A Level

Physics

Session: 1984 June
Type: Question paper
Code: 9240

PHYSICS 9240/1

ADVANCED LEVEL

PAPER 1

(Two and a half hours)

Attempt **all** *the questions in Section A. You are advised not to spend more than about one hour on this section. In Section B, attempt any* **three** *questions.*

For numerical answers, **all** *working should be shown.*

Mathematical tables, a data leaflet and squared paper are available.

The intended marks for questions or parts of questions are given in brackets [ ].

Section A

Attempt **all** *the questions in this section.*

You are advised not to spend more than about 1 hour on this section.

1 The reading of a speedometer fitted to the front wheel of a bicycle is directly proportional to the angular velocity of the wheel. A certain speedometer is correctly calibrated for use with a wheel of diameter 66 cm but, by mistake, is fitted to a 60 cm wheel. Explain whether the indicated linear speed would be greater or less than the actual speed and find the percentage error in the readings. [3]

2 Astronomical observations show that the centre of mass of the Earth-Moon system is $4{\cdot}7 \times 10^6$ m from the centre of the Earth. The distance between the centres of the Earth and the Moon is $384{\cdot}4 \times 10^6$ m. Find the mass of the Moon M_M in terms of the mass of the Earth M_E.

Explain why both Earth and Moon must rotate about their common centre of mass, rather than the Moon about the centre of mass of the Earth. [5]

3 An illuminated object O is placed 360 mm from a screen. It is found that there are two positions, P and Q, at which a converging lens of focal length 80 mm can be placed in order to obtain a focused image on the screen.

(*a*) What are the distances of P and Q from O?

(*b*) Find the ratio of the heights of the images on the screen when the lens is placed first at P, and then at Q. [5]

4

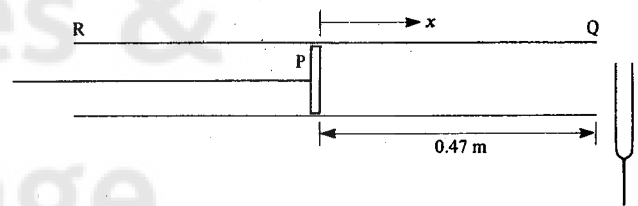


Fig. 4.1

A sound wave is generated by means of a tuning fork held near the end Q of a tube QR. As the piston P is moved from Q towards R, a loud sound is first heard when PQ is $0{\cdot}15$ m, and next when PQ is $0{\cdot}47$ m (Fig. 4.1). For this second resonance position, draw a graph showing the way in which the amplitude a of vibration of the air particles in the tube depends on the distance x from P. Explain why the relationship between the two lengths measured for PQ is not a simple ratio. [3]

5

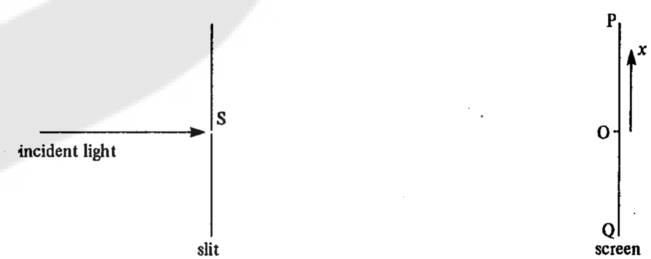


Fig. 5.1

Monochromatic light, incident normally on a narrow slit S (Fig. 5.1), is diffracted. A screen PQ is set up some distance from the slit in order to observe the diffraction pattern.

(*a*) Sketch a graph of intensity I against distance x from the central point O along the line PQ on the screen.

(*b*) Describe qualitatively what happens to the diffraction pattern as the width of the slit is gradually reduced. (Assume that it is practicable to reduce the slit-width until it is equal to the wavelength of the incident light.) [4]

6 Electromagnetic waves consist of transverse, sinusoidally-varying, electric and magnetic field components, perpendicular to each other and to the direction of propagation. The speed of propagation in vacuum is constant for electromagnetic waves of all wavelengths.

A beam of electrons has an associated wave property. Because it consists of a stream of moving electric charges, it also produces a magnetic field. The beam can pass through a vacuum. Discuss very briefly whether, on the basis of these experimental facts, electron beams could be classified as electromagnetic waves. [2]

7 In using a simple slide-wire potentiometer circuit, a large protective resistance is sometimes connected in series with the galvanometer. Why is this done? Explain how (if at all) the presence of this resistance affects (*a*) the position of the balance point, (*b*) the precision with which it may be found. [4]

8 Deduce the relation between the electric field strength E at the surface of a charged conducting sphere and the surface density of charge σ.

Measurements show that, on average, there is at the Earth's surface an electric field of intensity about 130 V m^{-1} directed vertically downwards. To what average surface density of charge does this correspond? What is the sign of this surface charge? [4]

9 A flat search coil of 500 turns, each of area $2{\cdot}5 \times 10^{-4}$ m^2, is connected to a galvanometer. The total resistance of the circuit is 200 Ω. The coil is first placed between the poles of an electromagnet, with its plane normal to the uniform magnetic flux; it is then removed to a point where the magnetic flux density is very small. As a result of this operation, a charge of $7{\cdot}5 \times 10^{-6}$ C is found to circulate in the circuit.

Find the magnetic flux density between the poles of the electromagnet. [5]

10

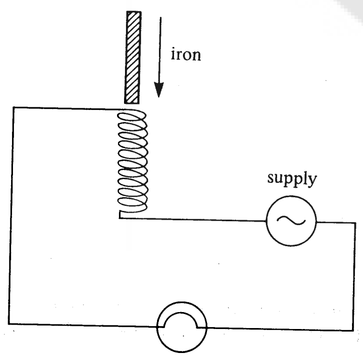


Fig. 10.1

The circuit shown in Fig. 10.1 consists of an air-cored inductor in series with an a.c. supply and a light bulb, the filament of which glows with a certain brightness. A soft iron rod is inserted into the inductor. Describe how and explain why the brightness of the filament changes (if at all). [3]

11 Using an electric drill, it takes 150 s to make a hole in a piece of brass of mass 0·45 kg. During this process, the average power delivered to the drill from the electricity mains is 300 W. How much electrical energy is used in drilling the hole?

If 70% of the energy supplied to the drill appears as heat in the brass, what is the initial rate of rise of temperature of the metal? [4]

(Specific heat capacity of brass = 390 J kg^{-1} K^{-1}.)

12 Deuterium is represented by the symbol $^2_1$H. What nucleons make up its nucleus? Use the data below to calculate the binding energy of the deuteron (the deuterium nucleus):

atomic masses: deuterium, $2{\cdot}01410\ m_u$,
hydrogen, $1{\cdot}00783\ m_u$;
rest mass of neutron, m_n: $1{\cdot}00867\ m_u$. [4]

Section B

Attempt any **three** *questions from this section.*

13 (*a*) In the SI statement of 1960, the metre was defined in terms of a fixed number of wavelengths in vacuum of a certain yellow line in the krypton spectrum. Previously, it was defined as the distance, at the melting-point of ice, between two lines on a platinum-iridium bar kept at the International Bureau of Weights and Measures.

(i) Base units should be readily reproducible and be capable of being measured accurately without mechanical or thermal disturbance. Explain briefly why the earlier definition of the metre was abandoned. Give **one** advantage of the newer definition over the old. [3]

(ii) Krypton light is used to measure a certain length. Explain the effect on the measurement if the wavelengths were counted in air instead of in vacuum. [2]

(iii) The length of a certain object is compared with the distance between the marks on the platinum-iridium bar. Explain the effect on the measurement if the bar were at room temperature instead of at the ice-point. [2]

(*b*) Interference fringes may be observed when a wedge air-film between two glass plates is illuminated near-normally with monochromatic light. These fringes may be used to measure the thickness of the wedge at a given point in terms of the wavelength of the light.

(i) Show by means of a sketch the arrangement of apparatus necessary to illuminate the film and to view the fringes by reflection. [3]

(ii) State how interference arises in this experiment. [1]

(iii) A general condition for interference effects between two sets of light waves to be observable is that the waves should be *coherent*. Explain the meaning of this term and show how this condition is satisfied in the above experiment. [2]

(iv) Why is the fringe at the apex of the wedge, where the glass plates are in contact, dark when viewed by reflection? [2]

(v) Show how the thickness of the wedge at a given point may be obtained in terms of the wavelength of light used. [3]

14 Explain what is meant by *angular acceleration* and *torque*, and give the SI unit for each quantity. [3]

Write down the mathematical relationship between angular acceleration $\ddot{\theta}$, torque T and moment of inertia I. [1]

Upon what factors does the moment of inertia of a body depend? [2]

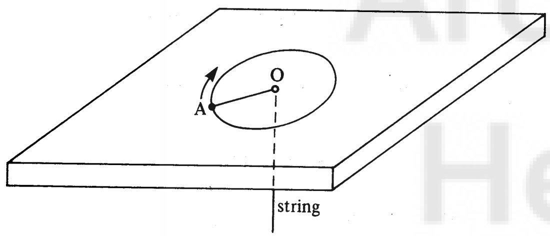


Fig. 14.1

A particle A of mass 0·020 kg is attached to a light string which passes through a smooth hole O in a smooth horizontal table and is held at a point below the table (Fig. 14.1). The particle is set into uniform motion in a circle of radius 0·50 m about O, making one revolution every 0·80 s.

(*a*) Draw a diagram showing the magnitudes and directions of the forces acting on the particle when it is rotating and is in the position shown. [4]

The string is now pulled down slowly so that the radius of rotation is reduced to 0·25 m.

(*b*) Explain why the angular momentum of the system remains constant during this operation, and hence find the new angular speed of the particle. [5]

(*c*) Calculate the work done in pulling the string down. [3]

15 A black body is sometimes stated to be a perfect absorber and a perfect radiator. What is meant by a *perfect absorber* and a *perfect radiator*? [3]

Explain how a small hole in a closed container can act as a very close approximation to a perfect absorber, even if the interior walls are only moderately absorbing. Discuss whether the hole will also be a very close approximation to a perfect radiator. [5]

The element of a radiant electric fire has diameter 0·015 m and length 0·25 m and is rated at 800 W. Assuming that the element radiates as an isolated black body, estimate its equilibrium temperature. [4]

In fact, the element does **not** emit as a perfect radiator. Explain qualitatively how this affects the equilibrium temperature. [3]

Also, your calculation neglected the radiation absorbed by the element from the room in which the fire is operating. How would this radiation affect the equilibrium temperature? Why is the error incurred by neglecting this radiation very small? [3]

16 Explain why the heat capacity of one mole of a gas measured at constant pressure is greater than the heat capacity measured at constant volume and derive an expression for the difference between these heat capacities. [5]

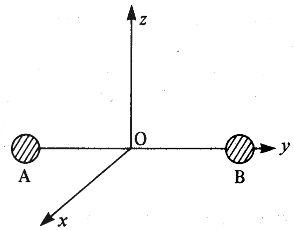


Fig. 16.1

Fig. 16.1 shows a simple model of an ideal diatomic gas molecule, in which A and B are identical atoms.

(*a*) Identify the degrees of freedom of this molecule. [3]

(*b*) Experiments show that, at normal temperatures, only five degrees of freedom are involved. Why are others not active? [2]

(*c*) If at a temperature T an amount of energy equal to $\frac{1}{2}kT$ is associated with each of the active degrees of freedom, what is the internal energy of one mole of these molecules? [2]

(*d*) Hence show that γ, the ratio of the principal heat capacities of this ideal diatomic gas, is 7/5. [3]

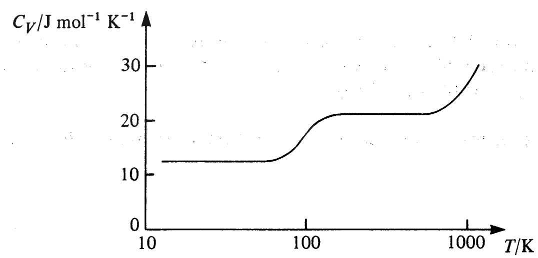


Fig. 16.2

Fig. 16.2 shows the way in which the molar heat capacity at constant volume of hydrogen depends on temperature. The molecules remain diatomic throughout this temperature range. Explain the changes in the value of C_V. [3]

17 Write down the approximate wavelength limits of the visible and X-ray regions of the electromagnetic spectrum. [2]

The basic components of a spectrometer for investigating spectra in any region of the electromagnetic spectrum are a collimator, a dispersive element, and a detection system.

(*a*) What is the function of the collimator? Sketch the arrangement of its components in a spectrometer for use in the visible region. How can one attempt to collimate the X-rays in an X-ray spectrometer? [4]

(*b*) The dispersive element in a spectrometer for use in the visible region is commonly a diffraction grating. Use the grating equation, $n\lambda = d \sin\theta$, to estimate a typical separation for the lines on such a grating. Explain whether or not such a grating could be used successfully in an X-ray spectrometer. [3]

(*c*) Name **one** detection system used in the visible and **one** used in the X-ray regions of the spectrum. [2]

Spectra from a discharge tube, and from an X-ray tube, may each show a line structure. Explain how *one* of these line spectra is produced. [4]

A beam of X-rays containing a continuous spectrum of wavelengths is directed at a crystal. It is found that the X-rays are scattered strongly in certain directions: the pattern of these directions gives information about the way in which the atoms in the crystal are arranged but the *spacing* of atomic planes cannot be deduced. Making reference to the Bragg equation, $n\lambda = 2d \sin\theta$, explain why strong scattering is observed in certain directions. What modification should be made to the experiment in order to investigate the atomic spacing? [3]

18 Explain the meanings of the terms *stress* and *strain* as applied to the deformation of a wire under tension. [2]

Draw a labelled diagram of an apparatus to investigate the way in which the strain of a steel wire depends upon the applied stress. Describe how you would use this apparatus to determine the Young modulus of the material of the wire. [8]

A load of 60 N is applied to a steel wire of length 2 m and area of cross-section 0·1 mm². The Young modulus for steel is 2×10^{11} Pa. What extension is produced? [2]

A temperature rise of 1 K causes a fractional increase of 1×10^{-5} in the length of the steel wire. If the temperature were to increase by 3 K during the course of the experiment, by how much would the length of the wire change? [2]

Discuss whether temperature changes are important in experiments to determine the Young modulus of a metal. [4]

PHYSICS **9240/2**

ADVANCED LEVEL

PAPER 2

($1\frac{1}{4}$ *hours*)

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

Read these notes carefully

There are **forty** *questions in this test. For each question* **five** *suggested answers are given: you are to choose the most appropriate one and indicate it on the separate answer sheet.*

Read the instructions on the separate answer sheet very carefully.

Attempt **all** *the questions. Marks will not be deducted for wrong answers: your total score on this test will be the number of correct answers given.*

Mathematical tables and a data booklet are available.

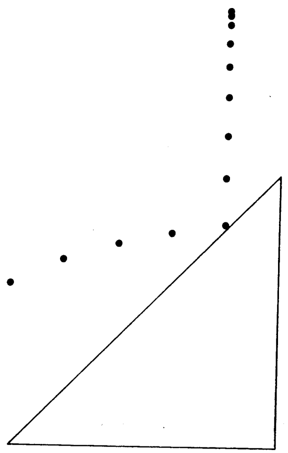
1 A student makes measurements from which he calculates the speed of sound as 327·66 m s⁻¹. He estimates that his result is accurate only to ±3%. Which one of the following gives his result reduced to the appropriate number of significant figures?

A 300 m s^{-1} **B** 327 m s^{-1} **C** 327·7 m s^{-1} **D** 328 m s^{-1} **E** 330 m s^{-1}

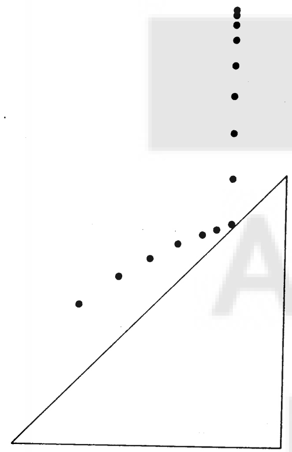
2 The potential energy of a body when it is at point P a distance x from a reference point O is given by $V = kx^2$, where k is a constant. What is the force acting on the body when it is at P?

A $2kx$ in the direction OP
B kx in the direction OP
C zero
D kx in the direction PO
E $2kx$ in the direction PO

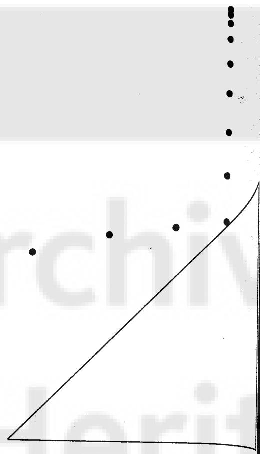
3 A ball, dropped on to a 45° inclined plane, makes an elastic collision with the surface. Stroboscopic photographs (a series of exposures on the same film at equal time intervals) are taken of the path of the ball. Which one of the following diagrams best represents the photographs?



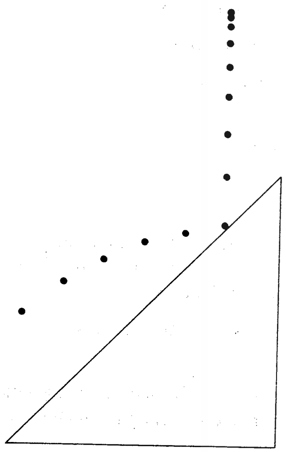
A



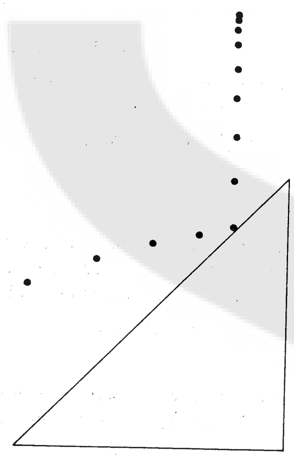
B



C



D



E

4 The sketch graph below (Fig. 1) describes the motion of a ball rebounding from a horizontal surface after being released from a point above the surface.

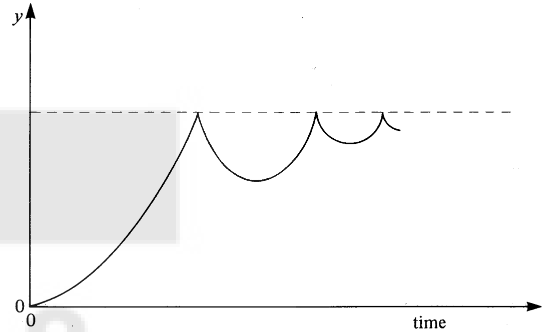
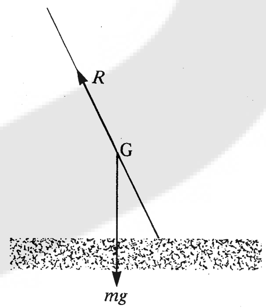


Fig. 1

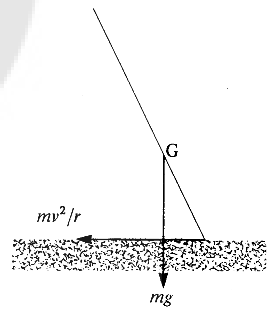
The quantity represented on the y-axis is the ball's

- **A** displacement.
- **B** velocity.
- **C** acceleration.
- **D** momentum.
- **E** kinetic energy.

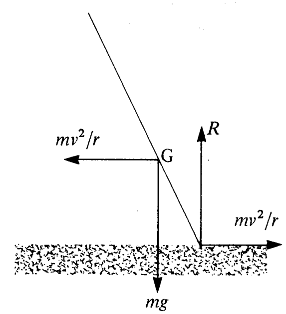
5 The diagrams represent a cyclist making a left turn at constant speed v, as viewed from behind. The mass of the bicycle and rider is m and their centre of mass is at G. Which one of the diagrams is a correct representation of the forces acting on the bicycle and its rider?



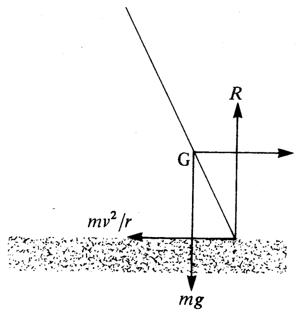
A



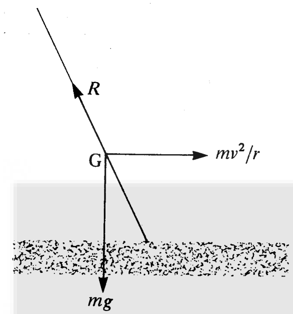
B



C



D



E

6 Two skaters of equal mass, facing each other and holding hands with arms outstretched, are spinning at angular velocity ω about a vertical axis midway between them. If they then move closer together so that they halve their separation, what is their new angular velocity?

A $\omega/4$ **B** $\omega/2$ **C** ω **D** 2ω **E** 4ω

7 According to one model X, the Earth is a solid sphere of uniform density. On another model Y, the Earth has a very dense core surrounded by less dense material. The models are adjusted so that they give the same values of g, the acceleration of free fall at the Earth's surface. The values g_h at height h above the surface and g_d at depth d below the surface are also calculated on both models. Which one of the following correctly describes the results?

	g_h	g_d
A	same for both models	greater for X than Y
B	same for both models	smaller for X than Y
C	same for both models	same for both models
D	greater for X than Y	same for both models
E	smaller for X than Y	same for both models

8 Which one of the following pairs of forces is **not** a valid example of action and reaction to which Newton's third law of motion applies?

A the centripetal force holding a satellite in orbit round the Earth and the weight of the satellite
B the forces of repulsion experienced by each of two parallel wires carrying currents in opposite directions
C the forces of attraction felt by each of two gas molecules passing near to each other
D the forces of attraction between an electron and a proton in a hydrogen atom
E the forces of repulsion between an atom in the surface of a table and an atom in the surface of a book resting on the table

9 All three systems represented as p, q and r in the diagrams below (Fig. 2) show simple harmonic motion.

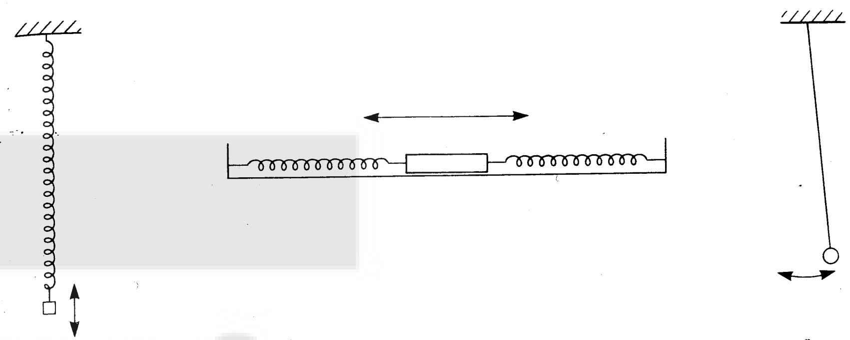


Fig. 2

In which system will the period be independent of the mass of the body?

A p only **B** q only **C** r only **D** p and r only **E** p, q and r

10 Two sources of sound have frequencies f_1 and f_2 respectively, f_1 being slightly greater than f_2. What is the *period* of the beats heard when the sources operate simultaneously?

A $f_1 - f_2$ **B** $1/(f_1 - f_2)$ **C** $2/(f_1 + f_2)$ **D** $(f_1 - f_2)/f_1 f_2$ **E** $2\pi/(f_1 - f_2)$

11 A point source of sound emits energy equally in all directions at a constant rate and a person 8 m from the source listens. After a while, the intensity of the source is halved. If the person wishes the sound to seem as loud as before, how far should he be now from the source?

A 2 m **B** $2\sqrt{2}$ m **C** 4 m **D** $4\sqrt{2}$ m **E** $8\sqrt{2}$ m

12 Which one of the following correctly compares characteristics of travelling and stationary plane waves?

	travelling wave	*stationary wave*
A	no medium required	requires a material medium
B	separation between two adjacent points of corresponding phase is one wavelength	separation between a node and the adjacent antinode is half a wavelength
C	the amplitude of vibration is the same at all points	amplitude of vibration varies with position
D	energy at any point is always kinetic	energy at any point changes from kinetic to potential and back again
E	energy is transported at a speed given by the frequency divided by the wavelength	no net transport of energy

13 The diagram below (Fig. 3) illustrates an experimental arrangement that produces interference fringes with a double slit.

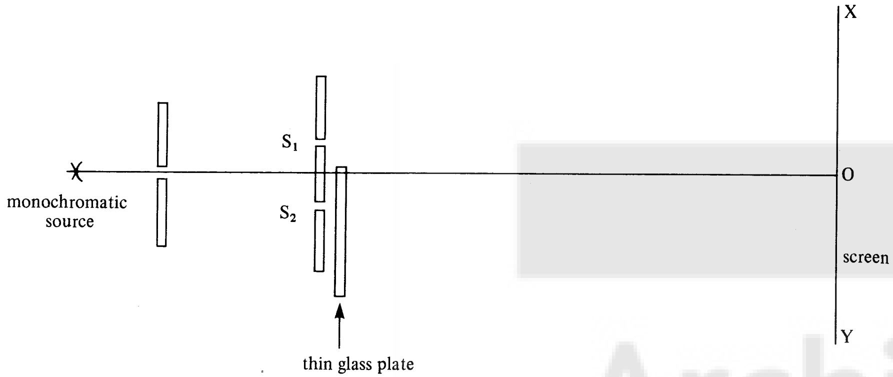


Fig. 3

When slit S_2 was covered with a very thin plate of glass as shown,

A the separation of the fringes increased.
B the separation of the fringes decreased.
C the fringe pattern moved towards X.
D the fringe pattern moved towards Y.
E the separation of the fringes decreased in the region OY but was unchanged in the region OX.

14 A photon of light enters a block of glass after travelling through a vacuum. The energy of the photon on entering the glass block

A increases because its associated wavelength decreases.
B decreases because the speed of the radiation decreases.
C stays the same because the speed of the radiation and the associated wavelength do not change.
D stays the same because the speed of the radiation and its wavelength increase by the same factor.
E stays the same because the frequency of the radiation does not change.

15 The critical angle for light going from medium X into medium Y is θ. The speed of light in medium X is v. The speed of light in medium Y is

A $v(1 - \cos\theta)$
B $v/\cos\theta$
C $v \cos\theta$
D $v/\sin\theta$
E $v \sin\theta$

16 A refracting astronomical telescope has several interchangeable eyepieces. In order to increase the instrument's magnifying power, the operator should replace the eyepiece with another of

A shorter focal length, moving it closer to the objective lens.
B shorter focal length, moving it further from the objective lens.
C shorter focal length, without changing its distance from the objective lens.
D longer focal length, moving it closer to the objective lens.
E longer focal length, moving it further from the objective lens.

17 The room-temperature resistivity of a typical semiconductor is several orders of magnitude greater than that of a typical metal. This is because

A the drift velocity of charge carriers in a semiconductor is very much less than in a metal.
B charge carriers collide with the lattice much more frequently in a semiconductor than in a metal.
C the number density of charge carriers is much less in a semiconductor than in a metal.
D in a semiconductor, the effect of electrons flowing in one direction is almost cancelled by the flow of holes in the other; in a metal, there are only electrons to be considered.
E impurities are deliberately introduced into semiconductors, and these increase the resistivity.

18 Fig. 4 shows the face of a cathode-ray oscilloscope tube, as viewed from in front. The electron beam passes through a region where there are electric and magnetic fields directed as shown. The deflections of the spot from the centre of the screen produced by the electric field E and the magnetic field B separately are equal in magnitude.

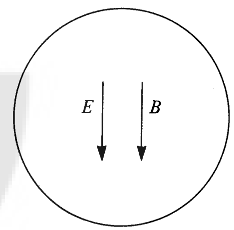
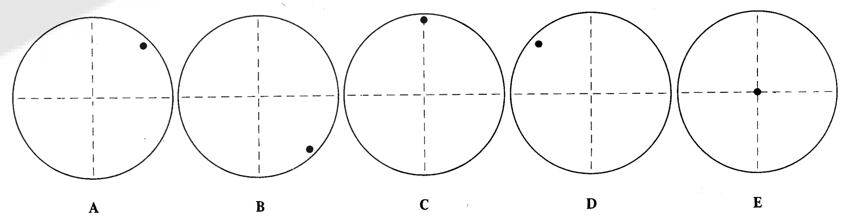


Fig. 4

Which one of the diagrams below shows a possible position of the spot on the screen when both fields are operating?



19 A mutual inductor consists of two coils X and Y as shown in Fig. 5 in which one quarter of the magnetic flux produced by X links with Y, giving a mutual inductance M.

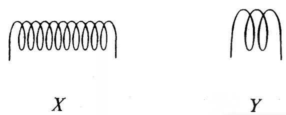


Fig. 5

What will be the mutual inductance when Y is used as the primary?

A $M/4$ **B** $M/2$ **C** M **D** $2M$ **E** $4M$

20 An electric motor driven from a constant voltage supply is used to raise a load. If the load is increased which one of the following sets of changes occurs?

	speed of rotation	*induced e.m.f. in coil (back-e.m.f.)*	*current in coil*
A	decreases	decreases	increases
B	increases	increases	decreases
C	decreases	decreases	decreases
D	increases	decreases	increases
E	decreases	increases	decreases

21 In Fig. 6 below, the point charge Q_1 causes an electric potential of 60 V and an electric field strength of 30 V m^{-1} at P, and the point charge Q_2 separately causes a potential of 120 V and a field strength of 40 V m^{-1} at P.

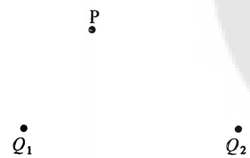
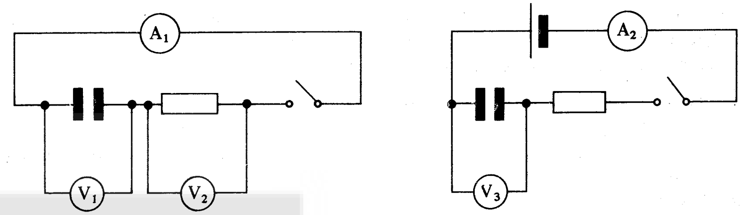


Fig. 6

Which one of the following gives possible values of potential and field strength at P due to the joint action of Q_1 and Q_2.

	potential/V	*field*/V m^{-1}
A	180	70
B	180	50
C	135	50
D	60	10
E	135	10

22



circuit 1 circuit 2

In circuit 1, a charged capacitor discharges when the switch is closed. In circuit 2, an uncharged capacitor is charged when the switch is closed. When the switches are closed, one of the five meters gives a reading θ which varies with time, as shown below (Fig. 7).

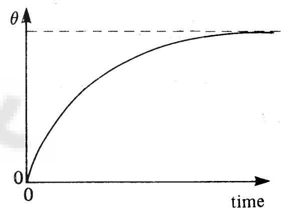


Fig. 7

Which meter records in this way?

A A_1 **B** A_2 **C** V_1 **D** V_2 **E** V_3

23 The current balance at a certain national standards laboratory has a force F between a pair of parallel coils (whose separation is constant) when a direct current of one ampere flows in each coil. The direct current is replaced by a sinusoidal alternating current which is adjusted to give a mean force equal to F. What is the r.m.s. current?

A 0·5 A **B** $\frac{1}{\sqrt{2}}$ A **C** 1 A **D** $\sqrt{2}$ A **E** 2 A

24 In an ideal transformer, the most important function of the soft-iron core is

A to reduce eddy currents.
B to improve the flux-linkage between the primary and secondary coils.
C to dissipate the heat generated by the two coils.
D to eliminate the back e.m.f. produced in the secondary.
E to produce a uniform radial field in the two coils.

25 An advantage of the platinum resistance thermometer is that

A it may be used to measure rapidly changing temperatures.
B it has a linear scale, because the resistance of a piece of platinum varies directly as thermodynamic temperature.
C it may be used to measure steady temperatures with very high accuracy.
D it absorbs energy from its surroundings very slowly so that it does not disturb the condition of the body under test when placed in contact with it.
E it is the only type of thermometer that can measure accurately temperatures over 3000 K.

26 The values of pV, the product of pressure and volume, used in the determination of thermodynamic temperature with a gas thermometer are those in which actual measurements have been extrapolated to zero pressure. This procedure is followed because

A measurements of p and V are more accurate at low pressure.
B extrapolating helps to eliminate errors made in measuring p and V.
C it was found that temperatures so defined agreed with the established centigrade temperature scale.
D it is impossible to make measurements at O K.
E at near zero pressure all gases behave ideally.

27 The behaviour of many real gases deviates from $pV_m = RT$ but can be represented quite closely over certain ranges of temperature and pressure by an equation of the form

$$\left(p + \frac{a}{V_m^2}\right)(V_m - b) = RT$$

in which the values of a and b are characteristic of the particular gas.

What are the units of a and b?

	a	b
A	Pa m^{-6} mol^2	m^3 mol^{-1}
B	Pa m^6 mol^{-2}	m^{-3} mol
C	Pa m^{-6} mol^2	m^{-3} mol^{-1}
D	Pa m^6 mol^{-2}	m^3 mol^{-1}
E	none because they are dimensionless constants	

28 A capillary tube closed at one end contains a column of dry air which is trapped by a thread of mercury (see Fig. 8).

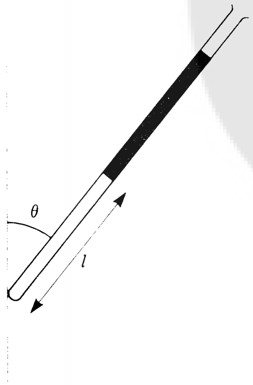
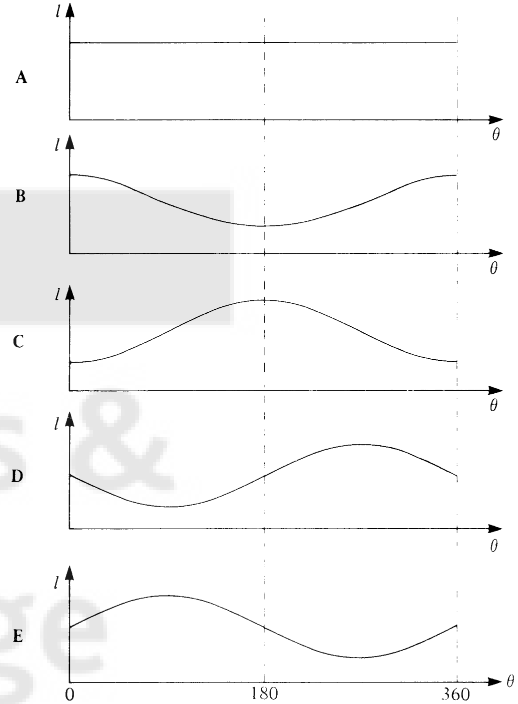


Fig. 8

Which one of the following diagrams shows the variation of the length l of the air column with the angle $\theta°$ of the tube to the vertical?



29 One mole of an ideal gas is heated at constant pressure p. Given that this results in an increase of volume ΔV accompanied by an increase of temperature ΔT, the amount of heat supplied was

A $p\Delta V$
B $C_{V,m}\Delta T$
C $C_{V,m}\Delta T + p\Delta V$
D $C_{p,m}\Delta T - p\Delta V$
E $p\Delta V/V$

30 A fixed mass of gas undergoes the cycle of changes represented by PQRSP as shown in Fig. 9 below. In some of the changes, work is done *on* the gas and, in others, work is done *by* the gas.

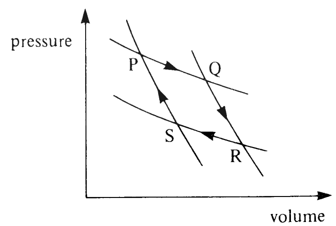


Fig. 9

In which pair of the changes is work done *on* the gas?

A PQ and RS
B PQ and QR
C QR and RS
D QR and SP
E RS and SP

31 A fixed mass of gas in a thermally insulated container is compressed. After compression, the temperature of the gas will have

A fallen, since more molecules bombard the container and so they must be moving slower.
B fallen, since the molecules collide more frequently with one another and so their average speed is lower.
C remained constant if the compression is very slow.
D risen, since doing work on the gas increases the kinetic energy of the molecules.
E risen, since there are more intermolecular collisions and so more heat is produced by them.

32 Fig. 10 below shows a thin resistance wire MN which is attached to large copper supports and which is heated by an electric current flowing in the direction shown.

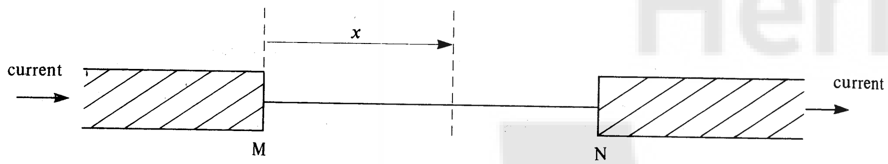
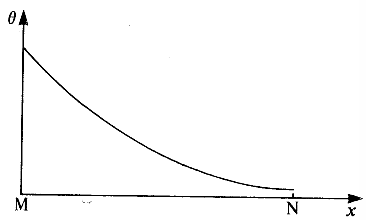
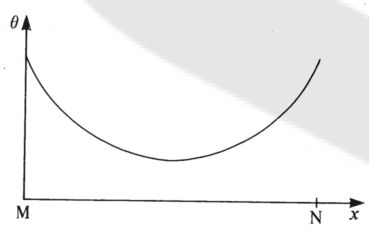


Fig. 10

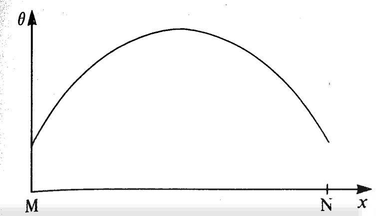
Assuming that heat loss occurs predominantly through the ends of the wire, which one of the following graphs best represents the variation of the steady state temperature θ along the wire MN as a function of the distance x measured from M?



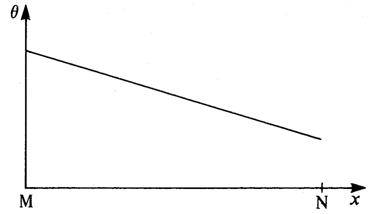
A



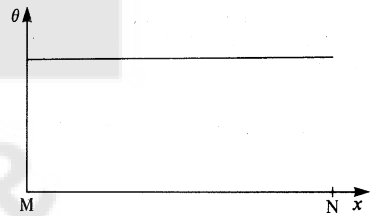
B



C



D



E

33 The minimum energy to ionise an atom is the energy required to

A add one electron to the atom.
B excite the atom from its ground state to its first excited state.
C remove one outermost electron from the atom.
D remove one innermost electron from the atom.
E remove all the electrons from the atom.

34 Bombardment of a certain material with α-particles produces an emission which penetrates lead, ejects protons from paraffin wax, and travels at speeds up to 5×10^7 m s^{-1}. What does this emission consist of?

A neutrons **B** α-particles **C** β-particles **D** X-rays **E** ultra-violet light

35 What is the relationship between the decay constant λ and the half-life $t_{\frac{1}{2}}$ of a radioactive isotope?

A $\lambda = t_{\frac{1}{2}}$
B $\lambda = 1/t_{\frac{1}{2}}$
C $\lambda = t_{\frac{1}{2}} \ln 2$
D $\lambda = (\ln 2)/t_{\frac{1}{2}}$
E $\lambda = \dfrac{1}{t_{\frac{1}{2}} \ln 2}$

36 Which one of the following statements is true of both α-particles and X-rays?

A They cause ionisation of the air when they pass through it.
B They can be detected after passing through a few millimetres of aluminium.
C They can be deflected by electric fields.
D They can be deflected by magnetic fields.
E They are used industrially for the photographic detection of flaws in metal castings.

37 A stationary thoron nucleus ($A = 220$, $Z = 90$) emits an alpha particle with kinetic energy E_α. What is the kinetic energy of the recoiling nucleus?

A $\frac{E_\alpha}{108}$ **B** $\frac{E_\alpha}{110}$ **C** $\frac{E_\alpha}{54}$ **D** $\frac{E_\alpha}{55}$ **E** E_α

38 The temperature of 1 kg of hydrogen gas is the same as that of 1 kg of helium gas if

A the gases have the same internal energy.
B the gases radiate energy at the same rate.
C the gas molecules have the same root mean square speed.
D the gas molecules have the same mean translational kinetic energy.
E the gas molecules occupy equal volumes.

39 In Fig. 11 below, E_1 to E_6 represent some of the energy levels of an electron in the hydrogen atom.

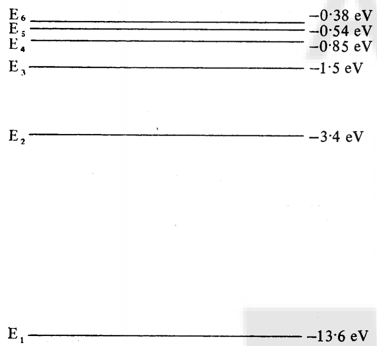


Fig. 11

Which one of the following transitions produces a photon of wavelength in the ultra-violet region of the electromagnetic spectrum?

[1 eV = $1{\cdot}6 \times 10^{-19}$ J.]

A $E_2 \rightarrow E_1$ **B** $E_3 \rightarrow E_2$ **C** $E_4 \rightarrow E_3$ **D** $E_5 \rightarrow E_4$ **E** $E_6 \rightarrow E_5$

40 In Fig. 12 below, a wire is subjected to a gradually increasing force F, which causes an extension e. The way in which e depends on F is shown by the line OP. The force is then gradually reduced and the relation between e and F in this case is shown by the line PQ.

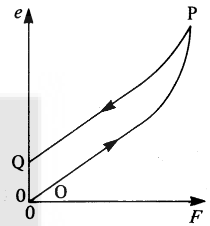
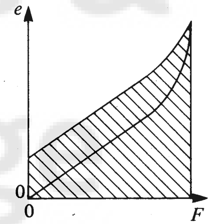
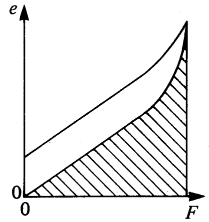


Fig. 12

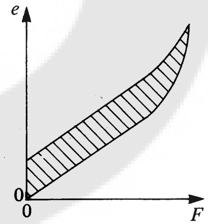
Which one of the shaded areas in the graphs below correctly represents the mechanical energy that can be *recovered* from the wire in this process?



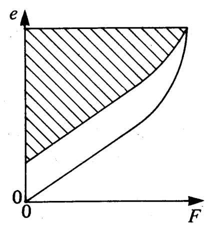
A



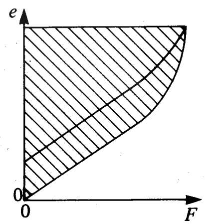
B



C



D



E

PHYSICS **9240/3**

ADVANCED LEVEL

PAPER 3

(One and a half hours)

Attempt **three** *questions.*

For numerical answers, **all** *working should be shown.*

Mathematical tables, a data leaflet and squared paper are available.

The intended marks for questions or parts of questions are given in brackets [ ].

1 Explain the meaning of (*a*) *displacement*, (*b*) *acceleration*. Define *simple harmonic motion* in terms of these quantities. *[4]*

A mass m is suspended by a light helical spring of force constant k (the force required per unit extension). Show that the mass can perform vertical simple harmonic oscillations.

Find expressions for the frequency of oscillation in terms of

(*c*) m and k,

(*d*) g, the acceleration of free fall, and e, the extension of the spring when the mass hangs in equilibrium. *[5]*

A small γ-emitting radioactive source is fixed to a loudspeaker diaphragm. This vibrates in simple harmonic motion at a frequency of 10 000 Hz with an amplitude of 1×10^{-5} m. Material which absorbs γ-rays of the same frequency as those emitted by the stationary source is placed in front of the speaker. This resonant absorption takes place over a very narrow range of frequencies. Explain how the Doppler effect accounts for the fact that γ-rays will pass through the absorber when the loudspeaker diaphragm is in motion. *[2]*

Calculate

(*e*) the maximum speed v_{max} of the diaphragm,

(*f*) the fractional change in frequency of the γ-rays at the absorber, $(f'-f)/f$, when the diaphragm is moving at this speed directly towards the absorber.

Sketch a graph to show how the intensity of the transmitted γ-radiation is likely to vary with the displacement of the speaker diaphragm. *[7]*

2 Describe an experiment to measure the maximum energy of photoelectrons emitted from a metal. With the aid of a sketch graph, summarise the results of such experiments with light of different frequencies and with different metals. Show how a value of the Planck constant may be deduced from the results, and explain how simple wave theory fails to account for them. *[10]*

Outline an experiment to demonstrate the phenomenon of electron diffraction. Summarise the results of such experiments with electrons of various speeds. State the de Broglie relationship, and explain how simple particle theory fails to account for this relationship. *[5]*

A certain electron stream and an X-ray beam produce identical diffraction patterns when they interact with the same object. Deduce an expression for the potential difference V required to accelerate the electrons from rest in terms of the wavelength of the X-ray beam, the charge and mass of the electron, and the Planck constant. *[3]*

3 Describe how a long metal wire and a metre rule may be used with other common laboratory items to compare two resistances. Deduce an expression relating the resistances to the quantities measured. *[6]*

Given that lengths on the rule can be measured to an accuracy of $\pm 0{\cdot}3$ mm, calculate the maximum uncertainty this may cause in the measurement of the ratio of two resistances when this ratio is approximately 2. Express your result (*a*) as a percentage error, (*b*) as an actual error in the ratio. *[6]*

Such accuracy is unlikely to be achieved in practice with simple apparatus. Suggest **two** significant causes of *systematic* error, and explain how their effects might be reduced. *[6]*

4 Explain what is meant by the *capacitance* of (*a*) an isolated conductor, (*b*) a parallel-plate capacitor. *[2]*

Derive an expression for the capacitance of two capacitors of capacitance C_1 and C_2 connected in series. *[4]*

Explain, in terms of electron flow, how a capacitor can

(*c*) offer infinite resistance to direct current, but

(*d*) allow alternating current to pass when an alternating e.m.f. is applied. *[3]*

A 100 W lamp designed for use on a 110 V mains may be operated on a 50 Hz 240 V a.c. mains supply by using a series resistor. Calculate

(*e*) the resistance required. *[2]*

Alternatively, a capacitor may be used instead of the resistor. Draw and label a phasor diagram relating the potential differences across the capacitor, the lamp, and the supply. Calculate, for the capacitor required,

(*f*) the root-mean-square potential difference across it,

(*g*) its reactance,

(*h*) its capacitance. *[7]*

[You may assume that the lamp has negligible inductance.]

5 Write down an expression for the force between two long parallel current-carrying conductors. Define the *ampere*. Show how this definition is equivalent to fixing the value of μ_0. *[4]*

Draw a labelled diagram to show the essential features of a moving-coil meter. Explain how a linear scale may be achieved. *[3]*

Deduce an expression for the angular current sensitivity, θ/I, of such a meter in terms of the flux density B, the number of turns N, and their mean area A, given that a torque (or couple) C is needed to rotate the coil through an angle θ of one radian. *[4]*

Two such meters, P and Q, differ from each other only in that P has eight times as many turns as Q and the resistance of P is twenty times that of Q. They are connected in turn to a thermocouple of negligible resistance to detect its e.m.f. Determine the ratio of the meter deflections, θ_P/θ_Q. *[4]*

Discuss which of these instruments is the more suitable for measuring a small e.m.f. from a source of (*a*) low resistance, (*b*) high resistance. *[3]*

6 Explain the meaning of the words in *italics* in the following statement. The nuclide $^{90}_{38}$Sr is a β^- *emitter* of *half-life* 28 years but the nuclide $^{238}_{94}$Pu emits two groups of *α-particles* which differ in energy by 0·045 MeV. Explain the significance of the symbols in $^{238}_{94}$Pu. [*5*]

Express the energy difference in joules and calculate the mass of this energy. [*2*]

Discuss how mass is conserved in the two types of plutonium (Pu) disintegration, despite there being this difference in the energies of the α-particles produced. [*3*]

If a ^{90}Sr source emits many β^- particles in one second today, how long will it take it to emit the same number of β^- particles in the year 2040 A.D.? [*3*]

In what year will the source take the whole year to emit the same number of β^- particles as it emits in one second today? [*5*]

PRACTICAL PHYSICS **9240/4**

ADVANCED LEVEL

(ALTERNATIVE A)

(*Three and a quarter hours*)

Answer Question **1** *and* **one** *other question.*

You will not be allowed to start work or write for the first fifteen minutes.

Squared paper and mathematical tables, including reciprocals, are available.

You are expected to record all your observations as soon as these observations are made and to plan the presentation of the records so that it is not necessary to make a fair copy of them.

The working of the answers is to be handed in.

Details on the question paper should not be repeated in the answer, nor is the theory of the experiment required unless specifically asked for. You should, however, record any special precautions you take and any particular features of your methods of going about the experiments.

Marks are given mainly for a clear record of the observations actually made, for their suitability and accuracy, and for the use made of them.

Provision has been made in the question paper for you to record your observations and readings and for you to plot the graphs required. Additional answer paper and graphs should be submitted **only** *if it becomes* **necessary** *to do so.*

1 In this experiment you will make a set of equal masses and use them to deduce the buckling load of a strut, and a value of *E*, the Young Modulus of the material of the strut.

Procedure

(*a*) As opportunity offers, measure *d*, the diameter of the given rod. Record your readings on page 4.

(*b*) Take the lump of plasticine (of known mass) and, moulding it suitably, divide it as nearly as you may judge, into six equal portions. Mark these A, B, C, D, E, F for future identification.

(*c*) Clamp the rod horizontally, as in Fig. 1.1, and fasten a short length of thread to the free end.

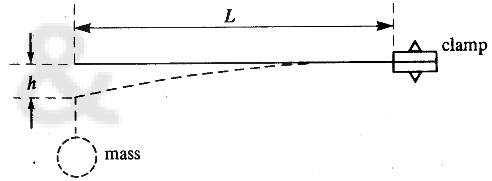


Fig. 1.1

Measure (and record on page 4) *L*, the free length of the rod. Suspend from the thread each of the masses A, B, C, D, E, and F, in turn: record, on page 4, the depression, *h*, of the free end.

By reference to your values of *h*, adjust the masses to make them as nearly equal as you can. On page 4, record the final depression produced by each adjusted mass.

(*d*) Turn the clamped rod so that it is vertical, with its free end UP, as in Fig. 1.2.

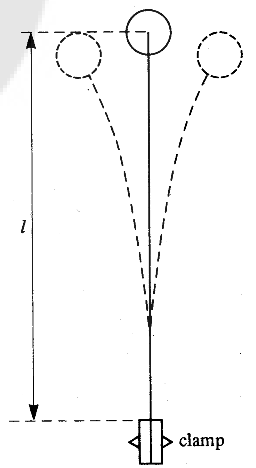


Fig. 1.2

Mould one of the masses around the free end and measure l, the distance from the clamp face to the centre of gravity of the mass. Measure f, the frequency of sideways oscillation of the mass when displaced horizontally.

Add a second mass, moulding the two together so that l has the same value as before. Measure the frequency for the new mass M. Repeat, adding the masses one at a time until all the masses are used in one large lump.

Record your readings on page 4, including in your tabulation values of M and f. Also record the type of device you use for your timing.

(*e*) On page 5, plot a graph of frequency against mass.

Record of readings to measure d, the diameter of the given rod

Record of L, the free length of the rod

Record of type of timing device used

Record of initial depressions h of unstandardised masses

Record of depressions h of standardised masses

Record of readings for l, M and f

(*f*) Extrapolate the lower part of the graph to find M_0, the value of M for which f is zero.

(*g*) Calculate a value of E, the Young Modulus, defined by the equation:

$$E = \frac{5.12\, M_0 g l^2}{\pi^3 d^4}$$

where g is the acceleration of free fall. [Take g to be 9·80 ms^{-2}].

2 In this experiment you will measure the atmospheric pressure by observing the behaviour of the vapour of a volatile liquid in an enclosed space.

Procedure

(*a*) The given capillary tube contains a bead of mercury some 100 mm long, trapping a short length of the volatile liquid and an air space saturated with the vapour of the liquid. Fasten the tube to the half-metre rule and arrange the whole so that (i) it may be supported at different angles to the vertical, (ii) measurements may be made of the following quantities: θ, the angle to the vertical; h, the length of the bead of mercury; a, the length of the saturated air space; l, the length of the column of the liquid. See Fig. 2.1.

Measure (and record on page 10) t, the air temperature.

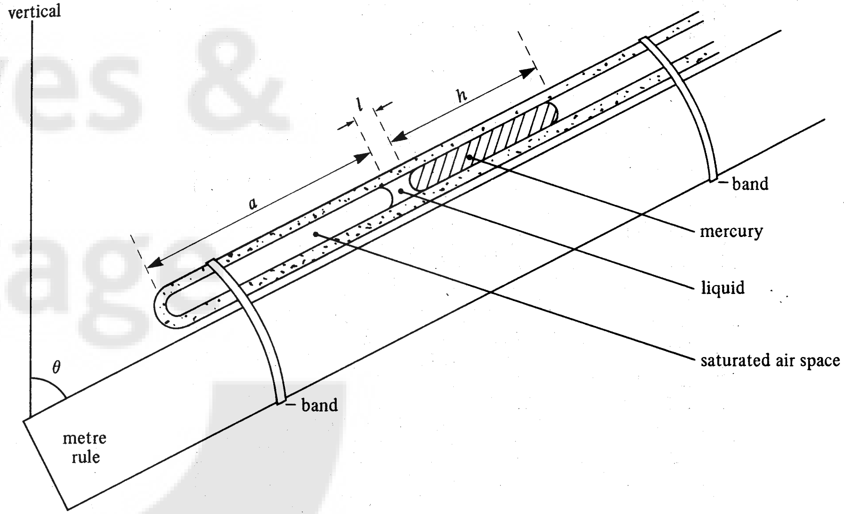


Fig. 2.1

(*b*) Starting with the tube vertical ($\theta = 0°$) and the open end uppermost, measure sets of values of the angle θ, and the lengths h, l, and a, in that order, for values of θ from 0° to 180°. Record your readings on page 10.

(*c*) From your readings, tabulate a^{-1} and $\cos\theta$. (N.B. $\cos(180° - \theta) = -\cos\theta$.)

On page 11, plot a graph of a^{-1} against $\cos\theta$. From it, deduce a value of m, the gradient of the line, and read off c, the intercept on the a^{-1} axis. Record these values on page 9.

(*d*) Calculate $\langle h \rangle$, the average value of h.

Record of values of c and m.

Hence calculate a value of p_1, given that $p_1 = c\langle h \rangle \rho g/m$, where the product ρg has the value in this experiment of $0{\cdot}133$ kPa mm^{-1} and $\langle h \rangle$ is expressed in mm.

(*e*) From the graph in Fig. 2.2, read off the value of p_v, the saturated vapour pressure of the liquid at the temperature t of your experiment.

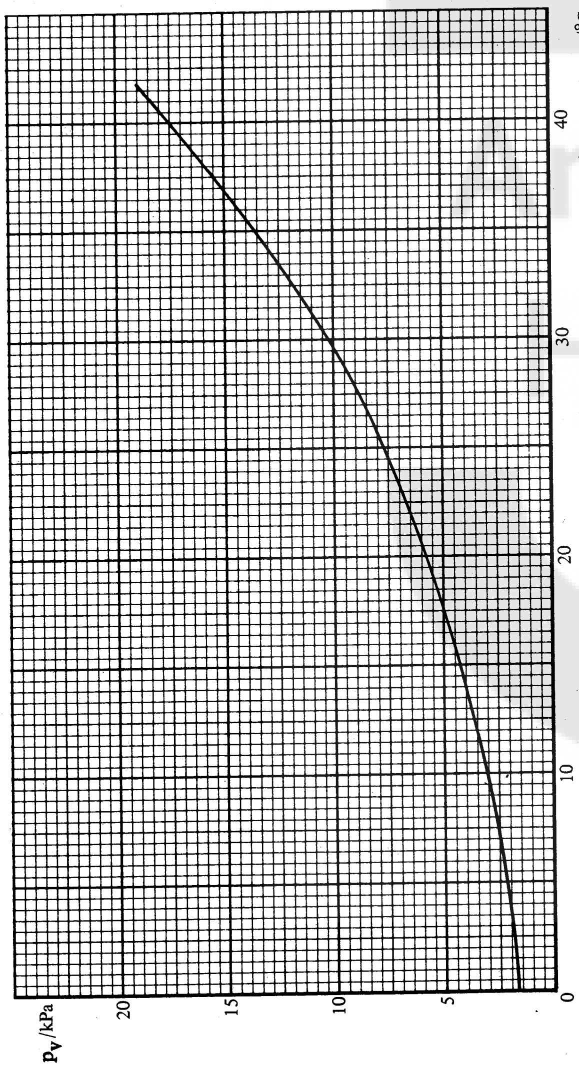


Fig. 2.2

Calculate a value of the atmospheric pressure, p_o, given that

$$p_o = p_1 + p_v.$$

Record of air temperature t

Records for: θ; h; l; a; a^{-1}; $\cos\theta$

3 In this experiment you will determine the resistance per unit length of wire A and the resistivity ρ of the metal of wire W.

(*a*) As opportunity offers, measure the diameter, d, of the wire W. Record your readings opposite on page 13. Also record opposite the air temperature at the start and at the end of the experiment and the value of the e.m.f. of the cell provided.

(*b*) Set up the circuit in Fig. 3.1, and use it to determine r, the resistance per unit length of wire A. In this circuit, B is a fixed resistor with its resistance shown on its label.

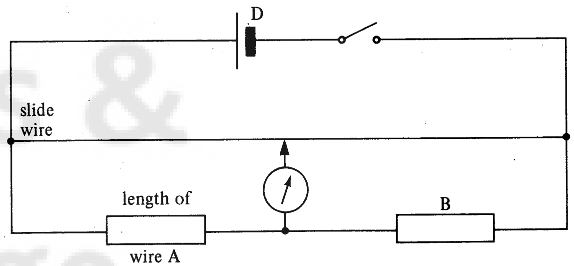


Fig. 3.1

You are advised to use as long a length of A as is practicable. Record your readings and result on page 13.

(*c*) Set up the circuit in Fig. 3.2.

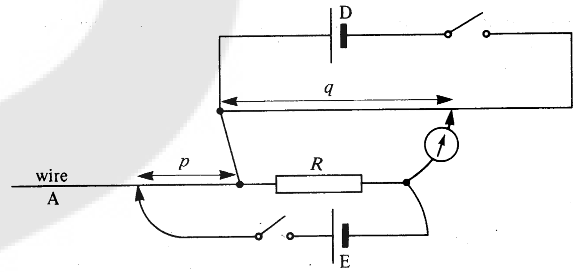


Fig. 3.2

The fixed resistance R is formed by connecting into the circuit a $0{\cdot}500$ m length of wire W. A variable series resistor is formed by connecting into the circuit different lengths, p, of wire A. Start by connecting about a metre of A into circuit and find q, the balance length. Record, on page 14, values of p and of q as p is decreased to about $0{\cdot}1$ m. Tabulate your results on page 14, together with values of q^{-1}.

(*d*) On page 15, plot a graph of q^{-1} against p.

(*e*) On page 14, calculate m, the gradient of the line, and read off c the intercept on the q^{-1}-axis.

Also calculate the value of the resistivity, ρ, given that

$$\rho = \frac{\pi d^2 cr}{2m},$$

where r is the resistance per unit length of A.

Record of readings for the diameter, d, of wire W

Records of air temperature at beginning and end of the experiment

Record of e.m.f. of cell provided

Records of readings for determining r, the resistance per unit length of wire A

Calculation of r

Records of p, q, q^{-1}

Records for gradient m and intercept c of the graph on page 15

Calculation of resistivity ρ of wire W *from* $\rho = \dfrac{\pi d^2 cr}{2m}$