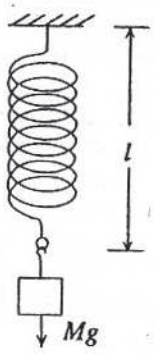
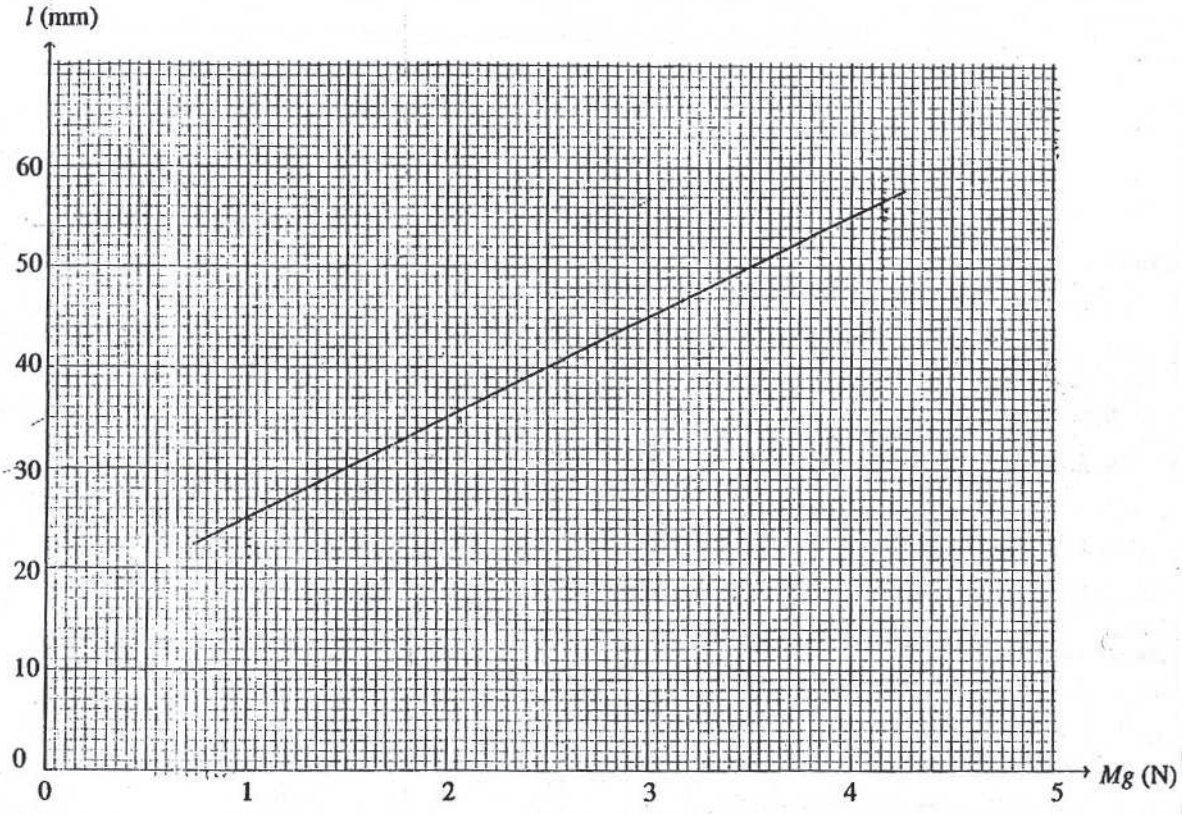
Essay Question

1. To determine the coefficient of static friction (μ) between two surfaces, you are given a uniform rectangular block of wood with a hook attached to one of its sides, a light spring, a metre ruler and five weights of mass (M) 0·1 kg, 0·2 kg, 0·3 kg, 0·4 kg and 0·5 kg. In order to calibrate the spring to measure forces, one end of the spring is attached to a fixed point and the other end is loaded with given weights as shown in the figure.



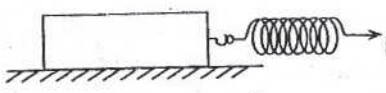
The force (Mg) applied on the spring and the corresponding length (l) of the spring are plotted as follows.



(*a*) When the block is hung from the spring the length of the spring was found to be 30 mm. Determine the **mass** of the block, using the above calibration graph.

.....

(*b*) Now the block is placed on a horizontal table and the spring is connected to the hook as shown in the figure. Then the spring is stretched horizontally until the block just starts to slide. When this occurs the length (l) of the spring is measured.



Write down the expression which relates the limiting frictional force F, with the normal reaction force R between the surfaces and μ.

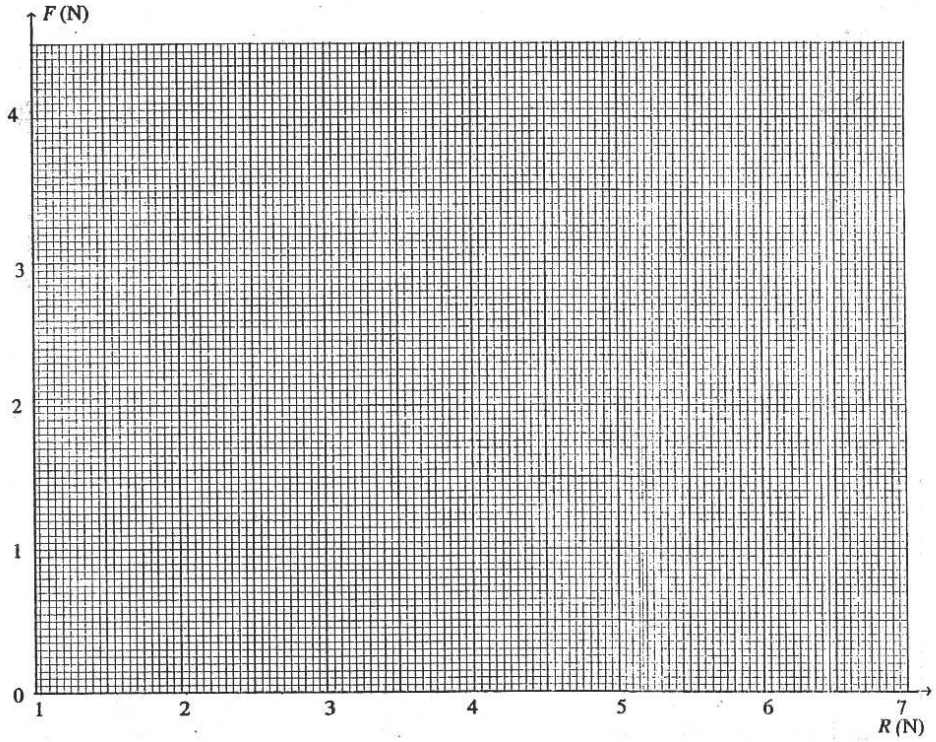
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(c) The above experimental procedure in *(b)* is repeated by placing each weight on top of the block. The corresponding l values thus obtained are given in the following table.

	R (N)	l (mm)	F (N)
block without any weight		25	
block + 0·1 kg weight		30	
block + 0·2 kg weight		35	
block + 0·3 kg weight		41	
block + 0·4 kg weight		48	
block + 0·5 kg weight		55	

(i) Complete the above table by calculating R values and obtaining corresponding F values.

(ii) Mark the above F and R pairs on the grid given below using crosses (×).



(iii) Draw the best straight line that passes through the above points.

(iv) Find the gradient of the graph, and hence determine a value for μ.

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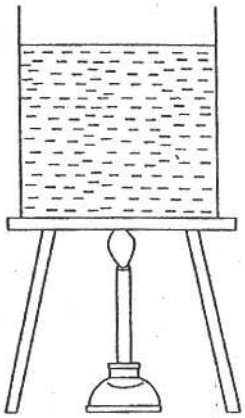
(d) What would be the best procedure to measure l in *(b)* using the metre ruler?

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2. A student plans to perform an experiment in the school laboratory to study the variation of the saturated vapour pressure of water with temperature using a capillary tube closed at one end carrying a small water thread inside.

(*a*) Complete the following diagram of the experimental arrangement that the student may use.



(*b*) How does the student insert water into the tube to form the water thread?

.....

.....

(*c*) What is the best position of the water thread to be located inside the tube at the room temperature? Is it closer to the open end of the tube or at the middle of the tube or near the closed end of the tube?

.....

Give reasons for your choice.

.....

.....

(*d*) Write down the steps that the student should follow to carry out this experiment.

.....

.....

.....

(*e*) At temperatures θ_1 and θ_2 (in Celsius) the lengths of the air column are l_1 and l_2 and the saturated vapour pressures of water are p_1 and p_2 respectively. The atmospheric pressure is P.

(i) Write down expressions for partial pressure of the dry air trapped inside the tube at the temperatures θ_1 and θ_2.

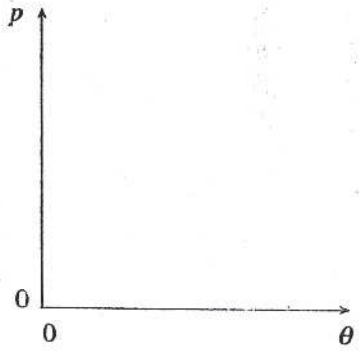
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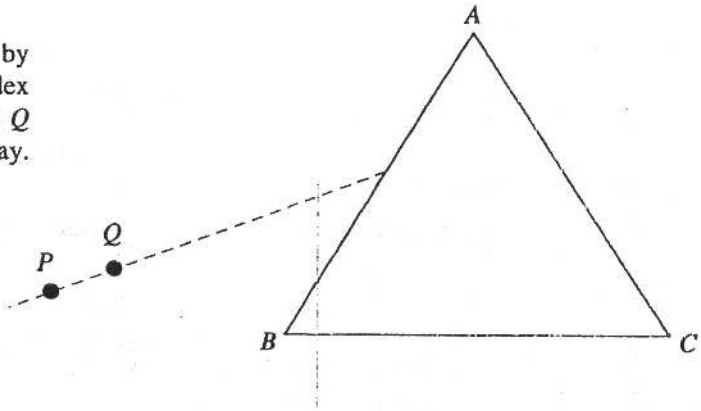
(ii) Write down the equation connecting P, p_1, p_2, l_1, l_2, θ_1 and θ_2.

.....

(*f*) Draw a rough sketch to show the variation of the saturated vapour pressure of water (p) with temperature θ (in Celsius).



3. The figure shows an arrangement used by a student to determine the refractive index of the material of a glass prism. P and Q are two pins used to trace the incident ray.



(*a*) The student has not placed the pins properly. How would you place them properly?

(1) .....

(2) .....

(*b*) (i) Describe how you would obtain the emergent ray experimentally.

.....

.....

(ii) Why is it **not** possible to use one pin instead of two pins for the above *(b)* (i)?

.....

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(*c*) Mark the following angles on the diagram.

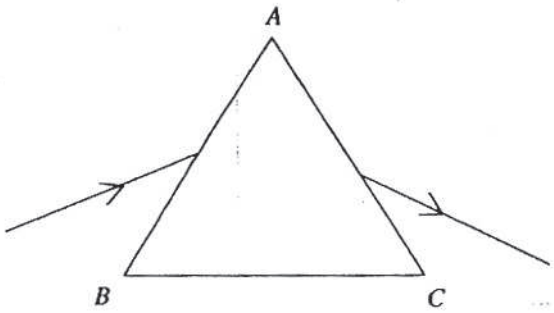
(i) Angle of incidence, i_1

(ii) Angle of refraction at the surface AB, r_1

(iii) Angle of incidence on the surface AC, r_2

(iv) Angle of emergence, i_2

(v) Angle of deviation, d



(*d*) Write down an expression for d in terms of i_1, i_2, r_1 and r_2.

.....

(e) For a particular incident ray $i_1 = 10°$ and $r_1 = 6°$.

(i) What is the refractive index of glass?

.....

.....

(ii) If the refracting angle of the prism is 60°, find the value of r_2.

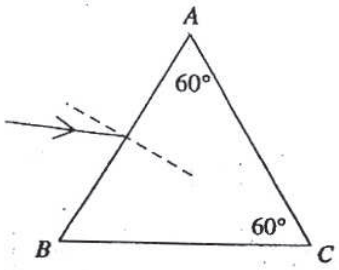
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(iii) Do you expect to receive an emergent ray from surface AC for the above incident ray? Explain your answer.

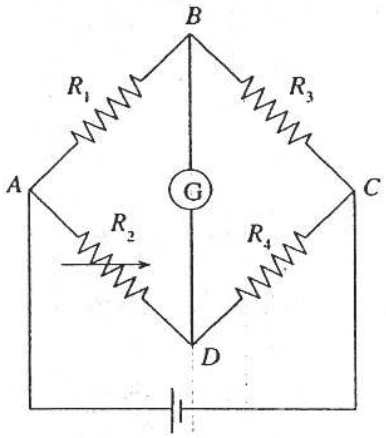
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(iv) Complete the corresponding path of the ray in the diagram given below.



4. A bridge circuit is shown in the diagram. R_1, R_3 and R_4 are resistances and R_2 is a variable resistance. G is a centre zero galvanometer.



(a) When R_2 increases from zero to a very high value what would you observe in the variation of the deflection of the galvanometer?

.....

(b) When the bridge is balanced for a certain value of R_2, the currents through R_1 and R_2 are I_1 and I_2 respectively.

(i) What are the currents through R_3 and R_4?

.....

(ii) What is the potential difference between B and D?

.....

(iii) Write down the relationships between

V_{AB} (potential difference between A and B) and V_{AD} .....

V_{BC} and V_{DC} .....

(iv) Write down expressions for V_{AB}, V_{BC}, V_{AD} and V_{DC}, in terms of R_1, R_2, R_3, R_4, I_1 and I_2.

V_{AB} = ... V_{BC} = ...

V_{AD} = ... V_{DC} = ...

(v) Obtain an expression for R_4 in terms of R_1, R_2 and R_3.

.....

.....

(vi) If $R_1 = 100\,\Omega$, $R_3 = 50\,\Omega$, and $R_2 = 82\,\Omega$, find the value of R_4.

.....

.....

(*c*) A student wants to use the above bridge to measure a very small resistance r (< 1 Ω). He is provided with the following.

Three 10 Ω, 100 Ω and 1000 Ω resistors.
Two 0 – 100 Ω and 0 – 1000 Ω resistance boxes.

He replaces R_4 with the unknown resistor r. Which of the above resistors or resistance boxes should he select for R_1, R_2 and R_3 in order to determine r as accurately as possible?

For R_1 .....

For R_2 .....

For R_3 .....

(*d*) When the bridge is balanced, if the cell and the galvanometer are exchanged what should be the deflection of the galvanometer?

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கல்விப் பொதுத் தராதரப்பத்திர(உயர் தர)ப் பரீட்சை, 2001 ஓகஸ்ற்
General Certificate of Education (Adv. Level) Examination, August 2001

භෞතික විද්‍යාව II
பௌதிகவியல் II
Physics II

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PART B — Essay

Answer four questions only.

(g = 10 N kg^{-1})

1. Bernoulli's equation for a fluid flow can be written as

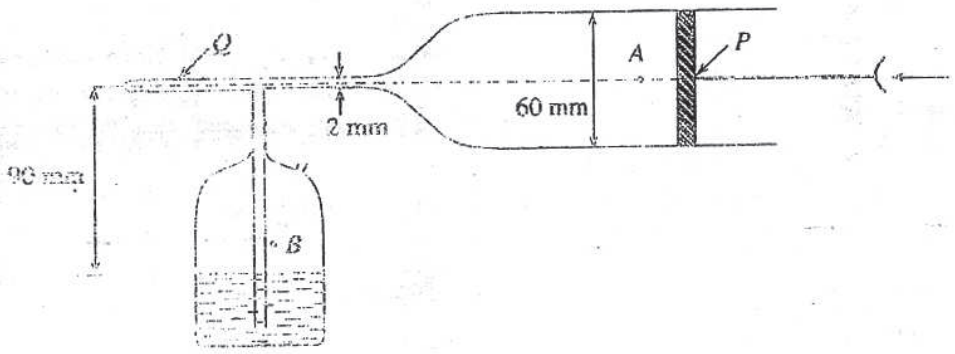
$$p + \frac{1}{2}\rho v^2 + h\rho g = \text{constant},$$

where all the symbols have their usual meaning.

(a) (i) State the conditions under which the Bernoulli's equation is valid.

(ii) Show that the above equation is dimensionally correct.

(b)



The insecticide sprayer shown in the figure has a pump with a diameter of 60 mm. The diameter of the outlet tube Q is 2 mm and the insecticide level is 90 mm below the tube. Assume that the pressure at A is same as that at B and air behaves according to all the conditions that you have mentioned in (a) (i).

(i) Calculate the minimum speed with which the piston P of the pump should be pushed if the air jet in the tube Q is to contain insecticide.
[Take the densities of insecticide and air to be 10^3 kg m^{-3} and 2 kg m^{-3} respectively.]

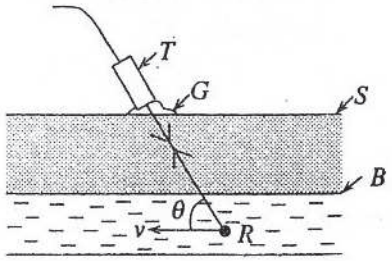
(ii) If the net resistive force acting on the piston of the pump is 20 N, determine the force that has to be applied on the piston, in order to maintain the speed calculated above.

2. The following passage gives some properties of ultrasound waves and describes a Doppler technique used in medical diagnosis. Read the passage carefully and answer the questions given below.

Doppler method is primarily used to obtain information of moving objects. In medicine this technique is used to investigate the movement of red blood cells.

By definition, ultrasound is sound having frequency greater than 20 kHz, which is above the audible range 20 Hz – 20 kHz for humans. The frequencies used for medical applications are usually in the range 1 MHz to 15 MHz. Use of ultrasound in medicine has several special advantages. The low intensity ($< 0{\cdot}1\ \mathrm{W\,m^{-2}}$) beams used are not known to produce any damage or undesirable side effects to humans. Unlike X-rays, ultrasound does not ionize atoms or molecules in human cells. Ultrasound is also reflected even by objects of small size.

The figure shows a set up used to measure the blood flow in a blood vessel.



T – ultrasound wave transmitting and detecting device
G – coupling gel
S – skin
B – blood vessel
R – a red blood cell which is travelling at a speed v

T transmits ultrasound waves with frequency f_t and after reflection from the blood cell receives them with a frequency f_r. θ is the angle between the ultrasound beam and the path of the blood cell.

In medicine $(f_r - f_t)$ is known as Doppler frequency f_d, which can be written as

$$f_d = 2f_t \frac{v\cos\theta}{u}$$

where u is the speed of ultrasound waves in soft tissue.

u is fairly constant for human soft tissue and its value is $1500\ \mathrm{m\,s^{-1}}$. The speed of ultrasound in air is about $300\ \mathrm{m\,s^{-1}}$ and densities of air and soft tissue are also fairly different. Therefore air/skin interface reflects about 99% of the incident ultrasound energy. This has to be eliminated when the test is carried out.

(i) What is normal audible range for humans?

(ii) State two major advantages of using ultrasound in medical diagnosis.

(iii) Is ultrasound a longitudinal or transverse wave?

(iv) What is the major difference between sound and ultrasound?

(v) Is ultrasound an electromagnetic wave? Give reasons for your answer.

(vi) (a) Calculate the wavelength of 15 MHz ultrasound waves in human soft tissue.
(b) Give a reason as to why ultrasound is also reflected from small objects.

(vii) Use the following steps to derive the formula for f_d given in the passage.
(a) What is the component of the velocity of the red blood cell R along the direction of device T?
(b) Considering the device as a stationary source and the red blood cell as a moving observer, write down an expression for the frequency (f') detected by the cell in terms of f_t, v, u, and θ.
(c) Now consider the cell as a moving source emitting signals of frequency f'. Hence write down an expression for f_r in terms of f', v, u and θ.
(d) Combine the above two expressions and obtain

$$f_d = f_r - f_t = 2f_t \frac{v\cos\theta}{u - v\cos\theta}$$

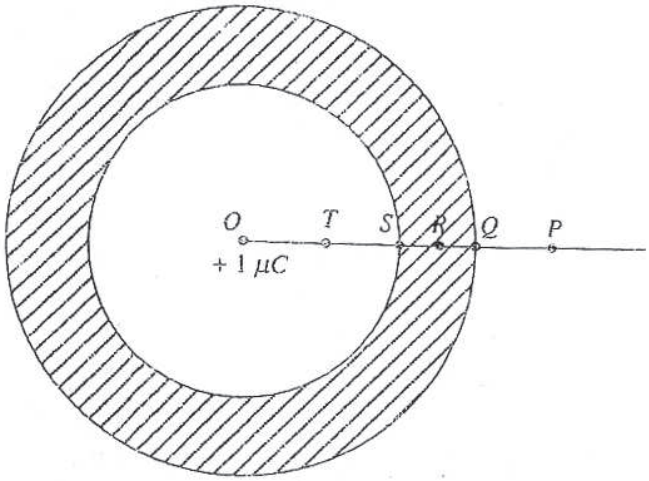
(since $v << u$, $u - v\cos\theta \approx u$).

(viii) For f_t = 15 MHz, f_d was found out to be 8 kHz. Calculate speed v of the red blood cell. Take θ to be 10°.

(ix) Why is it desirable to keep θ as small as possible?

(x) What is the purpose of using the coupling gel G?

3. A point charge +1 μC is placed at the centre O of an isolated conducting spherical shell of inner radius 10 cm and outer radius 15 cm as shown in the diagram. The points P, Q, R, S and T shown in the diagram are situated in such a way that $OP = 20$ cm, $OQ = 15$ cm, $OR = 12{\cdot}5$ cm, $OS = 10$ cm and $OT = 5$ cm.



$$\left(\frac{1}{4\pi\varepsilon_0} = 9\times10^9\ \mathrm{N\,m^2C^{-2}}\right)$$

(i) What are the induced charges on the inner and outer surfaces of the conducting shell?

(ii) Find the electric field intensities at points P, R and T. Sketch the variation of electric field intensity (E) with the distance (r) from the centre.

(iii) (a) Find the electric potentials at points P, Q, R and S.

(b) Find the electric potential difference between the points T and S. Hence find the electric potential at point T.

(c) Sketch the variation of electric potential (V) with the distance (r) from the centre.

(iv) If an additional charge of −1 μC is given to the conducting shell, find the charge densities on the inner and outer surfaces of the conducting shell.

4. A laminar flow of a viscous liquid is maintained on a stationary horizontal plate. The top layer of the liquid is moving with a constant velocity V and the stationary bottom layer is at a depth d.

(i) If the coefficient of viscosity of the liquid is η, write down an expression for the force F that has to be applied on the surface of an area A of the top layer.

(ii) Show in a diagram using arrows, the variation of the velocities of the intermediate layers.

(iii) A person pushes a block of mass 0.5 kg on a horizontal floor. When a horizontal force 0·25 N is applied on the block it attains a constant velocity of 0·01 $m\,s^{-1}$. If a thin layer of an oil is applied on the floor, the horizontal force required to push the block with the same velocity 0·01 $m\,s^{-1}$ reduces to 0·05 N. The contact surface area of the block is 1×10^{-2} m^2 and the thickness of the oil layer is 1 mm.

(a) Calculate the coefficient of viscosity of the oil.

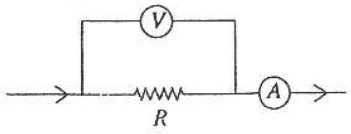
(b) Find the effective coefficient of sliding friction between the block and the floor after applying the oil layer.

(c) What is the energy that can be saved during one second due to the application of oil layer?

(d) In order to lift the block from the oil layered floor, in addition to the weight of the block a vertical force has to be applied upwards on the block. Explain the reason for this.

5. **Answer either part (a) or part (b).**

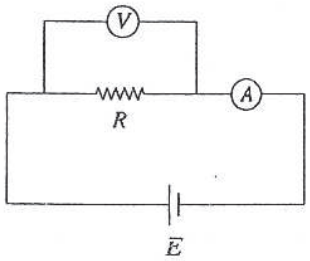
(a) The diagram shows how a voltmeter and an ammeter are connected to determine the resistance R of a resistor which is a part of an electrical circuit. Let V_m and I_m be the voltmeter and ammeter readings respectively.



(i) If the voltmeter and ammeter were perfect instruments, write down an expression for the resistance R.

(ii) If the resistance of the voltmeter is R_V, obtain an expression for the resistance R in terms of V_m, I_m and R_V.

To measure, the resistance of a nichrome wire a voltmeter of resistance 1000 Ω and an ammeter of resistance R_I are connected as shown in the diagram. The internal resistance of the cell E is negligible.



At room temperature of 30°C the voltmeter and ammeter readings are 4·00 V and 0·020 A respectively. When the nichrome wire is immersed in an oil bath at temperature 430°C the voltmeter and ammeter readings are 4·05 V and 0·018 A respectively.

(iii) Find the temperature coefficient of resistance of nichrome.

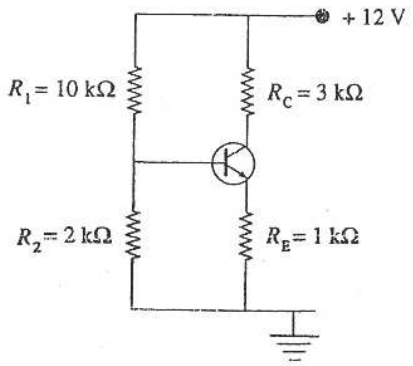
(iv) Find also the resistance R_I of the ammeter and the e.m.f. of the cell.

(b) (i) Draw $I - V$ characteristics of a junction diode. How would you use these characteristics to identify Si and Ge diodes.

(ii) Give the circuit diagram of a **half wave** rectifier and draw input and output waveforms.

(iii) An a.c. voltage of peak value 25 V is connected in series with a silicon diode and a load resistance 600 Ω. If the forward bias resistance of the diode is 40 Ω, find the peak current through the diode and the peak output voltage.

(iv) A silicon transistor is connected as shown in the circuit diagram. The circuit is designed such that the base current I_B is 20 times smaller than the current through the voltage divider. Find the base current I_B, the emitter current I_E and the collector – emitter voltage V_{CE} for the cirucit.



6. **Answer either part (a) or part (b).**

(a) A boiler which produces steam at atmospheric pressure has a metal bottom of thickness 2 cm and surface area 500 cm^2. The thermal conductivity of the metal is 400 $W\,m^{-1}\,°C^{-1}$. A heating element of power 20 kW is placed beneath the bottom. The boiler is well insulated and it can be assumed that no heat is lost to the surroundings.

(i) What is the maximum rate at which the steam is produced by the boiler? Specific latent heat of vaporization of water = $2{\cdot}3 \times 10^6$ J kg^{-1}.

(ii) What is the temperature of the outer surface of the bottom of the boiler?

After a long usage of the boiler a layer of thickness of 0·1 cm is formed on the inner side of the bottom of the boiler. The thermal conductivity of the material of the layer is 10 $W\,m^{-1}\,°C^{-1}$.

(iii) If the boiler still produces steam what is the maximum rate at which the steam is produced?

(iv) Using standard formulae find the temperature of the outer surface of the bottom of the boiler?

(v) By reducing the power of the heating element, will it be possible to maintain the temperature of water at 50°C

(1) with the boiler fully insulated

(2) without the insulation?

Explain your answer. (No calculations are necessary.)

(b) Give a labelled diagram of a set up that can be used to investigate photoelectric effect.

(i) Sketch the variation of photocurrent (I) with the potential difference (V) between the electrodes for light of fixed intensity and frequency.

Draw the expected variations of I with V for the light of

(1) same frequency but twice the intensity and

(2) same intensity but a higher frequency

on your above sketch. Label situation (1) as X and situation (2) as Y.

(ii) A surface of a metal is illuminated with light and photoelectrons are observed.

(1) What is the largest wavelength that will cause photoelectrons to be emitted?

(2) What is the stopping potential when light of wavelength 220 nm is used?

What is the maximum velocity of the emitted electrons?

Work function of the metal = 4·08 eV,

Mass of the electron = $9{\cdot}11 \times 10^{-31}$ kg,

Electronic charge = $1{\cdot}60 \times 10^{-19}$ C,

Velocity of light = $3{\cdot}00 \times 10^8$ $m\,s^{-1}$,

Planck constant = $6{\cdot}63 \times 10^{-34}$ J s.