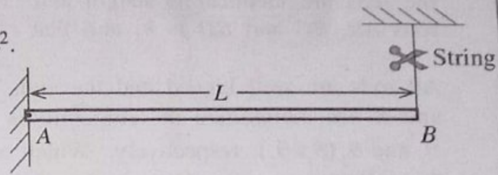
(4) $v=\sqrt{2g(h_2+h_3)}$

(5) $v=\sqrt{2gh_3}$

[See page seven

35. A uniform rod AB of mass M and length L is freely hinged at end A and kept horizontally by a string attached to end B as shown in the figure. What will be initial vertical linear acceleration of end B once the string is cut?

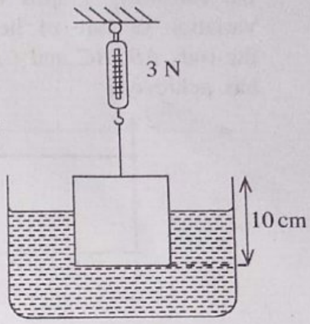
The moment of inertia of the rod about end A is $\frac{1}{3}ML^2$.



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

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

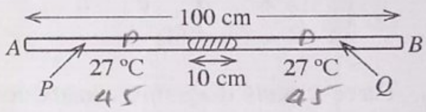
36. A homogeneous wooden cube of side 10 cm is hung in a tank of water by a light string attached to a spring balance as shown in the figure. Densities of wood and water are $800\ kg\ m^{-3}$ and $1000\ kg\ m^{-3}$ respectively. If the reading of the balance is 3 N what is the volume of wood under water?



(1) 400 cm^3 (2) 500 cm^3 (3) 600 cm^3

(4) 700 cm^3 (5) 800 cm^3

37. The length of a uniform glass tube AB sealed at both ends is 100 cm. It is kept horizontally and 10 cm long mercury (Hg) column is trapped at the middle when both air columns (P and Q) are at temperature 27 °C and same pressure. If the temperature of the air columns P and Q are increased to 47 °C and 127 °C respectively what will be the **difference** between the lengths of the two air columns? Neglect the expansion of mercury and glass.

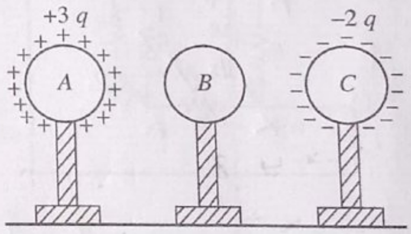


(1) 5 cm (2) 6 cm (3) 8 cm

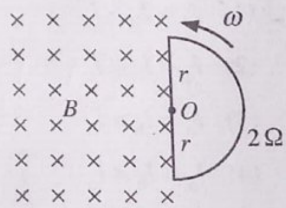
(4) 10 cm (5) 12 cm

38. Three identical conducting spheres A, B and C are mounted on insulating supports and separated as shown in the figure. The sphere A is given a charge $+3q$ and C is given $-2q$ charge. The sphere B does not have a net charge. Then the sphere B is first touched to sphere C, next sphere B is touched to sphere A and finally spheres brought back to the initial positions. The remaining final charge in each sphere is given by,

	Sphere A	Sphere B	Sphere C
(1)	$+3q$	$-q$	$-q$
(2)	$+2q$	0	$-q$
(3)	$+2q$	$-q$	0
(4)	$+q$	$-q$	$+q$
(5)	$+q$	$+q$	$-q$



39. A uniform magnetic field of flux density B is directed into the plane of paper as shown in the figure. A semicircular conducting loop of radius r rotates at constant angular velocity of ω about centre O and perpendicular to the plane. The resistance of the loop is $2\ \Omega$. What is the magnitude of current induced in the loop?



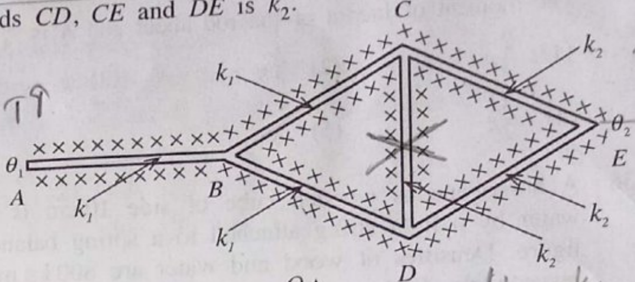
(1) $\frac{1}{4}\omega r^2 B$ (2) $\frac{1}{2}\omega r^2 B$ (3) $\omega r^2 B$

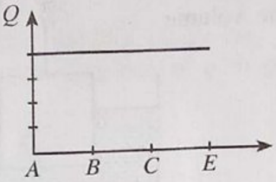
(4) $2\omega r^2 B$ (5) $4\omega r^2 B$

[See page ei

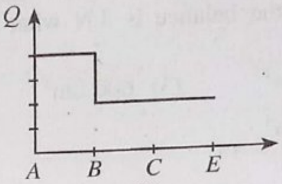
40. Six uniform metal rods AB, BC, BD, CD, CE and DE are connected as shown in the figure. All the rods are identical in length and cross-sectional area. The thermal conductivity of material of rods AB, BC and BD is k_1 and that of rods CD, CE and DE is k_2.

All rods are well lagged and the ends A and E are maintained at temperatures θ_1 and θ_2 $(\theta_1 > \theta_2)$ respectively. Which of the following graphs best represents the variation of rate of heat flow (Q) along the rods AB, BC and CE after steady state has achieved?

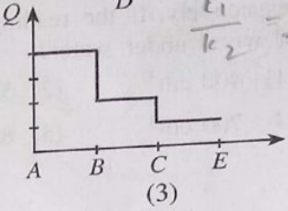




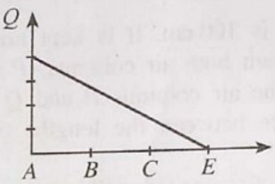
(1)



(2)



(3)



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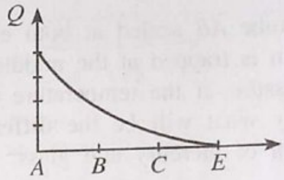
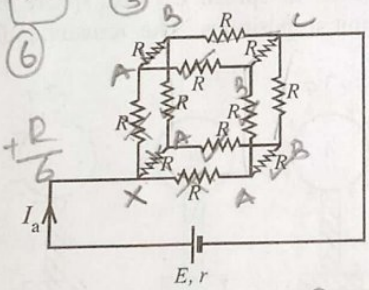
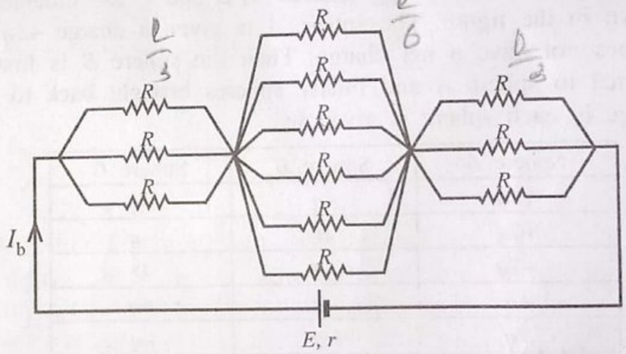
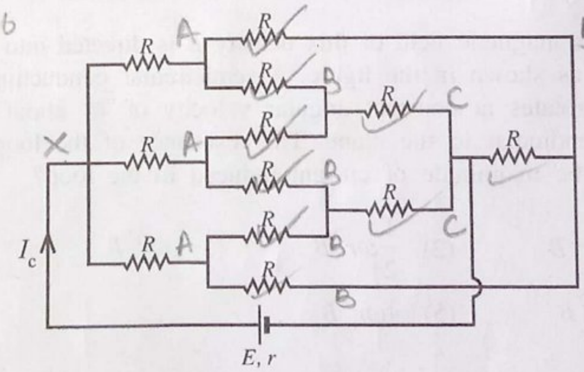


(5)

41. Three circuit diagrams constructed using 12 resistors are shown in figures. What is the correct relationship of the currents I_a , I_b and I_c flowing in the circuits respectively?







(1) $I_a > I_b > I_c$

(2) $I_a < I_b < I_c$

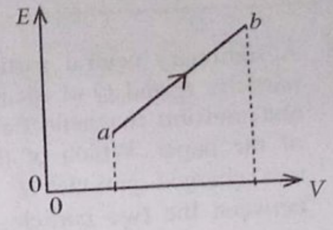
(3) $I_a = I_b > I_c$

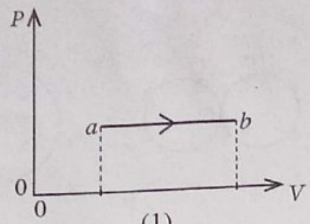
(4) $I_a = I_b < I_c$

(5) $I_a = I_b = I_c$

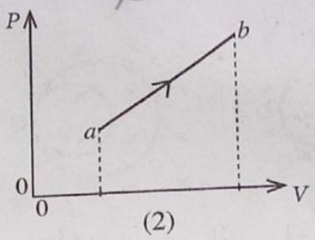
[See page nine

42. During a thermodynamic process from a to b, variation of mean kinetic energy E of a given mass of an ideal gas with volume V is shown in the figure. The corresponding variation of pressure P with volume V of the gas is best represented by

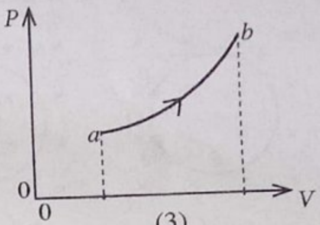




(1)



(2)



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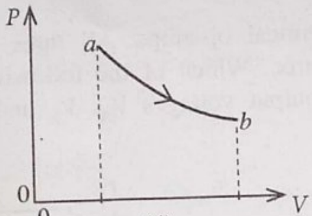
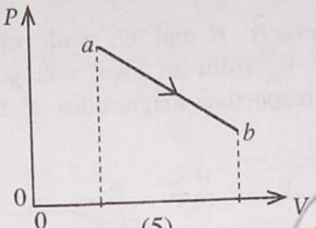
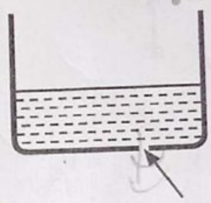


(4)



(5)

43. The bottom surface of a cylindrical container of cross-sectional area A has a small hole of radius r as shown in the figure. When a liquid of surface tension T is filled in the container up to a certain height the liquid starts to seep through the hole. The liquid is filled up to half of that height and an object is floated on the surface of the liquid. What should the minimum mass of the object be in order to seeps the liquid through the hole?

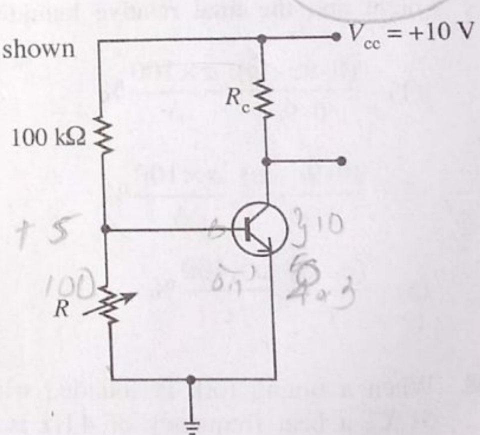


Hole

(1) $\frac{AT}{2rg}$ (2) $\frac{AT}{rg}$ (3) $\frac{2AT}{rg}$

(4) $\frac{rg}{AT}$ (5) $\frac{2rg}{AT}$

44. For which values of R would the silicon transistor circuit shown be in cutoff region and active region, respectively?



(1) 5 kΩ , 1·0 kΩ

(2) 5 kΩ , 2·5 kΩ

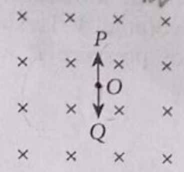
(3) 5 kΩ , 7·5 kΩ

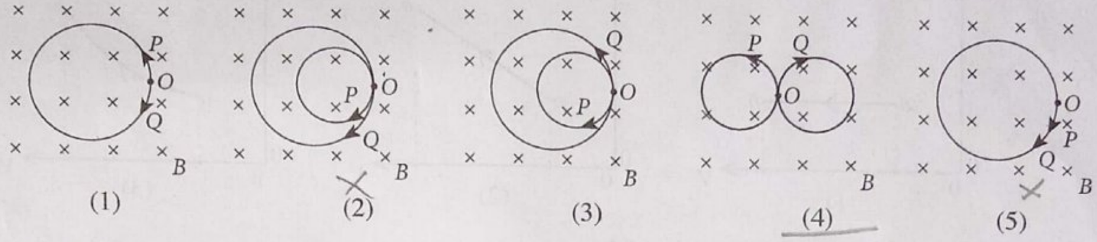
(4) 100 kΩ , 10 kΩ

(5) 100 kΩ , 50 kΩ

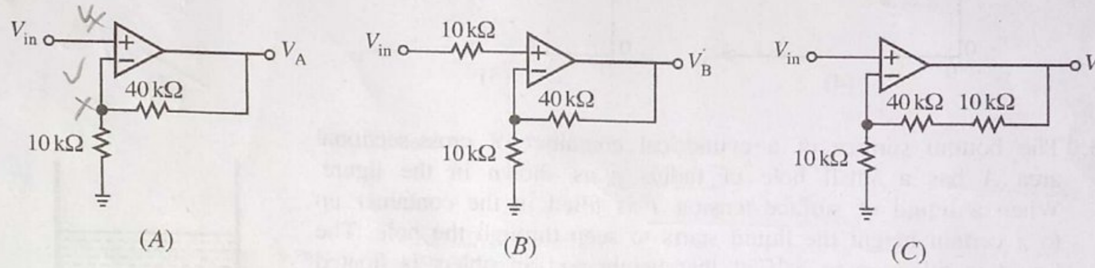
[See page ten

45. A stationary neutral particle at point O decays into two small charged particles P and Q of identical masses as shown in the figure. A constant and uniform magnetic field of flux density B is directed into the plane of the paper. Which of the following correctly shows the paths of the two charged particles P and Q? (Neglect the electrostatic interaction between the two particles)





46. The figure shows three circuits A, B and C, made of identical op-amps. All three circuits are fed by identical input voltage V_{in} from an ideal voltage source. Which of the following correctly gives the comparison of the respective magnitudes of the output voltages V_A, V_B and V_C of the three circuits?



(1) $V_A = V_B = V_C$ (2) $V_A = V_B < V_C$ (3) $V_A > V_B = V_C$

(4) $V_A = V_B > V_C$ (5) $V_A < V_B < V_C$

47. Ambient air at 30 °C and relative humidity (RH) 90% is cooled to 10 °C and some of the moisture in air is removed by an air-conditioning plant. Then this air is heated to 20 °C and passed to a computer laboratory. If the values of saturated water vapour pressure at temperatures 10 °C, 20 °C and 30 °C are given by a, b and c respectively, what is the ratio of moisture removed from the plant and the final relative humidity (RH) of the air at 20 °C?

(1) $\dfrac{(0\cdot 9c-a)}{0\cdot 9c}, \dfrac{a\times 100}{b}\%$ (2) $\dfrac{(0\cdot 9c-a)}{0\cdot 9c}, \dfrac{c\times 100}{b}\%$

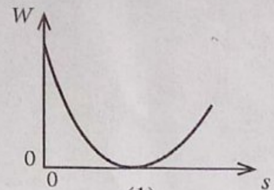
(3) $\dfrac{(0\cdot 9c-a)}{c}, \dfrac{a\times 100}{b}\%$ (4) $\dfrac{(c-a)}{c}, \dfrac{b\times 100}{c}\%$

(5) $\dfrac{(c-a)}{c}, \dfrac{a\times 100}{c}\%$

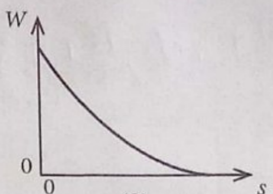
48. When a tuning fork is sounded with a tube closed at one end and filled with air at temperature 51 °C, a beat frequency of 4 Hz is heard. Same beat frequency is heard when the tuning fork is sounded with the tube filled with air at temperature 127 °C. In both situations the tube is sounded with the same overtone. What is the frequency of the tuning fork? Neglect the end correction of the tube. ($\sqrt{324} = 18$)

(1) 56 Hz (2) 60 Hz (3) 66 Hz (4) 76 Hz (5) 80 Hz

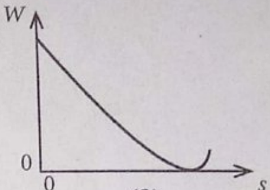
49. Suppose a spacecraft moves from the earth to the moon. Which one of the following graphs best represents the variation of the magnitude of its net weight (W) with distance (s)? (Neglect the effect of other objects)



(1)



(2)



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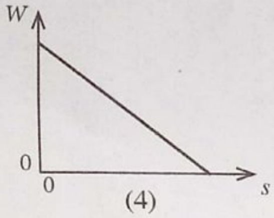

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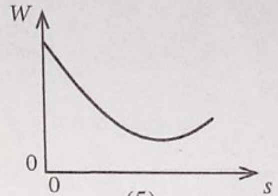
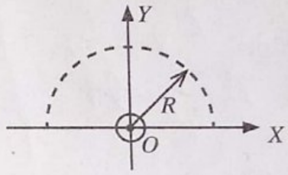
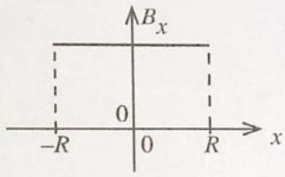


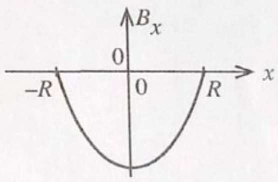
(5)

50. A long straight wire placed at the origin O carries a constant current directed out of the paper along the Z-axis. Figure shows a semicircle of radius R drawn on the X-Y plane centering the wire. Which one of the following graphs best represents the variation of the x–component of the magnetic flux density (B_x) along the semicircular path with x ?





(1)



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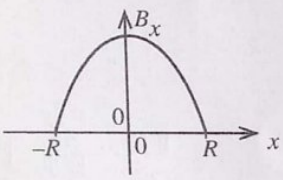
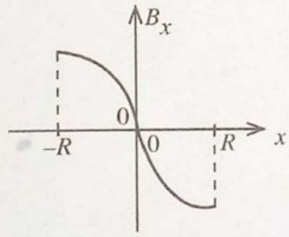


(3)



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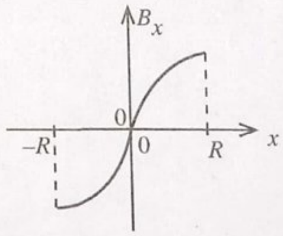

(5)

* * *

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය 2022(2023)
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தரப்) பரீட்சை, 2022(2023)
General Certificate of Education (Adv. Level) Examination, 2022(2023)

භෞතික විද්‍යාව II பௌதிகவியல் II **Physics II**	**PART B — Essay**		**01 E II**

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

- **Note**: For an example the number 65210 can be written as $6{\cdot}52\times10^4$ in scientific notation after rounding off to two decimal places.

5. (*a*) For a steady flow of a non-viscous, incompressible fluid, the Bernoulli's equation can be written as $P + \frac{1}{2}\rho v^2 + h\rho g$ = constant. Here all symbols have their usual meaning. Identify the terms in the left hand side of the equation.

(*b*) A racing car having a rear spoiler with a curved surface at the bottom is shown in Figure (1). According to the Bernoulli's principle, when the car is moving at high speed, a downward force acts on the spoiler.

A vertical cross-section of the rear spoiler of the racing car moving horizontally through air towards left with constant velocity v relative to the ground is shown in Figure (2).

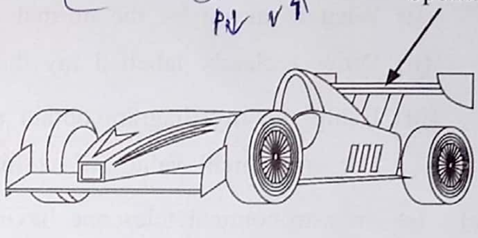

Figure (1)

(i) What is the velocity of air at point X relative to the car? Assume that the air is at rest relative to the ground.

(ii) As shown in Figure (2), the cross-sectional area of an imaginary flow tube far away from the spoiler is A_1 and the corresponding cross-sectional area of the same flow tube below the spoiler is A_2. If $\frac{A_1}{A_2} = 1{\cdot}2$, write down an expression for the speed (v_2) of air relative to the car flowing under the spoiler in terms of v.

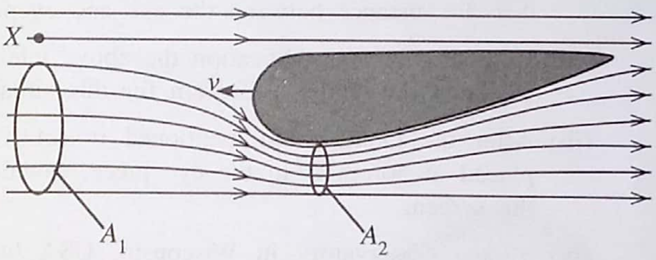

Figure (2)

(iii) If the effective horizontal cross-sectional area of the spoiler is $0{\cdot}2$ m^2, calculate the downward force acting on the spoiler. v = 360 km h^{-1} and density of air = $1{\cdot}2$ kg m^{-3}.

(iv) If wind is blowing horizontally relative to the ground from left to right with a constant velocity will the force calculated in (*b*) (iii) above increase or decrease? Give reasons to your answer without any calculations.

(*c*) When a car moves at high speed, the drag force (F_d) acting on the car due to air is given by $F_d = \frac{1}{2}C\rho A v^2$. Here C is known as the drag coefficient, ρ is the density of air, A is the effective frontal area of the car facing air and v is the speed of the car relative to air. Spoilers also change direction of airflow on vehicles and reduce the drag coefficient.

(i) Show that C is dimensionless.

(ii) Taking $C = 0{\cdot}3$, $A = 1{\cdot}4$ m^2, $\rho = 1{\cdot}2$ kg m^{-3} and v = 360 km h^{-1}, calculate the drag force F_d acting on the racing car mentioned in (*b*) above. Assume that air is at rest relative to the ground.

(iii) Calculate the power (P) needed to overcome the drag force when the car is moving at constant velocity of 360 km h^{-1}.

[see page ten

(iv) The car starts from rest and achieves the speed of $360\ \text{km h}^{-1}$. A student argues that the average power needed to overcome air drag in this process is $\frac{P}{2}$, where P is the value calculated in (*c*) (iii) above. Giving reasons state whether you agree with the argument of the student.

(v) The power needed to overcome other frictional forces acting on the car is 48 kW. The energy released by burning one litre of petrol is $4{\cdot}0 \times 10^7$ J and only 15% of this energy is used to move the car. When the car is travelling at constant speed of $360\ \text{km h}^{-1}$ determine the fuel efficiency of the car in km per litre.

(vi) If wind is blowing horizontally relative to the ground from left to right with a constant velocity of $10\ \text{m s}^{-1}$, calculate the power (P') needed to overcome the drag force when the car is travelling at constant velocity of $360\ \text{km h}^{-1}$ (Give your answer to the nearest integer in kW).

6. (*a*) (i) Define angular magnification (m) of an astronomical (optical) telescope.

(ii) Why is angular magnification a better measure compared to linear magnification for an optical instrument?

(*b*) An astronomical telescope is made with an objective lens L_o of focal length f_o and an eyepiece L_e of focal length f_e.

(i) What is meant by the normal adjustment of a telescope?

(ii) Draw a clearly labelled ray diagram for the telescope when it is in normal adjustment.

(iii) Using the ray diagram obtain an expression for the angular magnification of the telescope.

For very small values of α (in radians) $\tan(\alpha) = \alpha$.

(*c*) (i) An astronomical telescope having $f_o = 100$ cm and $f_e = 10$ cm is adjusted to form the final image of the moon at the least distance of distinct vision of the eye, $D = 25$ cm. The moon subtends an angle $0{\cdot}5°$ at the unaided eye. Calculate the angle (in degrees) subtended by the image of the moon through the telescope at the eye and the angular magnification in this adjustment. Assume that the distance between the eye and eyepiece is negligible. You may use $1° = 0{\cdot}018$ radians.

(ii) With a suitable modification the above telescope is used to take a real image of the moon on a screen. Draw the ray diagram for this situation clearly labelling the focal points and distances.

(iii) After the modification mentioned in (*c*) (ii) above, if the real image is formed on the screen placed at 30 cm from the eye piece, calculate the size of the image (diameter) of the moon on the screen.

(iv) Yerkes Observatory in Wisconsin, USA has the largest and the oldest refracting astronomical telescope functioning from 1897 to date. The observatory was the birthplace of modern astrophysics and collected over 170 000 photographic plates of astronomical objects.

The focal length of the objective lens of Yerkes telescope is $19{\cdot}0$ m. It gives a real image of the moon of diameter $17{\cdot}1$ cm on a photographic plate placed 30 cm behind the eyepiece. Calculate the focal length of the eyepiece of the Yerkes telescope and the angular magnification in this situation. (Give the angular magnification to the nearest integer.)

[*see page eleven*

7. (a) Young's modulus of a material is defined by $\frac{F}{A}\Big/\frac{e}{l}$, where all symbols have their usual meaning. Name the terms $\frac{F}{A}$ and $\frac{e}{l}$.

(b) As shown in Figure (1) a Karate player tried to break a wooden plank by a single kick from his heel. When the player hits the plank, the heel of the player comes to rest from an initial speed of 24 m s^{-1} in $4{\cdot}0$ ms without breaking the plank. The leg has an effective mass of $16{\cdot}0$ kg and the effective cross-sectional area of the smallest part of the leg bone is $3{\cdot}0 \times 10^{-4} \text{ m}^2$. The bone material of the leg can withstand a maximum compressive stress of $1{\cdot}8 \times 10^{7} \text{ N m}^{-2}$. Assume that the stress is uniformly distributed along the bone.

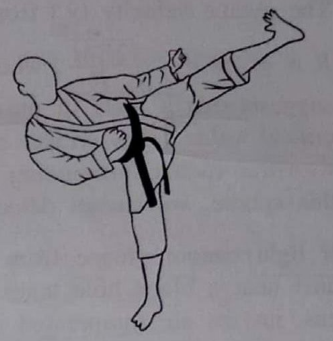

Figure (1)

(i) Determine the mean force acting on the leg during the heel of the player comes to rest from 24 m s^{-1}.

(ii) What is the maximum compressive stress on the bone of the leg?

(iii) Is there a possibility to fracture the bone? Give reasons for your answer.

(c) The leg bone of the Karate player is fractured in the process of kicking as mentioned in (b) above. He uses crutches made of single tube for walking until recovery as shown in Figure (2). The mass of player is 90 kg. Half of the player's weight is supported by crutches and other half is supported by his other leg. While he is standing each crutch makes an angle of 22° with the vertical. Each crutch is made of hollow aluminium tube with inner radius $1{\cdot}0 \times 10^{-2}$ m and outer radius $2{\cdot}0 \times 10^{-2}$ m respectively. Young's modulus of aluminium is $7{\cdot}0 \times 10^{10} \text{ N m}^{-2}$.

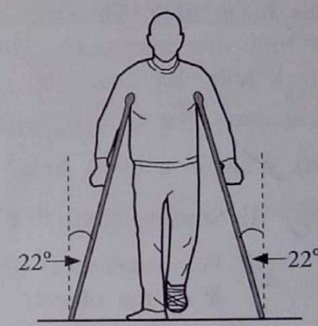

Figure (2)

(i) What should be the minimum coefficient of static friction between the end of a crutch and ground in order for him to stand still without slipping? Take $\tan(22°) = 0{\cdot}4$

(ii) Determine the magnitude of the compressive force acting on each crutch. Take $\cos(22°) = 0{\cdot}9$

- Round off your answers for (c) (iii), (c) (iv) and (d) (ii) below to two decimal places in scientific notation. See the note given before the question **5**.

(iii) Calculate the compressive stress and the compressive strain on a crutch. Take $\pi = 3$.

(iv) If the length of a crutch is 125 cm what is the change in length of a crutch?

(d) Suppose instead of the crutches mentioned in (c) above crutches made of two coaxial hollow tubes are used by the player. Inner tube of the cylindrical crutch is made of aluminium having Young's modulus E_1 and the outer tube is made of stainless steel having Young's modulus E_2. Respective cross-sectional areas of aluminium and stainless steel tubes are A_1 and A_2. The cross-section of the composite tube is shown in Figure (3).

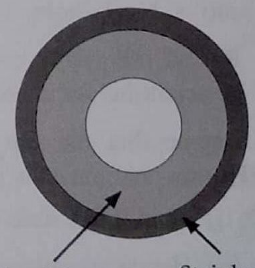

Figure (3)

(i) Show that the effective Young's modulus E of the composite tube is given by $E = \dfrac{E_1A_1 + E_2A_2}{(A_1 + A_2)}$.

(ii) Let $E_1 = 8{\cdot}0 \times 10^{10} \text{ N m}^{-2}$, $A_1 = 10{\cdot}0 \times 10^{-4} \text{ m}^2$, $E_2 = 2{\cdot}0 \times 10^{11} \text{ N m}^{-2}$, $A_2 = 6{\cdot}0 \times 10^{-4} \text{ m}^2$. The length of each crutch is 125 cm. Determine the change in the length of the composite tube when the force in (c)(ii) is applied to the crutch.

(e) Normally rubber caps are fixed to the lower ends of the aluminium crutches. Use physics principles to state advantages that would occur for a person walking using these crutches with rubber caps.

[see page twelve

8. Read the following passage and answer the questions.

Black holes are one of the most curious objects in the universe. They have enormous amount of matter packed into a minimal volume resulting a very strong gravitational field. Because no light can escape from a black hole, they are invisible.

The escape velocity (v_e) from the surface of a spherical object of mass M with uniform density and radius R is given by $\sqrt{\frac{2GM}{R}}$, where G is the universal gravitational constant. This expression for escape velocity suggests that a body of mass M will act as a black hole if its radius R is less than or equal to a certain critical value. This critical radius is known as the Schwarzschild radius R_S, and the surface of the sphere with this radius surrounding a black hole is called the event horizon. Since light cannot escape from within this sphere, we cannot detect events occurring inside it.

If light cannot escape from a black hole, how can we know the existence of such objects? Any gas or dust near a black hole tends to swirl around and pull into the black hole. This causes heating of the dust/gas, just as air compressed in a pump gets hotter. Temperatures of dust/gas in excess of 10^6 K can occur, so it emits not only visible light but also X-rays. Astronomers look for these X-rays emitted by the dust/gas before they cross the event horizon to detect the presence of a black hole.

There are also strong evidences for the existence of much larger supermassive black holes. One such black hole is found to exist at the center of our Milky Way galaxy, 26 000 light-years from Earth in the direction of the constellation Sagittarius. Astrophysicists have discovered a star designated by S4716 revolving around this black hole. This star completes one revolution around the supermassive black hole in a short period of time like four years. This means that the star is travelling at very high speed $8{\cdot}0 \times 10^6$ m s^{-1} around this black hole. By analyzing this motion, the mass of the unseen supermassive black hole can be calculated. You may take $G = 6{\cdot}0 \times 10^{-11}$ N m^2 kg^{-2} and speed of light $c = 3{\cdot}0 \times 10^8$ m s^{-1}.

(*a*) What is a black hole?

(*b*) (i) Starting from first principles derive the expression for the escape velocity $v_e = \sqrt{\frac{2GM}{R}}$

(ii) For a spherical object with uniform density ρ, show that v_e is directly proportional to the radius R of the object.

(iii) Letting $v_e = c$ in the expression derived in (*b*) (i) above, obtain an expression for the Schwarzschild radius (R_S) for a spherical object of mass M in terms of G, M and c.

(*c*) What is the reason for defining an event horizon?

(*d*) Can a black hole emit X-rays? Give reasons for your answer.

(*e*) Determine the peak wavelength (λ_m) of radiation emitted by gas or dust with temperature 10^6 K swirling into a black hole. (Wein's displacement constant = 2900 μm K).

- Round off your answers for (*f*) (i) to **two** decimal places and (*f*) (ii) to **one** decimal place respectively in scientific notation. See the note given before the question 5.

(*f*) Assume that the star S4716 revolves around the supermassive black hole in a circular path of radius r. Further assume that the star and the supermassive black hole are spherical in shape with uniform density.

(i) Using the data given in the paragraph determine the value of r. (Take $\pi = 3$)

(ii) Hence calculate the mass, M_B, of the supermassive black hole.

(iii) Calculate the Schwarzschild radius, R_S, of the supermassive black hole.

(*g*) Suppose hypothetically, the sun suddenly becomes a black hole with the same mass as it has today.

(i) Would the earth continue to revolve around the sun along the same orbit as of today? Give reasons for your answer.

(ii) Could life on earth get affected due to this? Give the main reason for your answer.

(iii) Show that the sun would become a black hole if its mass could shrink to a sphere of 2·4 km in radius. Take the mass of the sun as $1{\cdot}8 \times 10^{30}$ kg.

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

Part (A)

(*a*) The capacity of a cell is defined as the maximum constant current that can be drawn in one hour and its unit is given by ampere-hour (Ah). Two identical cells each of capacity 6 Ah and e.m.f. 5·0 V are connected to form a battery.

Calculate the capacity (in Ah) and the e.m.f. (in V) of the battery if the two cells are connected

(i) in series and

(ii) in parallel.

(*b*) An electric car battery is made using identical 192 cells each with e.m.f. 4·0 V. Eight cells are connected as shown in Figure (1) to form a battery module. A total of 24 such modules are connected in series to form a 24 kWh electric car battery.

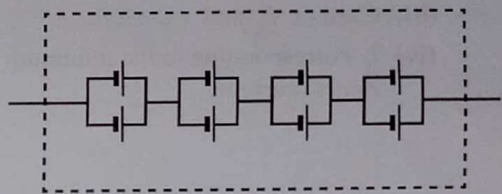

Figure (1): Battery Module

(i) Calculate the e.m.f. (in V) and the capacity (in Ah) of a single module. (You may use 1 kWh = 10^3 V Ah)

(ii) Calculate the capacity (in Ah) and the e.m.f. (in V) of the 24 kWh electric car battery.

(*c*) The above electric car travelling at a constant speed of 36 km h^{-1} on a horizontal road experiences a total resistive force of 480 N against its motion. The power consumption of the air conditioner (A/C) of the car is 1·2 kW. Calculate the maximum distance that the car can travel consuming only 50% of the full stored energy (in kWh) of the battery,

(i) with A/C on for the entire journey. (Assume that the power consumption of the A/C is constant during the entire journey.)

(ii) with A/C off for the entire journey.

(*d*) The electrical circuit used for heating the interior of the above car is shown in Figure (2). When the interior of the car needs to be heated during cold weather, the driver can set a switch to pass a current through the resistors R_1 or R_2 ($R_1 < R_2$). The current passing through the resistors R_1 and R_2 dissipates power and heats up the interior. Therefore resistors act as heaters. Suppose the battery develops an internal resistance over time. An ammeter with internal resistance of 10 Ω and an ideal voltmeter are connected to test the circuit.

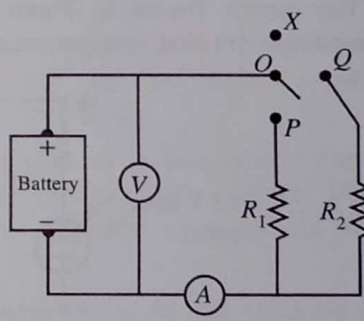

Figure (2)

(i) The driver can complete the circuit by connecting *OP* or *OQ*. Identify and write down the appropriate connections to get a low and a high rates of power dissipation. For example, making the connection *OX* switch off the heaters and disconnects R_1 and R_2 from the circuit.

(ii) The voltmeter reading is 255 V when the heaters are off. The voltmeter reading drops to 250 V and the ammeter reads 5·0 A when the circuit is connected to R_1. Calculate the e.m.f. of the battery, the internal resistance of the battery, and the value of resistance of the resistor R_1.

(iii) Calculate the power dissipation of the heater operating in the power mode mentioned in (*d*) (ii) above.

[*see page fourteen*

Part (B)

(*a*) The circuit shown in figure (1) is used to obtain an appropriate output voltage V_{out} from a variable input voltage V_{in} using a Zener diode and a transistor arrangement. The circuit uses a Zener diode with minimum current of 10 mA and a silicon transistor. Let resistance $R_S = 70\ \Omega$, the load resistance $R_L = 90\ \Omega$ and the Zener voltage $V_Z = 8{\cdot}3$ V. Suppose $V_{in} = 23$ V.

Calculate the following,

(i) V_{out} (Take $V_{BE} = 0{\cdot}7$ V)
(ii) Current I_L
(iii) Current I_S and
(iv) I_C corresponding to the minimum Zener current.

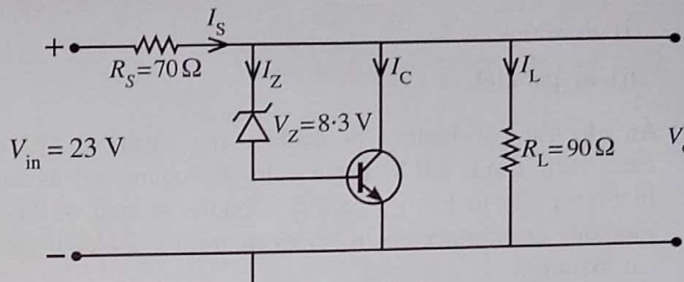

Figure (1)

(*b*) The circuit in Figure (1) can regulate a voltage variation in the input to maintain a constant V_{out}.

(i) Calculate the amount of power dissipated across the R_S resistor when $V_{in} = 23$ V and 30 V.
(ii) Using your calculations in (*b*)(i) above, briefly explain how a change in the input voltage is regulated by the circuit.

(*c*) The circuit in Figure (1) can also regulate a voltage variation in V_{out} due to an increase in output load resistance.

(i) If the load resistance is increased, what will happen to Zener current I_Z and I_C? Explain your answer.
(ii) Briefly explain how the Zener diode and transistor combination regulate the output voltage when the load resistance is increased.

(*d*) The circuit shown in Figure (2) is used to charge a battery from a solar panel with an internal resistance (r) that can generate up to 15 V. The output voltage of the circuit should not exceed 14 V.

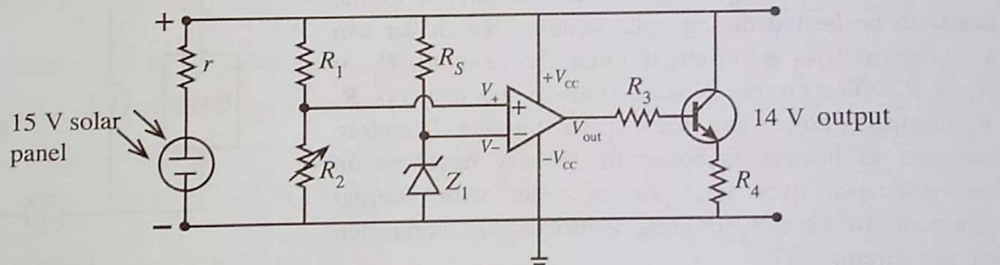

Figure (2)

(i) Write down the operational mode of the operational amplifier in the above circuit from the given choices. (inverting amplifier, non-inverting amplifier, comparator)
(ii) Under bright sunlight R_2 is adjusted to produce 14 V output voltage. When $R_1 = 9$ kΩ and $R_2 = 5$ kΩ for the output of the op-amp to be positively saturated, calculate the most appropriate maximum voltage V_{Z_1} for that Zener diode Z_1 should have.
(iii) If the output of the op-amp saturates for 100 μV voltage difference between the non inverting input and the inverting input, calculate the open-loop voltage gain of the op-amp when the output voltage of the circuit is 14 V? Assume that the output saturation voltage of the op-amp is 2 V below the supply voltage.
(iv) Briefly explain the action of the op-amp and the transistor in this circuit when the solar panel produces less than 14 V under weak sunlight.

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

Part (A)

(*a*) Clearly identifying the symbols used, write down an expression for the volume expansivity (γ) of a liquid.

(*b*) In the tank of a filling station at Nuwaraeliya, the temperature of petrol in a certain day is 7 °C in the morning and 27 °C in the afternoon. The average volume expansivity of petrol is $9{\cdot}6 \times 10^{-4}\ °C^{-1}$ and the density of petrol at 7 °C is $730\ kg\ m^{-3}$. A car is going to be filled 20 litres of petrol from the filling station.

(i) What is the mass of 20 litres of petrol at 7 °C? ($1\ m^3$ = 1000 litres)

(ii) If the temperature of $1\ m^3$ of petrol at 7 °C increases to 27 °C, calculate its new volume. (Round off your answer to three decimal places in m^3.)

(iii) What is the density of petrol at 27 °C? [Take $\frac{7{\cdot}3}{1{\cdot}019} = 7{\cdot}164$. Give your answer to the nearest integer in $kg\ m^{-3}$.]

(iv) Calculate the mass of 20 litres of petrol at 27 °C.

(v) How many extra kilograms of petrol would the car get if 20 litres of petrol is filled at 7 °C instead of at 27 °C from the filling station.

(*c*) A tank of a petrol bowser is made of metal and the internal volume of the tank is 25 000 litres at 7 °C. In a hot day, the temperature of petrol and the tank became 27 °C and the tank was completely filled by the petrol due to the expansion. The average volume expansivity of petrol is $9{\cdot}6 \times 10^{-4}\ °C^{-1}$ and linear expansivity of metal is $2{\cdot}4 \times 10^{-5}\ °C^{-1}$.

- Round off your answers for (*c*) (i), (*c*) (iii) and (*c*) (iv) below to two decimal places in scientific notation. See the note given before the question **5**.

(i) Calculate the apparent volume expansivity of petrol in the tank.

(ii) Hence calculate the volume of petrol (in litres) at 7 °C. [Take $\frac{1}{1+1{\cdot}776\times10^{-2}} = 0.98$]

(iii) How much heat is absorbed by the tank and petrol from outside to increase the temperature from 7 °C to 27 °C? Mass of the metal of the empty tank is $2{\cdot}0 \times 10^3$ kg. Specific heat capacities of metal and petrol are $5{\cdot}0 \times 10^2\ J\ kg^{-1}\ K^{-1}$ and $2{\cdot}2 \times 10^3\ J\ kg^{-1}\ K^{-1}$ respectively.

(iv) Suppose at 7 °C the tank is half filled with petrol and the rest with air at atmospheric pressure of $1{\cdot}0 \times 10^5$ Pa and sealed. Saturated vapour pressure of petrol at 27 °C is $7{\cdot}47 \times 10^4$ Pa. Determine the total pressure inside the tank at 27 °C. Neglect the volume expansion of metal and petrol for this calculation.

(v) How many moles of petrol vapour present inside the bowser at 27 °C in the situation (*c*) (iv) above? Universal gas constant $R = 8{\cdot}3\ J\ mol^{-1}\ K^{-1}$. Assume that the petrol vapour behaves as an ideal gas.

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Part (B)

A dosimeter is an instrument used to measure ionizing radiation exposure. It can be used to measure the amount of radiation exposed to the human body which is an essential measure for the safety. There are two kinds of dosimeters namely active and passive. The active dosimeter can be used to obtain a real-time exposure value. Passive dosimeter measures the amount of radiation a person absorbs over a set period of time. The most commonly used passive dosimeter is Thermoluminescent dosimeter (TLD).

When a thermoluminescent crystal is exposed to ionizing radiation, it absorbs and traps the energy of the radiation in its crystal lattice. When heated, the crystal releases the trapped energy in the form of visible light. The intensity of light is proportional to the intensity of the ionizing radiation the crystal was exposed to. The emitted light is allowed to incident on a photo sensitive surface and thereby produce a weak current. Finally this current is amplified and measured.

A Geiger-Müller counter can be used to detect ionizing radiation. Absorber plates made of different materials and various thicknesses can be used to determine the type of radiation incident on a GM counter.

(*a*) Write down **three** types of radiations that can ionize air.

(*b*) Write down an advantage of an active dosimeter over a passive dosimeter.

(*c*) The activity of a radioactive materiel of half-life 1 hour is measured by a Geiger-Müller counter. If the initial count rate is 64 counts per second, calculate the count rate after 3 hours.

(*d*) How is it possible to detect the type of ionizing radiation incident on a Geiger-Müller counter using different absorber plates?

(*e*) A TLD dosimeter emits blue light of wavelength 400 nm with an intensity of 198 nW. Assume that the emitted light is incident normally on a photo sensitive surface made of cesium with a work function of 2·0 eV. (Planck constant = $6{\cdot}6 \times 10^{-34}$ J s, speed of light = $3{\cdot}0 \times 10^{8}$ m s^{-1}, electron charge = $1{\cdot}6 \times 10^{-19}$ C, 1 eV = $1{\cdot}6 \times 10^{-19}$ J)

(i) Determine the number of photons of blue light incident on the photo sensitive surface per second.

(ii) If 10 electrons are ejected for each 100 photons incident on the photo sensitive surface, determine the current produced by the photo sensitive surface.

(iii) Calculate the maximum kinetic energy (in J) of the ejected photoelectrons from the photo sensitive surface.

(*f*) A CT scanner takes a series of X-ray images from different angles around a human body. The CT scanner in a medical laboratory operates full-time for a research purpose. A TLD dosimeter placed near the CT scanner has recorded radiation dose of 250 mSv/year.

(i) A radiation scientist in the operator room of the CT scanner can be exposed to 10% of radiation during the operation. Calculate the maximum dose in mSv/year that the scientist could be exposed to.

(ii) The occupational dose limit for a radiation worker is 20 mSv/year. If the scientist works 6 hours a day for 146 days in a year prove that the radiation exposure he receives does not exceed the occupation dose limit.

(iii) If the mass of the scientist is 75 kg, how much radiation energy (in J) does he expose in a year?

[For X - rays, dose in Sv = dose in Gy; 1 Gy = 1 J kg^{-1}]

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