AL/2021(2022)/01/E-I

සියලුම හිමිකම් ඇවිරිණි /முழுப் பதிப்புரிமையுடையது/All Rights Reserved]

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
இலங்கைப் பரீட்சைத் திணைக்களம்
Department of Examinations, Sri Lanka

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2021(2022)
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2021(2022)
General Certificate of Education (Adv. Level) Examination, 2021(2022)

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 of the following pairs of physical quantities have same dimensions?
(1) Stress and strain (2) Work and energy
(3) Velocity and displacement (4) Weight and mass
(5) Torque and angular momentum

2. In a vernier calliper a length of 19 main scale divisions is equally divided into 20 vernier scale divisions. What should be the length of a main scale division in order to have a least count of 0·025 mm?
(1) 0·5 mm (2) 1·0 mm (3) 1·5 mm (4) 2·0 mm (5) 2·5 mm

3. Bending of light when passing a sharp edge is due to
(1) reflection. (2) refraction. (3) interference.
(4) diffraction. (5) total internal reflection.

4. If no external forces act on a system, which of the following is conserved in any type of collision?
(1) total kinetic energy (2) total potential energy
(3) total mechanical energy (4) total angular velocity
(5) total linear momentum

5. The mean kinetic energy of an ideal gas depends on its
(1) pressure. (2) volume. (3) density.
(4) absolute temperature. (5) specific heat capacity.

6. A block of mass M moving at velocity $2v$ on a flat frictionless surface makes a **perfect inelastic** collision with another block of mass M moving at velocity v along the same direction. What is the velocity of the first block after the collision?
(1) 0 (2) $\frac{1}{2}v$ (3) v (4) $\frac{3}{2}v$ (5) $2v$

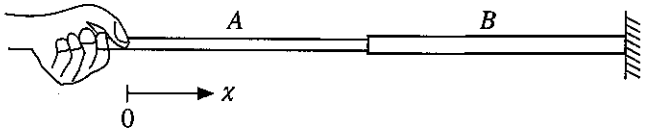
7. The breaking strain of an aluminium rod is 0·2%. What is the minimum cross-sectional area of the rod to withstand a force of $3{\cdot}5 \times 10^3$ N? (Young's modulus of aluminium is $7{\cdot}0 \times 10^{10}\ \text{N m}^{-2}$)
(1) $1{\cdot}0 \times 10^{-3}\ \text{m}^2$ (2) $4{\cdot}0 \times 10^{-4}\ \text{m}^2$ (3) $4{\cdot}0 \times 10^{-5}\ \text{m}^2$
(4) $2{\cdot}5 \times 10^{-5}\ \text{m}^2$ (5) $1{\cdot}0 \times 10^{-5}\ \text{m}^2$

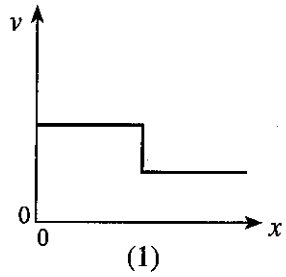
[*See page two*

8. What is the charge of a down quark (d)? (The elementary charge is e.)

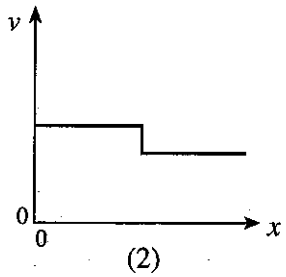
(1) $+e$ (2) $+\frac{2}{3}e$ (3) $-\frac{1}{3}e$ (4) $-\frac{2}{3}e$ (5) $-e$

9. The figure shows a composite string made of same material. The cross-sectional area of string B is twice that of string A. The other end of the string B is attached to a fixed wall. If both strings are under same tension which of the following graphs best represents the variation of speed v of transverse waves generated in strings with distance x?

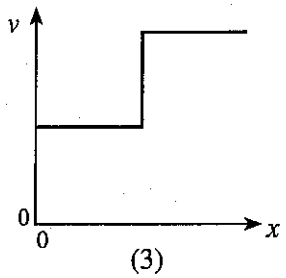




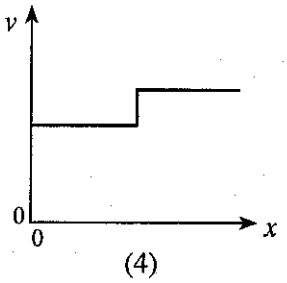
(1)



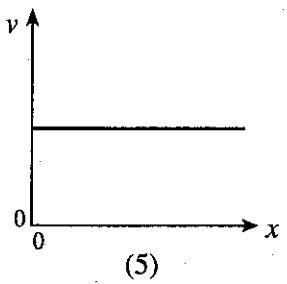
(2)



(3)



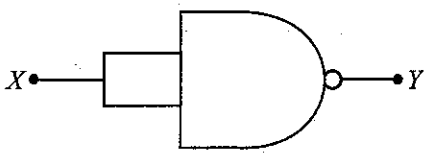
(4)



(5)

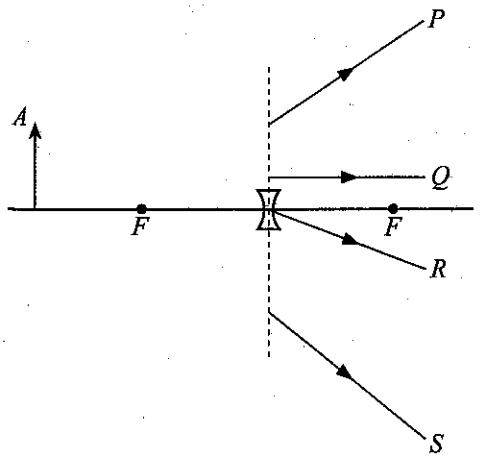
10. The given circuit is equivalent to a

(1) NOT gate.
(2) OR gate.
(3) AND gate.
(4) NOR gate.
(5) EXOR gate.



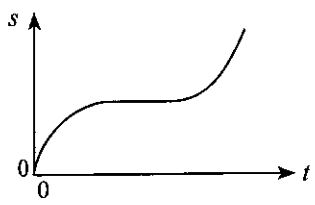
11. An object is placed in front of a concave lens as shown in the figure. The paths of the refracted rays emitting from point A of the object are

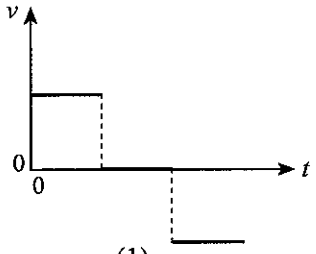
(1) P and R only.
(2) Q and R only.
(3) P, R, and S only.
(4) P, Q, and R only.
(5) all P, Q, R and S.



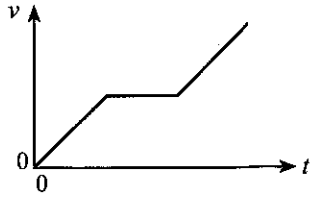
[See page three

12. The displacement-time (s-t) graph for the motion of an object is shown in the figure. The corresponding velocity-time (v-t) graph would be best represented by,

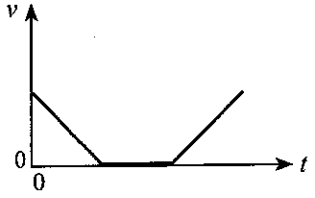




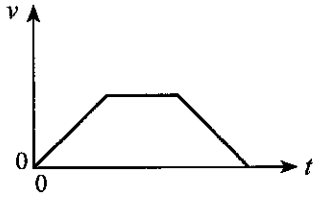
(1)



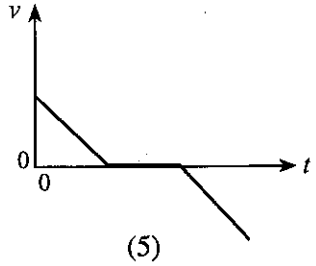
(2)



(3)

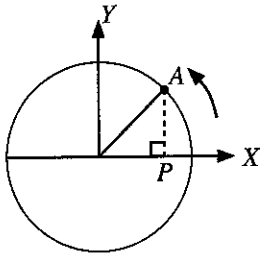


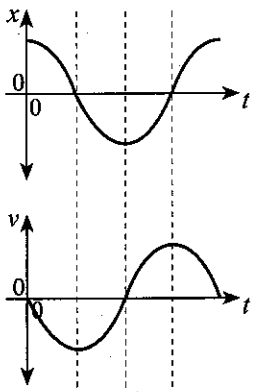
(4)



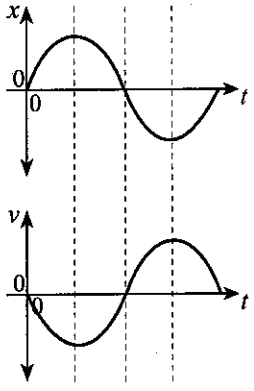
(5)

13. An object A moving in a circular path at a uniform angular velocity is shown in the figure. The variation of displacement (x) and velocity (v) of the point (P) of projection of the object on the X-axis with time (t) is best represented by,

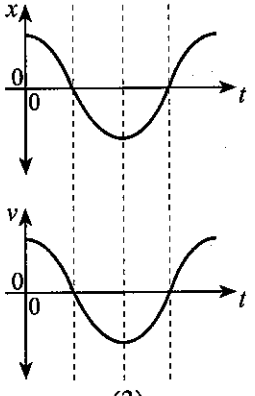




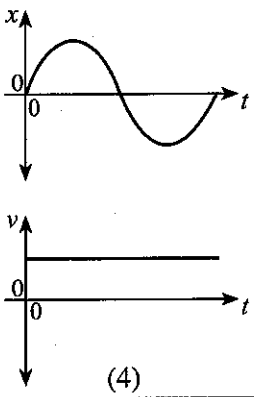
(1)



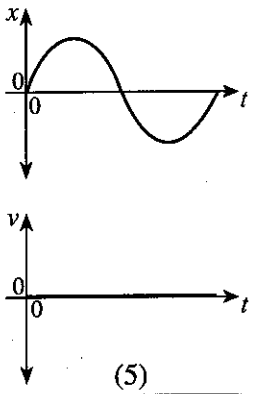
(2)



(3)



(4)



(5)

[See page four

14. Water rises in a long vertical capillary tube up to a height of 2·0 cm. When the tube is inclined at an angle 60° with the vertical, what is the length of the water column in the tube?

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

15. Consider the following statements regarding the moment of inertia of a body.

(A) It depends on mass of the body.

(B) It depends on mass distribution of the body.

(C) It depends on angular velocity of the body.

Of the above statements,

(1) Only (A) is true. (2) Only (B) is true.

(3) Only (A) and (B) are true. (4) Only (B) and (C) are true.

(5) All (A), (B) and (C) are true.

16. A liquid of density ρ flowing at speed $3v$ through a horizontal tube of cross-sectional area A strikes a vertical wall perpendicularly and flows down along the wall without recoil. The force exerted on the wall by the liquid is

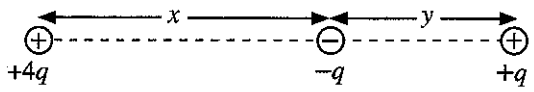
(1) $3\rho Av^2$ (2) $9\rho Av^2$ (3) $18\rho Av^2$ (4) $9\rho A^2v^2$ (5) $18\rho A^2v^2$

17. Two point charges $+4q$ and $-q$ are fixed at distance x apart as shown in the figure. Another point charge $+q$ does not experience a net electric force when it is kept along the same line at distance y from $-q$. The relation between x and y is given by

(1) $x = y$ (2) $\sqrt{2}x = y$

(3) $x = \sqrt{2}y$ (4) $x = 2y$

(5) $2x = y$

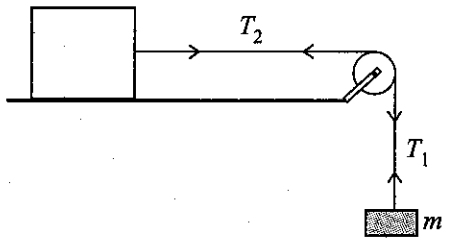


18. A block placed on a horizontal frictionless table is attached to mass m by a light inextensible string that passes over a pulley as shown in the figure. When released from rest, mass m and the pulley accelerate. If the tensions in the sections in the string are T_1 and T_2 as marked, which of the following is true?

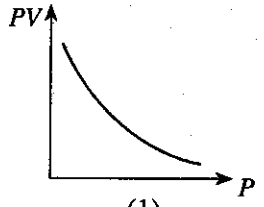
(1) $mg = T_1 = T_2$ (2) $mg > T_1 = T_2$

(3) $mg > T_1 < T_2$ (4) $mg = T_1 > T_2$

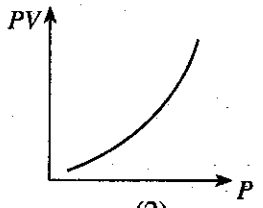
(5) $mg > T_1 > T_2$



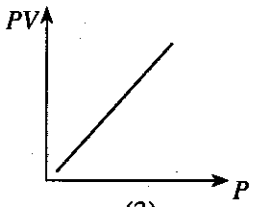
19. The variation of product (PV) of pressure and volume with pressure (P) for a fixed mass of an ideal gas at constant temperature is best represented by



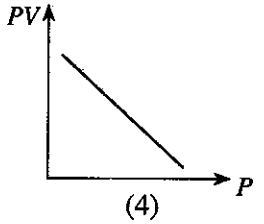
(1)



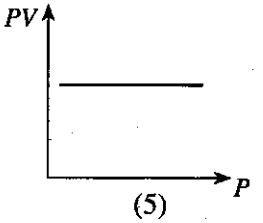
(2)



(3)



(4)



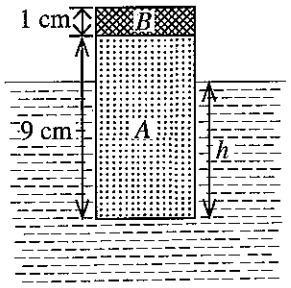
(5)

[See page five

20. The diameter and mean density of Jupiter are 11 times and $\frac{1}{4}$ times respectively to that of Earth. If the gravitational intensity at the surface of Earth is $10\,N\,kg^{-1}$ what is the gravitational intensity at the surface of Jupiter?

(1) $27{\cdot}5\,N\,kg^{-1}$ (2) $44{\cdot}0\,N\,kg^{-1}$ (3) $48{\cdot}4\,N\,kg^{-1}$ (4) $110\,N\,kg^{-1}$ (5) $440\,N\,kg^{-1}$

21. A composite solid cylinder consisting parts A and B is made from materials whose densities are $600\,kg\,m^{-3}$ and $2000\,kg\,m^{-3}$ respectively. The height of part A is 9 cm and that of B is 1 cm. The cylinder floats in water of density $1000\,kg\,m^{-3}$ as shown in the figure. What is the height (h) of the cylinder under water?



(1) 2·6 cm (2) 5·4 cm

(3) 7·4 cm (4) 8·0 cm

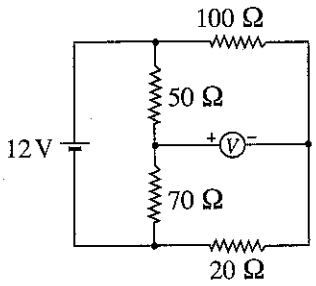
(5) 9·0 cm

22. If the doping concentrations of emitter, base and collector of a bipolar junction transistor are n_E, n_B and n_C respectively which of the following is true?

(1) $n_C > n_B > n_E$ (2) $n_E > n_C > n_B$ (3) $n_B > n_E = n_C$

(4) $n_C > n_E > n_B$ (5) $n_E = n_C > n_B$

23. Consider the circuit shown in the figure. The internal resistance of the 12 V cell is negligible and the centre zero voltmeter is ideal. What is the value of the voltmeter reading?



(1) +5 V (2) +3 V

(3) 0 V (4) –3 V

(5) –5 V

24. When a plate $PQRST$ is hanging freely from point X it balances as shown figure (1). When hanging freely from point Y it balances as shown in figure (2). The centre of gravity of the plate is most likely to be found at

(1) A (2) B

(3) C (4) D

(5) E

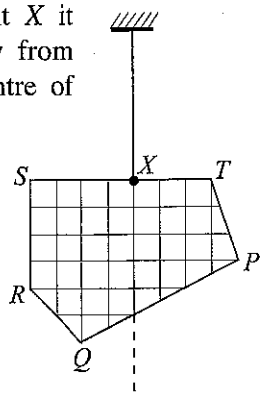


Figure (1)

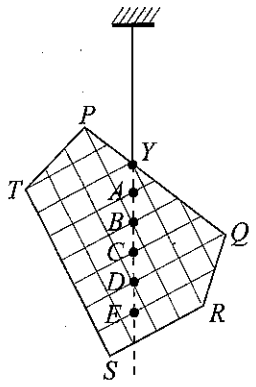


Figure (2)

25. Wind generated by cyclone Burevi passed across a region in Sri Lanka with speed of $30\,m\,s^{-1}$. If the wind had passed over a roof of a house with effective cross-sectional area of $100\,m^2$, what was the lifting force on the roof due to wind? (Assume that air inside the house was still and the density of air is $1{\cdot}3\,kg\,m^{-3}$)

(1) $5{\cdot}85\times10^2N$ (2) $5{\cdot}85\times10^4N$ (3) $7{\cdot}61\times10^4N$ (4) $1{\cdot}17\times10^5N$ (5) $1{\cdot}95\times10^5N$

[See page six

26. A small spherical liquid drop of radius r and density ρ falls with terminal velocity v in still air. The coefficient of viscosity of air is η and the density of air can be neglected. Consider the following statements regarding the terminal velocity v of the droplet.

(A) It is directly proportional to r^2.

(B) It is directly proportional to ρ.

(C) It is inversely proportional to η.

Of the above statements,

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

27. Consider the following statements made regarding electromagnetic (EM) waves.

(A) They can be transverse or longitudinal.

(B) They require a medium to propagate.

(C) They are not deflected by electric or magnetic field.

Of the above statements,

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

28. When uranium $^{235}_{92}U$ nucleus is bombarded with a slow neutron (n), the following nuclear reaction may take place.

$$^{235}_{92}U + n \longrightarrow {}^{102}_{44}X + {}^{131}_{a}Y + bn$$

The values of a and b are respectively,

(1) 48 and 1 (2) 48 and 2 (3) 48 and 3 (4) 49 and 2 (5) 49 and 3

29. A metal surface is illuminated with monochromatic blue, red and yellow light separately. Consider the following statements.

(A) If red light ejects photoelectrons, then blue light should also eject photoelectrons.

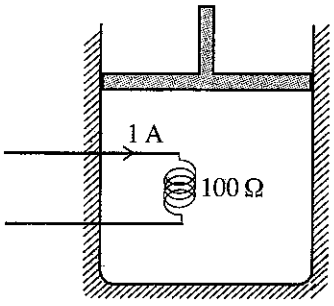
(B) If yellow light ejects photoelectrons, then red light should also eject photoelectrons.

(C) If blue light ejects photoelectrons, then red light should also eject photoelectrons.

Of the above statements,

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

30. Air is trapped in a well-insulated container by a frictionless piston as shown in the figure. The air is heated by a coil of resistance 100 Ω passing a current of 1 A for 5 minutes. The air expands from a volume of 0·4 m^3 to 0·5 m^3 at a constant pressure of 150 kPa during the heating process. The change in internal energy of the air is,



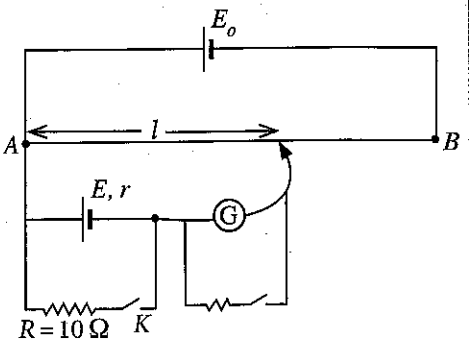
(1) 5 kJ (2) 15 kJ

(3) 30 kJ (4) 45 kJ

(5) 60 kJ

[See page seven

31. A student used the potentiometer circuit shown in the figure to determine the internal resistance (r) of cell E. When key K is opened, the balance length (l) is 60·0 cm and when key K is closed the balance length is 50·0 cm. What is the internal resistance of the cell E?

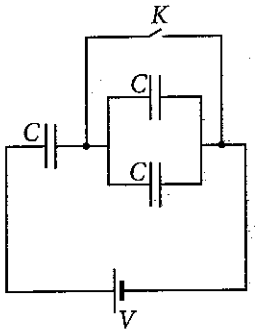


(1) 1·0 Ω (2) 1·2 Ω

(3) 2·0 Ω (4) 5·0 Ω

(5) 6·0 Ω

32. Three capacitors each of capacitance C are connected to a battery and a key K as shown in the figure. Initially the key K is closed. Once the capacitors are fully charged, the key K is opened. If the potential difference across the battery is V, the total charge of the capacitors in the circuit is



(1) not changed.

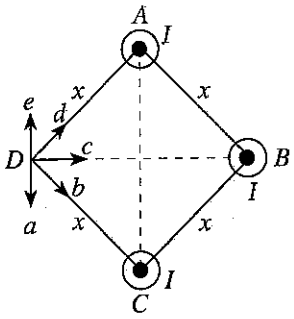
(2) decreased by $\frac{1}{3}CV$.

(3) decreased by CV.

(4) increased by $\frac{1}{3}CV$.

(5) increased by CV.

33. Three long straight conducting wires A, B and C are kept at the three vertices of a square as shown in the figure. They are parallel to each other and carry equal currents of I directed out of the plane of the paper. The direction of the resultant magnetic flux density at point D is given by,

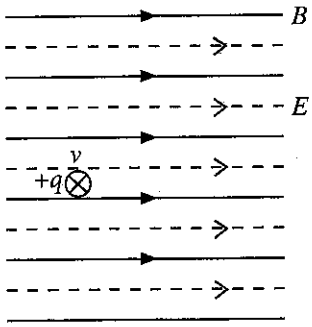


(1) a (2) b

(3) c (4) d

(5) e

34. A uniform magnet field of flux density (B) 1 T and a uniform electric field of field intensity (E) 300 V m^{-1} are parallel to each other in a region as shown in the figure. A particle of charge $+q$ enters at a velocity (v) 400 m s^{-1} perpendicular to the fields and directed into the plane of the paper. The magnitude of the resultant force acting on the particle is

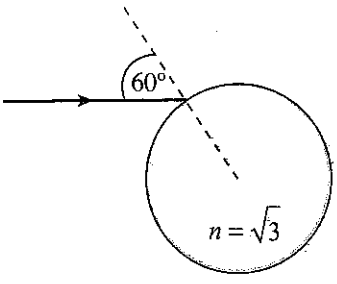


(1) 0 (2) 100q

(3) 300q (4) 500q

(5) 700q

35. A monochromatic ray of light falls on the surface of a glass sphere with incident angle 60° as shown in the figure. Refractive index of glass is $\sqrt{3}$. The total angle of deviation of the emerging ray from the sphere is



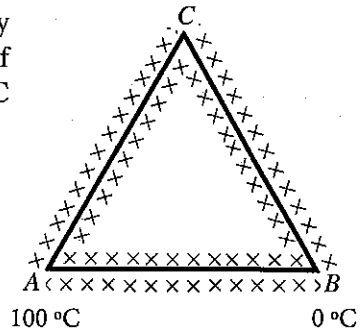
(1) 0° (2) 30°

(3) 60° (4) 90°

(5) 180°

[See page eight

36. An equilateral triangle is constructed using three rods having same cross-sectional area as shown in the figure. All the rods are perfectly lagged. Thermal conductivity of the material of AB is twice that of the materials AC and CB. Ends A and B are maintained at 100 °C and 0 °C, respectively. At the steady state,



The ratio $\frac{\text{Rate of heat flow through } AB}{\text{Rate of heat flow through } AC}$ is equal to

(1) 0·25 (2) 0·5

(3) 1 (4) 2

(5) 4

37. Consider the following statements about an astronomical telescope and a compound microscope.

Statement	Astronomical Telescope	Compound Microscope
(A) The focal length of the objective lens is	large	small
(B) The final image at normal adjustment is	at infinity	at infinity
(C) The total angular magnification is	less than 1	greater than 1

What is/are the correct statement/s for both instruments?

(1) Only (A) (2) Only (B)

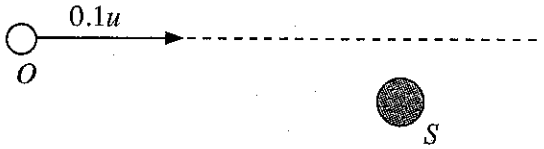
(3) (A) and (B) only (4) (B) and (C) only

(5) (A) and (C) only

38. A flywheel of moment of inertia 0·4 kg m^2 is rotated with uniform angular speed of 10 rad s^{-1} by a motor of power 100 W. When the motor is switched off, the angular deceleration of the flywheel is

(1) 1 rad s^{-2} (2) 20 rad s^{-2} (3) 25 rad s^{-2} (4) 200 rad s^{-2} (5) 400 rad s^{-2}

39. A sound source S emits sound of constant frequency f_0. An observer O travels in the direction shown at a speed of $0{\cdot}1u$ where u is the speed of sound in air. Which of the following gives the correct relationship between f_0 and the frequency f of the sound heard when the observer is travelling towards the source?



(1) $f = 1{\cdot}1f_0$

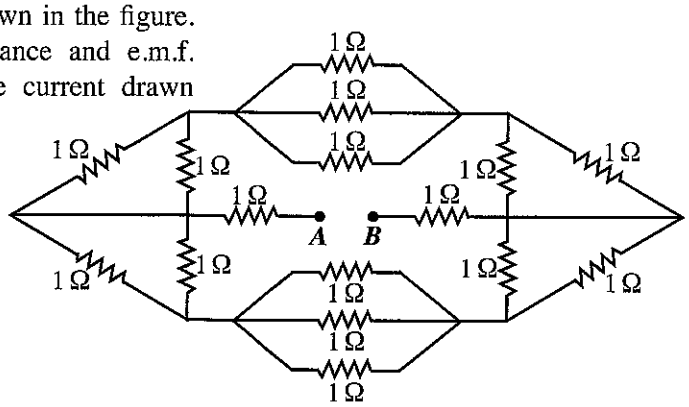
(2) $f_0 < f < 1{\cdot}1f_0$

(3) $f_0 < f \leq 1{\cdot}1f_0$

(4) $f = 0{\cdot}9f_0$

(5) $f_0 > f > 0{\cdot}9f_0$

40. Sixteen 1 Ω resistors are connected as shown in the figure. If a battery of negligible internal resistance and e.m.f. 8 V is connected between A and B, the current drawn from the battery is,



(1) 1 A (2) 2 A

(3) 3 A (4) 4 A

(5) 5 A

[See page nine

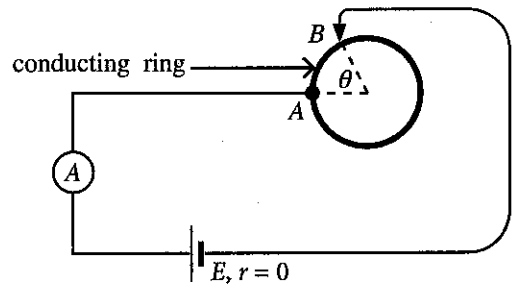
41. Two light rays of red and blue colour are made to pass separately through a glass prism of refracting angle 60°. If both rays suffer **minimum deviation** while passing the prism, which of the following is correct with regard to the angle of refraction of the red ray (r_R) and the angle of refraction of the blue ray (r_B) at the surface of incidence of the prism?

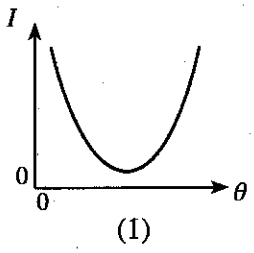
(1) $r_R > r_B$ (2) $r_R < r_B$ (3) $r_R = r_B \neq 30°$
(4) $r_R = r_B = 30°$ (5) $r_R = r_B = 60°$

42. An open copper vessel of mass 2·0 kg is at a temperature of 150 °C. Water of mass 0·1 kg at 25 °C is quickly poured into the vessel. What is the mass of water converted into vapour? Assume that there is no loss of heat to the surroundings. (Take specific heat capacity of copper $4{\cdot}0 \times 10^2$ J kg^{-1} K^{-1}; specific heat capacity of water $4{\cdot}0 \times 10^3$ J kg^{-1} K^{-1}; specific latent heat of vapourization of water $2{\cdot}5 \times 10^6$ J kg^{-1})

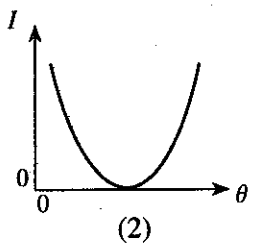
(1) 1 g (2) 2 g (3) 3 g (4) 4 g (5) 5 g

43. A conducting ring is connected to a circuit as shown in the figure. Point A is fixed, but point B can be moved along the ring so that the angle θ changes. The cell and the ammeter are ideal. Which of the following graphs best represents the variation of the ammeter reading I with the angle θ?

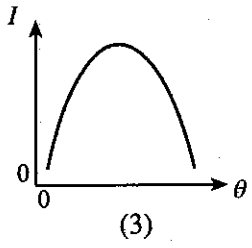




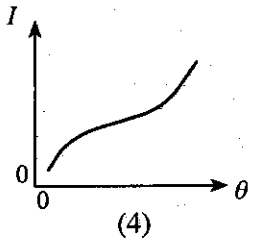
(1)



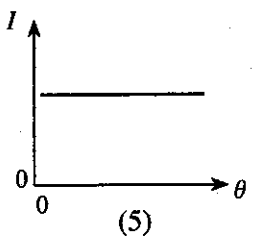
(2)



(3)



(4)



(5)

[See page ten

44. A straight conducting wire PQ of length l and mass m has to be placed at rest on a frictionless insulating inclined plane, which makes an angle θ to the horizontal. A uniform magnetic field of flux density B acts vertically upwards as shown in the figure. The magnitude and the direction of the current I that should pass through the wire in order to keep the wire at rest is given by

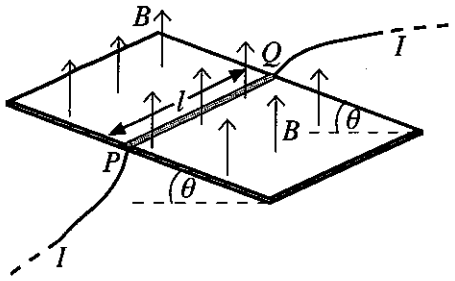
(1) $I = \frac{mg\sin\theta}{lB}$ and Q to P

(2) $I = \frac{mg\sin\theta}{lB}$ and P to Q

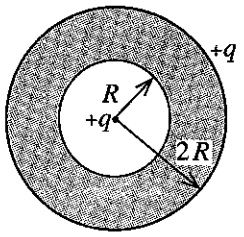
(3) $I = \frac{mg\tan\theta}{lB}$ and Q to P

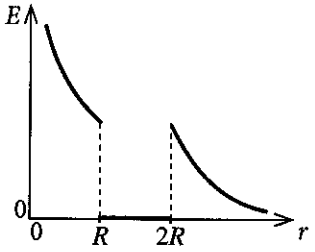
(4) $I = \frac{mg\tan\theta}{lB}$ and P to Q

(5) $I = \frac{mg}{lB}$ and Q to P

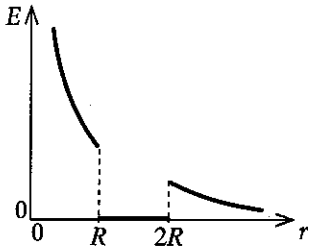


45. A solid conducting sphere of radius $2R$ contains a cavity of radius R inside it as shown in the figure. The sphere carries a net charge of $+q$. Another point charge of $+q$ is placed at the centre of the sphere. Which of the following graphs best represents the variation of the electric field intensity E with the radial distance r from the centre of the sphere?

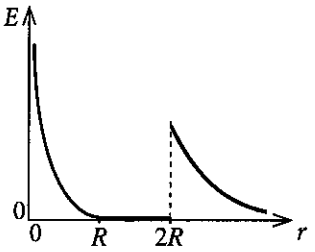




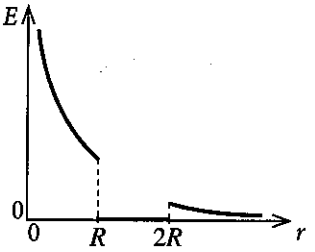
(1)



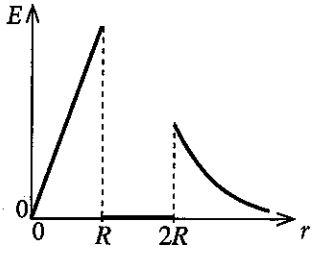
(2)



(3)



(4)



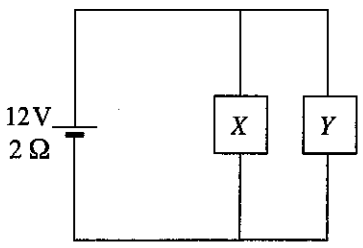
(5)

46. A battery of e.m.f. 12 V and internal resistance 2 Ω is connected to two devices X and Y as shown in the figure. The resistances of X and Y are 6 Ω and 3 Ω respectively. When the devices are in operation what is the power consumed by each device X and Y respectively?

(1) 3 W, 6 W (2) 6 W, 3 W

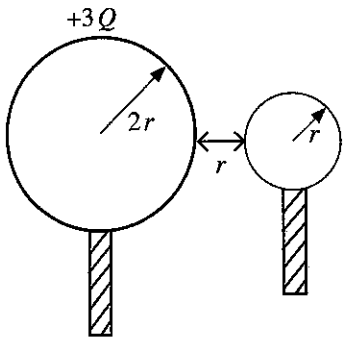
(3) 6 W, 6 W (4) 6 W, 12 W

(5) 12 W, 6 W



[See page eleven

47. A conducting sphere of radius $2r$ is given a charge of $+3Q$. Another uncharged conducting sphere of radius r is touched to the first sphere and then separated by a distance r as shown in the figure. What is the electrical potential energy of the system now? (Assume that the charge distributions of spheres are uniform and the system is in free space.)



(1) $\frac{Q^2}{4\pi\varepsilon_o r}$ (2) $\frac{Q^2}{8\pi\varepsilon_o r}$

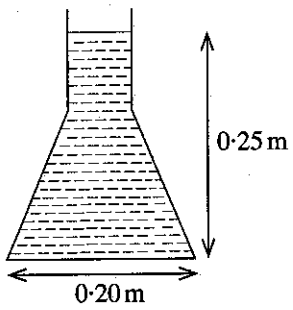
(3) $\frac{Q^2}{16\pi\varepsilon_o r}$ (4) $\frac{3Q^2}{8\pi\varepsilon_o r}$

(5) $\frac{3Q^2}{16\pi\varepsilon_o r}$

48. A ball is thrown vertically upward from the ground. The time duration between the two instances that the ball passes the point at a height of 25 m on its path from the ground is 4 s. What is the initial velocity of the ball? (Neglect air resistance)

(1) 20 m s^{-1} (2) 25 m s^{-1} (3) 30 m s^{-1} (4) 35 m s^{-1} (5) 40 m s^{-1}

49. The figure shows a vertical cross-section of a conical flask filled with water. The height of the water level in the flask is 0·25 m and its circular base has a internal diameter of 0·20 m. The volume of water in the flask is $2{\cdot}5 \times 10^{-3}$ m^3. What is the magnitude of the total force exerted by the water on the inclined surface of the flask? Density of water = 10^3 kg m^{-3}. (Take $\pi = 3$)

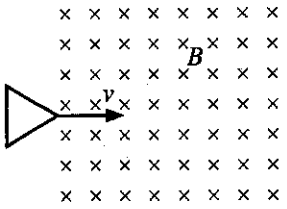


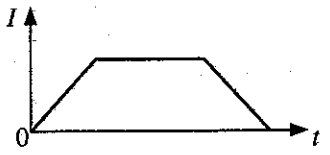
(1) 10 N (2) 20 N

(3) 30 N (4) 40 N

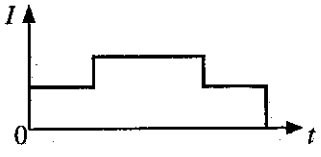
(5) 50 N

50. An equilateral triangular conducting loop passes a region of uniform magnetic field of flux density B at a uniform velocity v as shown in the figure. The variation of the induced current (I) in the loop with time (t) is best represented by

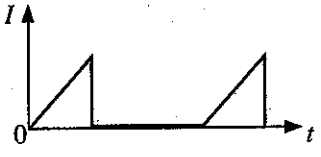




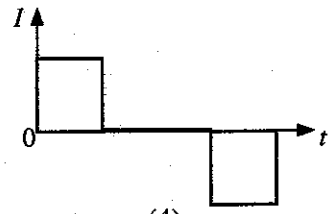
(1)



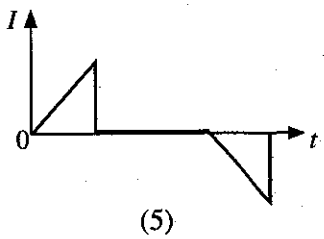
(2)



(3)



(4)



(5)

* * *

AL/2021(2022)/01/E-II

සියලුම හිමිකම් ඇවිරිණි/முழுப் பதிப்புரிமையுடையது/All Rights Reserved]

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம்
Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka Department of Examinations, Sri Lanka
ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம் இலங்கைப் பரீட்சைத் திணைக்களம்

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
இலங்கைப் பரீட்சைத் திணைக்களம்
Department of Examinations, Sri Lanka

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය, 2021(2022)
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2021(2022)
General Certificate of Education (Adv. Level) Examination, 2021(2022)

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 the second paper		
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

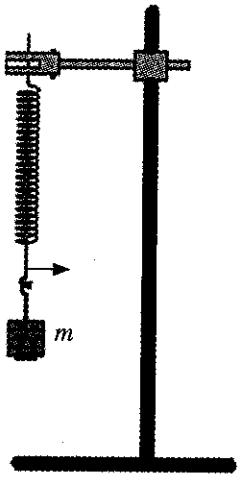
Do not write in this column

PART A — Structured Essay

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

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

1. A mass (m) is suspended by a helical spring with a pointer attached at its lower end is shown in the figure. A student is asked to verify the relationship between the mass (m) with its periodic time (T) of vertical oscillations and to determine the spring constant (k) by using a graphical method.



(a) (i) Write down an expression for periodic time (T) of vertical oscillations of a mass (m) suspended by a massless spring of spring constant (k).

.....

(ii) Rearrange the expression written in (a) (i) above in order to verify the relationship between mass (m) and periodic time (T) by plotting a suitable straight line graph.

.....

(b) (i) If the student is provided with a set of 50 g weights, what is the other essential measuring instrument that he needs to do this experiment?

.....

(ii) It is advisable to use a locating pointer in this experiment. Draw an arrow head at the appropriate position of this pointer in the above figure.

(iii) What is the purpose of using this locating pointer?

.....

.....

(c) (i) Why does the accuracy in determination of the spring constant (k) depends mainly on the accuracy in determination of the periodic time (T) of oscillation of the mass?

.....

(ii) What is the characteristic property of the instrument mentioned in (b) (i) above which affect the fractional error of time measurement? (Let the value of this property be x.)

.....

[*see page three*

Do not write in this column

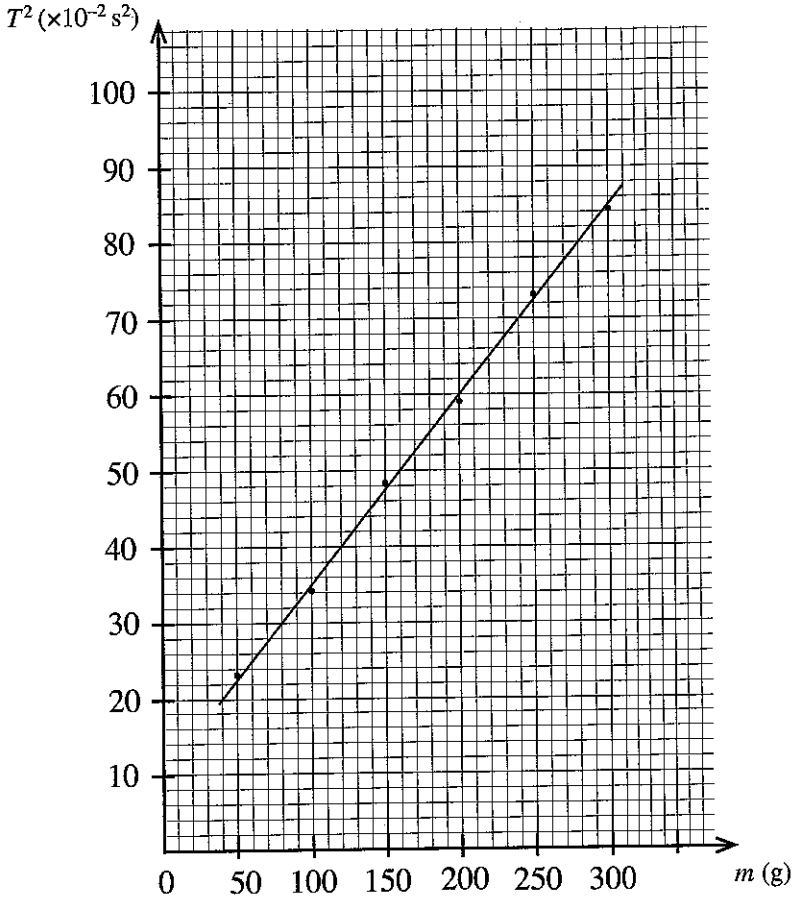
(iii) Let the approximate time per oscillation be t. Write down an expression for the minimum number of oscillations (n) that should be taken in terms of x and t in order to obtain a percentage error of 1% in periodic time determination.

.....

.....

.....

(*d*) The student obtained the following graph in order to calculate the spring constant (k) of the helical spring.



(i) Calculate the spring constant (k) of the helical spring in SI units using the above graph. (Take $\pi^2 = 10$)

.....

.....

.....

.....

(ii) Give the reason for obtaining a non zero intercept. (Mentioning that there are errors in data points is not an acceptable answer.)

.....

[*see page four*

Do not write in this column

2. You are asked to determine the relative humidity of air in the laboratory by measuring the dew point. You are provided a copper calorimeter with polished outer surface, a thermometer, water, a sufficient amount of small pieces of ice and a transparent glass plate. An incomplete experimental set up that can be arranged for this purpose is shown in figure (1).

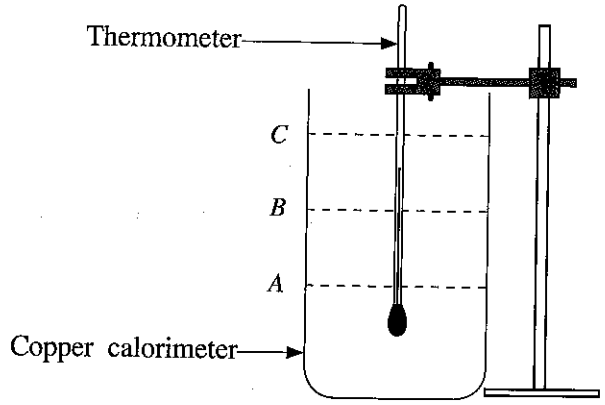


Figure (1)

(*a*) In order to perform this experiment you have to pour water into the calorimeter. Out of the three water levels *A*, *B* and *C* shown in figure (1) select the most appropriate level.

Appropriate level : .....

(*b*) Three thermometers *P*, *Q* and *R* having temperature scale ranges –10 to 50 °C, –10 to 100 °C and –10 to 200 °C respectively are available in the laboratory. Select the most appropriate thermometer for this experiment.

Appropriate thermometer: .....

Give the reason for your selection: .....

.....

(*c*) What is the other important item necessary to perform this experiment which is not given?

.....

(*d*) In order to determine the dew point you have to measure two temperatures. Write down the experimental steps that you would follow to measure the first temperature accurately with the observation that you notice.

Experimental steps: .....

.....

.....

Observation: .....

(*e*) In order to measure the second temperature accurately write down the experimental steps that you would follow with the observation that you notice.

Experimental steps: .....

.....

Observation: .....

[*see page five*

Do not write in this column

(*f*) Write down a **disadvantage** of using water at 0 °C instead of ice pieces to perform this experiment.

.....

.....

(*g*) (i) Give **two** errors that can occur if the transparent glass plate is not used in this experiment. (Assume that a face mask or/and a face shield is/are not used)

(1) .....

(2) .....

(ii) If three glass plates *L*, *M* and *N* with dimensions of 5 cm × 5 cm, 20 cm × 20 cm, and 80 cm × 80 cm respectively are available, what would be the best glass plate to be used in this experiment? Give reasons for **not selecting** the other two plates.

The best plate: .....

Reasons for **not selecting** other two plates:

(1) .....

(2) .....

(*h*) In this experiment the average value of the dew point and laboratory temperature are found to be 26·0 °C and 30·0 °C respectively. Determine the relative humidity of air in the laboratory, using the graphs given in figure (2). In the graph *X*-axis gives the laboratory temperature and *Y*-axis gives the dew point. In the figure straight lines represent different relative humidity values of 100%, 90%, 80% etc.

Relative humidity : .....

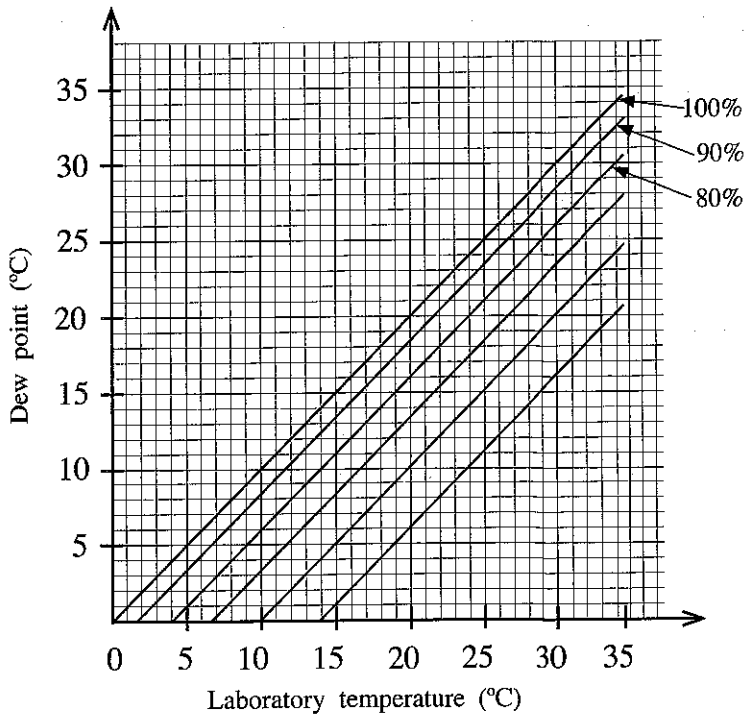


Figure (2)

[*see page six*

Do not write in this column

3. You are asked to determine the refractive index (n_l) of a transparent liquid using the apparent displacement of the image of an object. You are provided with a tall cylinder, sufficient amount of liquid, a travelling microscope, a small pin (O), fine plastic pieces which can float on the liquid and a large syringe.

(a) Write down an expression for the apparent displacement (d) produced by a transparent block made of material of refractive index (n) and thickness (h) placed in air when an object (O) is placed at the opposite side of the block as shown in the figure (1).

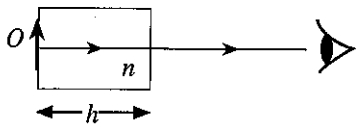


Figure (1)

.....

.....

.....

(b) As in figure (2) the small pin O is placed at the bottom of the empty cylinder. The travelling microscope is focused from above to view a clear image of O and the reading is taken (say x). Then the liquid is poured up to a certain height (h).



Figure (2)

(i) What you should do to the travelling microscope to see a clear image of the pin again? Let the microscope reading be (y) in this situation.

.....

.....

(ii) Write down the experimental steps that you follow to measure the height (h) of the liquid column. (Let the reading be z.)

.....

.....

.....

(iii) Write down expressions for height (h) of the liquid column and the apparent displacement (d) of the image using the readings x, y and z.

h =.....

d =.....

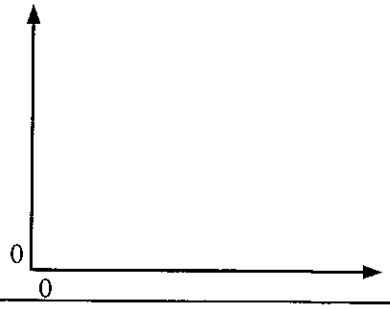
(c) (i) If the expression you have written in part (a) above is used to determine the refractive index of the liquid (n_l) using a graphical method what is the variable that you are going to change in it?

.....

(ii) What will be the dependent variable of the straight line graph that you going to draw?

.....

(iii) Clearly labelling the axes sketch the graph that you would expect.



[see page seven

Do not write in this column

(*d*) Obtain an expression for the refractive index (n_l) in terms of the gradient (m) of the graph.

.....

.....

(*e*) If the gradient $m = 0{\cdot}20$, calculate the value of refractive index (n_l) of the liquid.

.....

.....

.....

(*f*) When the height of the liquid column is 5·0 cm, water is slowly poured so that the liquid floats on water. The total apparent displacement of the image of the pin is 1·5 cm and the refractive index of water is $\frac{4}{3}$. Calculate the height of the water column in the cylinder.

.....

.....

.....

.....

.....

4. Figure (1) shows a part of an experimental set up to determine the resistivity (ρ) of material of a given wire with the aid of a metre bridge. The resistance value of the resistance box is R and the resistance of the given wire is S. The length of the metre bridge wire AB is 100 cm.

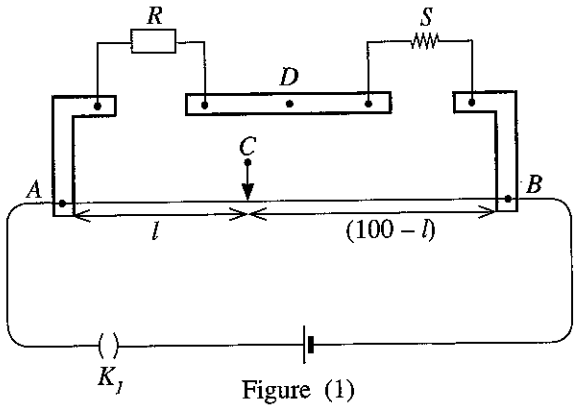


Figure (1)

(*a*) A centre-zero galvanometer has to be connected between points C and D. To protect the centre-zero galvanometer the circuit in figure (2) can be used.

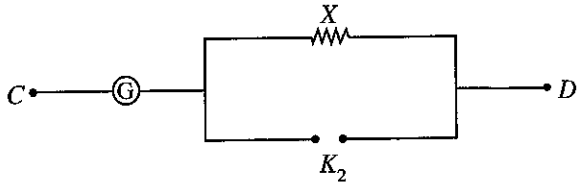


Figure (2)

(i) Name the type of key K_2 : .....

(ii) Select the suitable value for the resistance X from resistances 1 Ω, 10 Ω, 100 Ω, and 1000 Ω.

The value of X : .....

[*see page eight*

Do not write in this column

(*b*) Before taking measurements how do you check whether the circuit is connected properly?

.....

.....

(*c*) When the resistance value of resistance box is R, the balance length of the metre bridge wire is l (in cm). Write down an expression for $\frac{R}{S}$ in terms of l. Neglect the end corrections of the metre bridge wire.

.....

.....

(*d*) For $R = 9\ \Omega$, $26\ \Omega$ and $56\ \Omega$ the balance lengths are 27·0 cm, 52·0 cm and 70·0 cm respectively at 30 °C.

(i) What is the most appropriate value of resistance R that must be used in order to determine the value of S accurately? Give the reason.

Value : .....

Reason : .....

(ii) Calculate the most accurate value of S using the relevant balance length and R.

.....

.....

.....

(*e*) The values of diameter measured in four different places in the given wire are 0·39 mm, 0·40 mm, 0·40 mm and 0·41 mm, and the length of the wire is 48·0 cm. Calculate the resistivity of the material of the wire. (Take $\pi = 3$.)

.....

.....

.....

.....

(*f*) When the above wire is kept at constant temperature of 100 °C in an oil bath, for $R = 20\ \Omega$ in the resistance box the balance length is 40·0 cm. Calculate the temperature coefficient of resistance of the material of the wire.

.....

.....

.....

.....

.....

(*g*) For a certain type of material the temperature coefficient of resistance is negative around room temperature. Name the type of material.

.....

* *

[*see page nine*

සියලුම හිමිකම් ඇවිරිණි/முழுப் பதிப்புரிமையுடையது/All Rights Reserved]

ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව ශ්‍රී ලංකා විභාග දෙපාර්තමේන්තුව
இலங்கைப் பரீட்சைத் திணைக்களம்
Department of Examinations, Sri Lanka

අධ්‍යයන පොදු සහතික පත්‍ර (උසස් පෙළ) විභාගය 2021(2022)
கல்விப் பொதுத் தராதரப் பத்திர (உயர் தர)ப் பரீட்சை, 2021(2022)
General Certificate of Education (Adv. Level) Examination, 2021(2022)

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

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

5. A pile driver system is shown in figure (1). The steel arm of mass 2000 kg pivoted at point A is shown in figure (2) with its dimensions. The centre of gravity of the arm is located at G. A pulley of mass 200 kg is attached at the upper end (B) of the arm and it can be rotated by an electric motor. A cable is wound around the pulley and its free end is connected to a steel cylinder of mass 800 kg. Neglect the mass of the cable. The lengths AB and AC are 10 m and 2 m respectively. The horizontal distance from point A to the line of action of the weight of the steel arm is 2 m. The arm is operated using a hydraulic system.

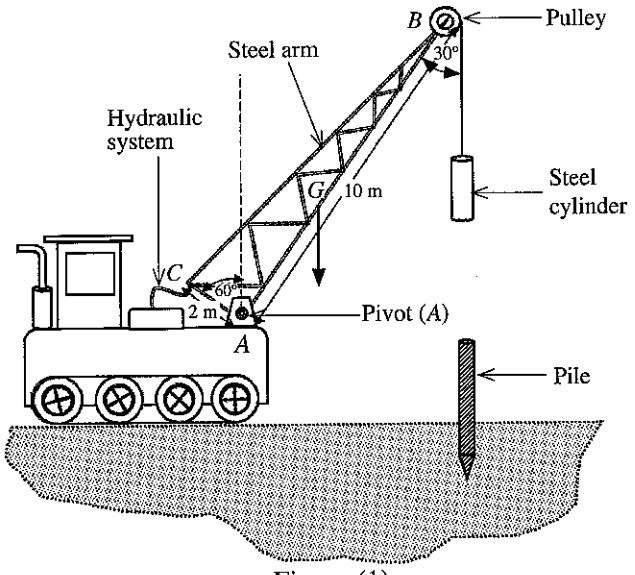


Figure (1)

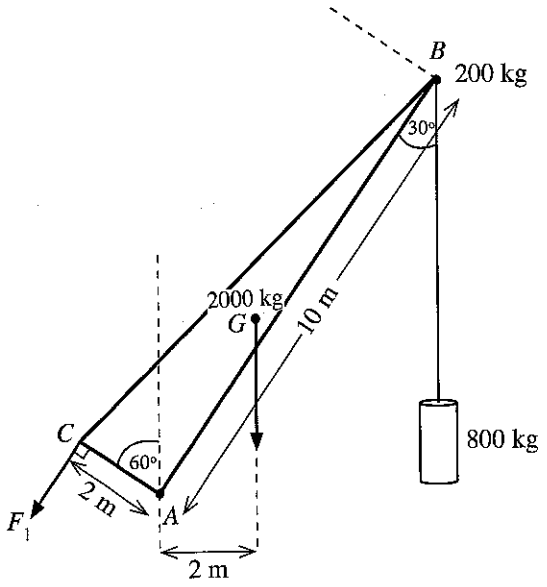


Figure (2)

(a) To keep the arm and its attachments at equilibrium position a force F_1 has to be applied at point C using the hydraulic system as shown in figure (2). The direction of F_1 is perpendicular to the length AC. Calculate the value of this force F_1 by taking moments about point A. For this calculation neglect the size of the pulley.

(b) The force F_1 in (a) above is provided by compressed oil of a hydraulic pump as shown in figure (3). The cross-sectional area of the piston of the master pump is 4 cm^2 and the cross-sectional area of the piston at point C is 60 cm^2. A force F_2 has to be applied to the piston of the master pump in order to obtain the force F_1.

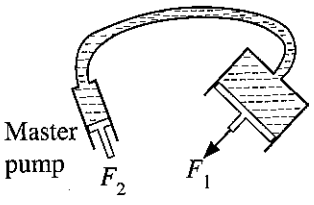


Figure (3)

(i) Name the principle that must be used to calculate force F_2.

(ii) Find the value of F_2.

(iii) What is the pressure of the compressed oil in the hydraulic pump?

[see page ten

(c) The radius of the pulley is 10 cm. The moment of inertia I of a pulley of mass M and radius r about its axis of rotation can be given by $I = \frac{1}{2}Mr^2$. The cable moves without slipping.

(i) When the arm is at its maximum vertical position as shown in figure (2) the steel cylinder is moved upward at a constant linear acceleration of $0{\cdot}5\ m\ s^{-2}$ by rotating the pulley. Calculate the torque that must be applied to **the pulley** by the motor in order to raise the cylinder.

(ii) When the cylinder has moved upward to a certain height the motor is switched off and the cylinder comes to a momentarily stop after some time. Next the cylinder attached to the cable is allowed to drop onto the pile while the pulley rotates freely. The centre of gravity of the cylinder drops from a height of $\frac{45}{8}$ m before the cylinder hits the pile. Calculate the velocity of the cylinder just before hitting the pile. For this calculation neglect frictional torques acting against rotation.

(iii) After the collision, the cylinder and the pile penetrate as a composite object into the soil without any recoil. What type of collision is this? How do you identify this type of collision in terms of loss of kinetic energy.

(iv) Calculate the velocity of the cylinder and the pile just after the collision. The mass of the pile is 480 kg.

(v) If the distance penetrated by the pile in one hit is 20 cm, calculate the average value of the resistance force produced by soil against penetration. [Take $(6{\cdot}25)^2 = 39$]

6. Read the following passage and answer the questions.

The Doppler effect is the apparent change in the observed frequency of a wave when there is a relative motion between the source producing the waves and the observer. Here all the speeds must be measured relative to the medium in which waves propagate. Since air is assumed to be at rest relative to the earth, normally the relevant velocities are measured relative to the earth for sound waves. The change in frequency Δf (= observed frequency – emitted frequency) as a result of the Doppler effect is known as the Doppler shift.

The Doppler effect occurs for electromagnetic waves too, such as light waves or micro waves. If the speeds of the observer and the source are very much less than the speed c of electromagnetic waves, the Doppler effect relationships derived for sound waves could be used for electromagnetic waves by substituting c instead of the speed of sound.

The speeds of moving vehicles could be determined by measuring the relevant Doppler shift using electromagnetic waves. The instrument used for this purpose is known as a speed trap which consists of a radar transmitter and a radar receiver. From the transmitter microwaves are emitted in short pulses and aimed directly to a moving car as shown in figure (1).

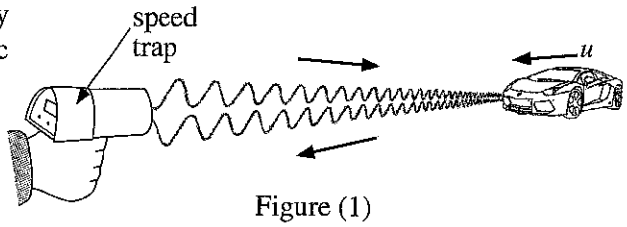


Figure (1)

The emitted microwaves reflect from the surface of speeding car and return to the receiver of the speed trap. By measuring the resulting Doppler shift, the speed at which the car moves is determined and recorded. In this type of applications, use of microwaves has an advantage over the other waves because they can penetrate fog, light rain and smoke.

(*a*) What is the Doppler effect?

(*b*) Normally the relevant velocities in Doppler effect are measured relative to the earth for sound waves. What is the reason for this?

(*c*) (i) The radar transmitter emits microwaves of frequency f_0. The car shown in the figure (1) approaches the speed trap at speed u. Write down an expression for the frequency f' of microwaves received by the car in terms of f_0, u and c considering the transmitter of the speed trap as a stationary source and the car as a moving observer.

(ii) Now the car acts as a moving source emitting microwaves with frequency f'. Write down an expression for the frequency f'' of microwaves detected by the receiver of the speed trap in terms of f', u and c.

(iii) Combining expressions obtained in (*c*) (i) and (*c*) (ii) above, derive an expression for f'' in terms of f_0, u and c.

[see page eleven

(iv) Taking $u <<< c$, show that the Doppler shift Δf observed by the speed trap is given by $\Delta f = f_0 \frac{2u}{c}$

(v) If $f_0 = 3{\cdot}0 \times 10^{10}$ Hz and $\Delta f = 7000$ Hz, calculate the speed u of the car in km h^{-1}. (Take $c = 3{\cdot}0 \times 10^8$ m s^{-1})

(*d*) Suppose a wind is blowing towards the speed trap from the car. Does this affect the speed measurement of the car? Give the reason for your answer.

(*e*) If the speed trap is not aimed directly to the car but rather at an angle to it, will the speed of the car measured be greater, equal or less than the value calculated in (*c*) (v) above? Give the reason for your answer.

(*f*) Now consider a police car with the speed trap moving at a speed V is chasing behind the car moving with speed u as shown in figure (2). In this situation the relationship obtained for Δf in (*c*) (iv) above has to be modified as $\Delta f = f_0 \frac{2(V-u)}{c}$.

(i) Determine Δf if $V = 100$ km h^{-1}. Use the value of u obtained in (*c*) (v) above. (Give your answer to the nearest integer in Hz)

(ii) Explain why $\Delta f < 0$ in this case.

(iii) Which method is more accurate to determine the speed u of the car by considering the Doppler shifts obtained in (*c*) and (*f*) above? Justify your answer.

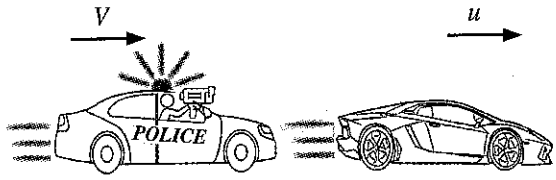


Figure (2)

(*g*) Write down an advantage of using microwaves in this type of applications.

7. (*a*) (i) Write down an expression for the viscous force F acting on a small sphere of radius r moving at terminal velocity v in a homogeneous fluid at rest having coefficient of viscosity η.

(ii) A small sphere of radius r made of material of density β is moving vertically downward at terminal velocity v in a homogeneous fluid of density ρ (where $\rho < \beta$) at rest and coefficient of viscosity η. Obtain an expression for the terminal velocity v in terms of ρ, β, r, η and g.

(*b*) A mixture of spherical sediment particles has to be separated depending whether their sizes are greater than or less than 2 μm using respective terminal velocities. The mixture is mixed and shaken well with small quantity of water and gently poured on to the surface of water in a beaker. After this the height of the water column in the beaker is 10 cm. The densities of material made of sediment particles and water are 1900 kg m^{-3} and 1000 kg m^{-3} respectively. The coefficient of viscosity of water is $1{\cdot}0 \times 10^{-3}$ Pa s. How long will it take to precipitate all particles having diameter greater than or equal to 2 μm? Assume that all particles reach their terminal velocities as soon as they are poured on to water surface.

(*c*) (i) A person without wearing a face mask or face shield releases tiny droplets of diameter 20 μm to the atmosphere at an initial horizontal velocity of 20 m s^{-1} by coughing. If the density of droplets is 1080 kg m^{-3} and the density of air is negligible, what is the vertical terminal velocity acquired by droplets? The coefficient of viscosity of air is $2{\cdot}0 \times 10^{-5}$ Pa s. Assume that air is still.

(ii) Sketch the velocity-time (t) graphs separately for

(I) the vertical component of the velocity (v_V) and

(II) the horizontal component of the velocity (v_H) of a droplet.

(iii) If the height to the mouth from the ground is 1·50 m, how long will the droplets suspend in still air? For this calculation assume that all droplets reach their terminal velocity as soon as they enter the atmosphere.

(iv) Practically the evaporation of exhaled droplets while they are in air has to be considered. Giving reasons, briefly explain what will happen to the horizontal displacement of the droplets as a result of evaporation during airborne time.

(v) Low atmospheric temperature or high relative humidity conditions can cause more droplets to settle on the ground. Justify this statement.

[see page twelve

8. (*a*) A proton of mass m and charge $+q$ moving at speed v enters perpendicularly to a uniform magnetic field of flux density B.

(i) Write down an expression for the magnitude of force F acting on the proton due to the magnetic field.

(ii) Due to the above force the proton moves in a circular path. Derive an expression for radius r of the path.

(iii) Obtain an expression for the time T taken by the proton to complete one cycle in terms of m, q and B.

(iv) Let $m = 1{\cdot}6 \times 10^{-27}$ kg, $q = 1{\cdot}6 \times 10^{-19}$ C, $v = 9{\cdot}6 \times 10^{5}$ m s^{-1} and $B = 3{\cdot}0 \times 10^{-5}$ T. (Take $\pi = 3$).

(I) Determine the radius (r) of the circular path of the proton.

(II) What is the number of revolutions per second that the proton makes?

(*b*) Now an another proton enters with the same velocity v at an angle θ with the direction of the magnetic field, as shown in figure (1).

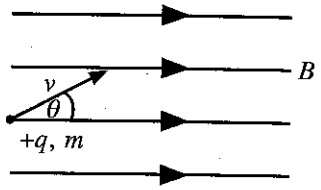


Figure (1)

(i) Name the shape of the path of the proton. Using the parallel and perpendicular components of the velocity of the proton with respect to the field explain how you arrived at the answer.

(ii) Using the values in (*a*) (iv) above calculate the time required for the proton to complete one periodic time T.

(iii) During this time T the proton travels a distance p parallel to the magnetic field. Write down an expression for the distance p travelled by the proton during this time in terms of v, θ and T.

(iv) If $\theta = 30°$ calculate the value of p? (Take $\sqrt{3} = 1{\cdot}7$)

(v) If the distance travelled by the proton along the direction of the magnetic field is 16320 km, what is the time taken to travel this distance?

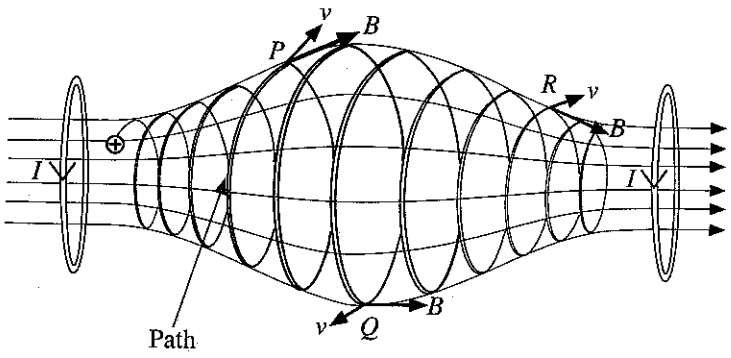


Figure (2)

(*c*) A non-uniform magnetic field can be formed using two current carrying coils as shown in figure (2). This type of magnetic field forms a "magnetic bottle" and it is an arrangement that permits to confine charged particles. The path of a positive charge particle is shown in the same figure.

(i) Explain why the radius of the path of the particle at position P is smaller than that of at position Q.

(ii) Copy the relevant points with directions of v and B from figure (2) on to your answer sheet and draw the directions of the magnetic force experienced by the charge particle at each positions P, Q and R using arrows.

(iii) Giving reasons prove that the charge particle may oscillate back and forth between the two ends of the magnetic bottle.

[see page thirteen

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

Part (A)

(*a*) A conducting metal wire of length l and area of cross-section A has n number of free electrons per unit volume. Electron charge is e.

(i) Write down an expression for the total number of free electrons available in the wire.

(ii) When a potential difference is applied across the ends of the wire a current I flows through the wire. Derive an expression for the drift velocity (v) of electrons in the wire in terms of I, n, e and A.

(*b*) An electrician uses two metallic wires X and Y made of same material having the same length (l) but different cross-sectional areas A_1 and A_2. They are connected in series and then in parallel to the same constant voltage source separately.

(i) Write an expression for the ratio of respective drift velocities of electrons $\left(\frac{v_X}{v_Y}\right)$ moving in the wires X and Y when they are connected in series.

(ii) Write an expression for the ratio of respective drift velocities of electrons $\left(\frac{v_X}{v_Y}\right)$ moving in the wires X and Y when they are connected in parallel.

(iii) Plot two graphs separately to show the variation of respective drift velocities (v_X and v_Y) along the length (l) of above series and parallel wire combinations. (Take $A_1 > A_2$)

(*c*) (i) A copper wire has a cross-sectional area of $2{\cdot}5 \times 10^{-7}\ m^2$. Calculate the drift velocity of electrons through the wire when the current is 4·0 A.
($e = 1{\cdot}6 \times 10^{-19}$ C; Number of free electrons per unit volume in copper = $8{\cdot}0 \times 10^{28}\ m^{-3}$)

(ii) In a conductor, free electrons have random motion and the random speed (mean thermal speed) at a given temperature can be calculated considering the mean kinetic energy and mean thermal energy of free electrons at that temperature. The mean thermal energy of free electron at temperature T is given by $\frac{3}{2}kT$ where k is the Boltzmann constant. Calculate the mean thermal speed of free electrons in copper at temperature of 27 °C.
(Take mass of electron = $9{\cdot}0 \times 10^{-31}$ kg, Boltzmann constant = $1{\cdot}4 \times 10^{-23}\ J\ K^{-1}$)
(Take $\sqrt{1{\cdot}4} = 1{\cdot}18$)

(iii) The mean thermal speed of free electrons in a conductor is typically very large compared to the drift velocity. But why do the free electrons with their mean thermal speed in a conductor can not cause any current flow without applying an external electric field?

(*d*) The mobility (μ) of charge carriers in a conductor is defined as the magnitude of the drift velocity per unit external electric field intensity that is being applied.

(i) Calculate the mobility of electrons in the copper wire mentioned in (*c*) (i) above if an electric field of intensity 50 V m^{-1} is applied along the wire.

(ii) In the development of organic light emitting diodes (OLED) mobilities of charge carriers of organic materials are increased to lower the applied electric field and there by achieving a higher efficiency. What is the percentage reduction of applied electric field intensity if the mobility and drift velocity of charge carriers of an organic material are increased by 20% and 10% respectively?

[see page fourteen

Part (B)

Figure (1) shows the current (I) – voltage (V) characteristic curve for a diode.

(a) Name the diode which is represented by figure (1).

(b) Figures (2) and (3) show silicon diodes and two resistors with resistances R_1 and R_2. A and B inputs can be 0 V or 5 V. For all the calculations use the characteristic curve given in figure (1).

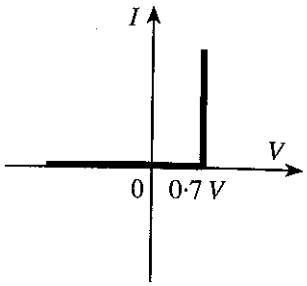


Figure (1)

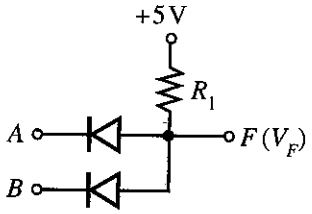


Figure (2)

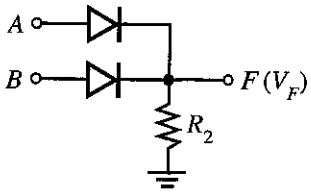


Figure (3)

(i) For different combinations of input voltages given below, determine the output voltages V_F at F and complete the following table for the circuits given in figure (2) and figure (3) respectively. (For this purpose copy the table twice on to your answer sheet)

A(V)	B(V)	V_F(V)
0	0	
0	5	
5	0	
5	5	

(ii) When considering the output F only, if 5 V (or close to 5 V) represents binary 1 and 0 V (or close to 0 V) represents binary 0, name the respective gates corresponding to the circuits shown in figure (2) and (3) above and write down their truth tables.

(iii) Calculate the suitable values of R_1 and R_2 which limits 0·5 mA of total current flowing through both diodes in each circuit.

(c) A student wants to build a logic circuit that will ring an alarm at an office with one door and one window if the door or window or both are opened after office hours. The related logical variables are as follows.

Inputs: Time: T = 0 (during office hours), T = 1 (after office hours).
Door: D = 0 (door is closed), D = 1 (door is opened).
Window: W = 0 (window is closed), W = 1 (window is opened).

Outputs: F = 0 (alarm not ringing), F = 1 (alarm ringing)

(i) Using logical variables T, D, W and F mentioned above, write down a truth table that will satisfy the required conditions.

(ii) Obtain the corresponding logical expression for F.

(iii) Simplify the logical expression that you have written in (c) (ii) above. (You may use the identities $W+\overline{W}=1$ and $\overline{D}W+D=D+W$).

(iv) Draw the **simplest** logical circuit that can be used for this purpose.

[see page fifteen

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

Part (A)

When exercising, human body produces energy and a high percentage of this energy is converted into heat. If this heat is not removed the body temperature will rise. In order to maintain the normal body temperature, heat is dissipated by evaporating the water in sweat. The heat of evaporation of water is provided by the body.

(*a*) When a person of mass 75 kg is riding an exercise bike the rate of energy produced is 800 W. Out of this energy 75 % is converted into heat. Neglect the loss of heat due to respiration process.

(i) What is the amount of heat produced by this person during 30 minutes of cycling?

(ii) In order to release this heat, what is the mass of water that should be evaporated? The specific heat of evaporation of water at body temperature is $2{\cdot}4 \times 10^6$ J kg^{-1}. (Equation $Q = mL$ can be used for this.)

(iii) What is the volume of water in millilitres which corresponds to the mass calculated in (*a*) (ii) above? The density of water is $1{\cdot}0 \times 10^3$ kg m^{-3}.

(iv) Calculate the temperature rise of the body during the 30 minutes period if this amount of heat is not released from his body. Average specific heat capacity of the body is 3600 J kg^{-1} K^{-1}.

(*b*) The above person inhales a volume of $4{\cdot}5 \times 10^{-4}$ m^3 of air at atmospheric pressure and at 27 °C in each breath. The respiration rate of the person is 20 breaths per minute. At the lungs, inhaled air is heated up to 37 °C.

(i) Determine the final volume of air inhaled inside the lungs after a breath. Assume that the pressure of inhaled air inside the lungs is equal to the atmospheric pressure.

(ii) Calculate the rate of work done by the lungs in order to remove all the air inhaled while exhalation. (Atmospheric pressure = $1{\cdot}0 \times 10^5$ Pa)

(*c*) A closed gymnasium has several exercise bikes. When people are not exercising in the gymnasium, temperature of the gymnasium is 30 °C and the relative humidity is 75 %. Saturated vapour pressure of water at 30 °C is 32 mm Hg.

(i) Write down an expression for relative humidity in terms of water vapour pressures.

(ii) Determine the water vapour pressure existing in the gymnasium.

(iii) What is the mass of water vapour present in the gymnasium? At 30 °C absolute humidity of saturated water vapour is 30 g m^{-3}. The volume of the gymnasium is 600 m^3.

(iv) Suppose **four** people are riding exercise bikes in the gymnasium. Assume that the temperature of gymnasium does not change and the mass of water vapour released by each person during 30 minutes is equal which is same as the value obtained in (*a*) (ii) above. What is the new relative humidity in the gymnasium after 30 minutes?

(v) Once the riding of bikes is over the gymnasium is cooled to 20 °C and some of the water vapour is removed by an air-conditioner. The mass of water vapour removed by the air-conditioner is 6300 g. What is the final relative humidity of the gymnasium at 20 °C? Absolute humidity of saturated water vapour at 20 °C is 20 g m^{-3}.

[*see page sixteen*

Part (B)

Figure (1) shows a hollow cube with four different types of metal surfaces. The cube filled with hot water is used to demonstrate the intensity variation of thermal radiation emitted from different surfaces with temperature. Four thermal detectors are kept at same distance from each surface to measure the temperature of the surface.

[Let Stefan constant $\sigma = 6{\cdot}0 \times 10^{-8}$ W m^{-2} K^{-4},

Wien's displacement constant = 2900 μm K]

For following calculations you may use

$(300)^4 = 8 \times 10^9$, $(310)^4 = 9 \times 10^9$, $(360)^4 = 16 \times 10^9$, and $(373)^4 = 19 \times 10^9$.

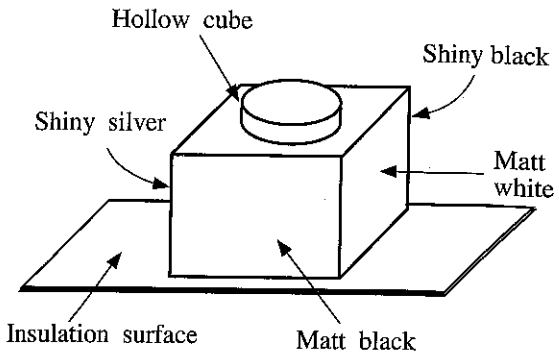


Figure (1)

(*a*) (i) What are the factors affecting absorption and emission of thermal radiation from a surface?

(ii) The measuring range of a thermal detector is from 200 K to 400 K. Calculate the peak wavelengths λ_m (wavelength at the maximum intensity) corresponding to the minimum and the maximum temperatures of a blackbody surface that can be measured using the thermal detector.

(iii) Name the region of the electromagnetic spectrum that the peak wavelengths obtained in (*a*) (ii) above belongs to.

(*b*) The above cube consists of four different type of surfaces of matt white, matt black, shiny silver, and shiny black. Thermal detectors display the readings of (not in order) 87 °C, 72 °C, 47 °C and 37 °C corresponding to the surfaces of the cube.

(i) Identify and writedown the temperature readings corresponding to each surface.

(ii) Which surface has the maximum surface emissivity?

(iii) If the room temperature is 27 °C, assuming the emissivity of the surface identified in (*b*) (ii) above to be 1, calculate the **relative** emissivity of the shiny silver surface.

(*c*) Net rate of radiation heat transfer per unit area (Q) between two parallel surfaces with emissivities e_1 and e_2 and temperatures T_1 and T_2 ($T_1 > T_2$) respectively is given by,

$$Q = \frac{\sigma\left(T_1^4 - T_2^4\right)}{\left(\frac{1}{e_1} + \frac{1}{e_2} - 1\right)}$$

A special box type Thermos flask consists of three walls A, B, and C as shown in figure (2). The outer surface of wall A and the inner surface of wall B are coated with silver. Walls A and B are separated by a vacuum.

(i) What is the reason for maintaining a vacuum in between walls A and B?

(ii) Why silver coated surfaces are used for walls A and B?

(iii) Calculate the net rate of radiation heat transfer per unit area between outer wall of A and inner wall of B if the emissivity of the silver coated surfaces is 0·02. Assume that the temperature of the outer wall of A and inner wall of B are 100 °C and 27 °C, respectively. (Take $\frac{1}{99} = 0{\cdot}01$)

(iv) If the heat transfer between the outer A and inner B walls is due to conduction, instead of radiation, calculate the thickness of an insulator material of thermal conductivity $6{\cdot}6 \times 10^{-2}$ Wm^{-1}K^{-1} that must be used to obtain the same rate of heat transfer per unit area calculated in (*c*) (iii) above. Here assume steady state conditions.

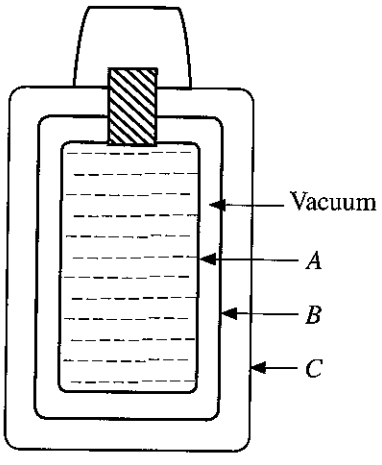


Figure (2)

* * *