Cambridge Assessment

A Level

Physics

Session: 1974 June
Type: Question paper
Code: 861

PHYSICS 861/1

ADVANCED LEVEL

PAPER 1

(Two hours and a half)

Candidates must answer **five** *questions, including at least* **one** *from* **each** *section.*

Mathematical tables and squared paper are available.

Marks indicate the relative credit given for the various parts of the questions.

N.B. In tables of data in this question paper, the *italic* symbol for a physical quantity may be separated by an oblique from other letter symbols in upright type, e.g. time, t/s. The symbols in upright type indicate the units in which the quantity is expressed, e.g. time, t, in seconds.

SECTION A

1 (*a*) Fig. 1 shows a metric micrometer.

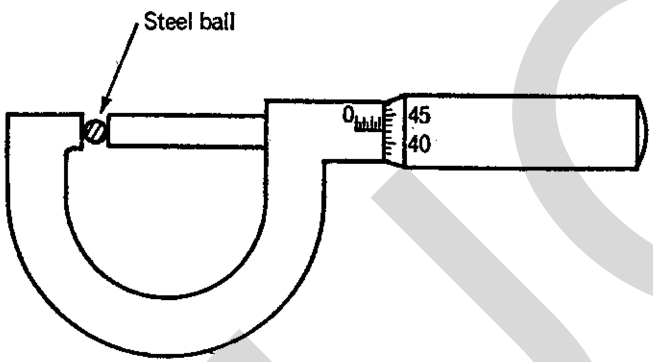

Fig. 1

(i) What is the reading on the micrometer scale? [2 *marks*]

(ii) What precautions would you take in using the micrometer to measure the diameter of the ball? Explain the reason for each. [6 *marks*]

(*b*) You are given a travelling microscope, a balance and some mercury. Explain how you would

(i) investigate the uniformity of the bore, [2 *marks*]

(ii) find the average diameter, [4 *marks*]

of a long, glass capillary.

The travelling microscope may be read to ± 0·1 mm. Discuss whether it would be possible to use this apparatus to detect a variation of 1 % in the diameter of the tube between two points 25 mm apart. [6 *marks*]

2 What quantities are conserved in (*a*) elastic, (*b*) inelastic, collisions? If any quantity is *not* conserved in either of these cases, explain what happens to it. How would you recognise that a head-on collision between two particles of the same mass moving with the same speed was fully inelastic? [7 *marks*]

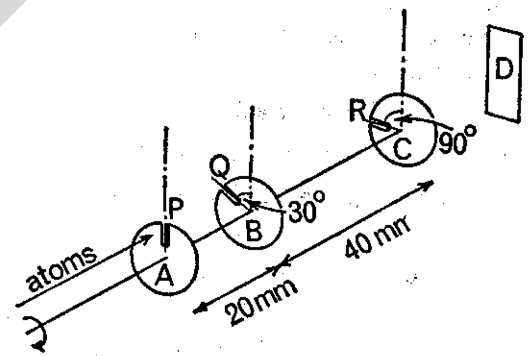

Fig. 2

In Fig. 2, the discs A, B, C are mounted on a common axle which rotates in a clockwise direction: P, Q, R are slits cut in the discs. A beam of atoms moving parallel to the axis with a range of speeds is incident at A. All atoms emerging from R are condensed on the plate D.

(i) At what speed must the discs rotate if all the atoms emerging from R do so with a speed of 250 m s^{-1}? [5 *marks*]

(ii) Why are *three* discs used? [3 *marks*]

(iii) The mass of D was initially 2·000 g. After exposure to the atomic beam for 600 s, the mass of the plate and condensed atoms was 2·012 g. What force did the beam exert on D? [5 *marks*]

3 Give brief descriptions of experiments to demonstrate what is meant by (*a*) *terminal velocity*, (*b*) *turbulence*. [9 *marks*]

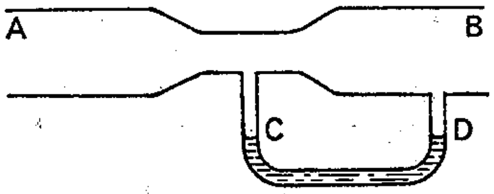

Fig. 3

Fig. 3 represents a device used to measure the rate of flow of a gas through the pipe AB. The flow causes a difference in the manometer levels at C and D. This is an example of the Bernoulli effect.

(*c*) What is the *Bernoulli effect*? [3 *marks*]

(*d*) How does it apply in this device? [2 *marks*]

(*e*) Which level will be the higher when gas flows from A to B? [1 *mark*]

(*f*) Explain how the levels depend on the rate of flow. [3 *marks*]

(*g*) What would happen if the direction of flow were reversed? [2 *marks*]

4 Explain what is meant by the *Young modulus*, the *elastic limit*, *yield point* and *breaking point*, of a wire. [6 *marks*]

Sketch the apparatus you would use to measure the Young modulus of a steel wire. [2 *marks*]

What readings would you take, and how would you calculate the result from them? [5 *marks*]

Calculate suitable values for the other quantities involved

if the cross-sectional area were about 0·5 mm². [4 *marks*]

It is sometimes stated that, in such an experiment, it is desirable to use a reference wire to eliminate the effects of thermal expansion. Discuss whether it is appropriate to take this precaution for the reason stated. [3 *marks*]

[Take $g = 10\ \mathrm{m\ s^{-2}}$. Use the following approximate values for steel: the Young modulus $= 2 \times 10^{11}\ \mathrm{N\ m^{-2}}$; elastic limit $= 1 \times 10^{9}\ \mathrm{N\ m^{-2}}$. If the temperature of 1 m of steel wire were increased by 1 K, its length would increase by approximately 1×10^{-5} m.]

SECTION B

5 Explain what is meant by the statement that two bodies are at the same temperature. [3 *marks*]

Define the *kelvin*. [2 *marks*]

How does temperature feature in the molecular model of a gas? [3 *marks*]

Explain how a scale of temperature may be set up using a temperature-dependent property of a substance. [3 *marks*]

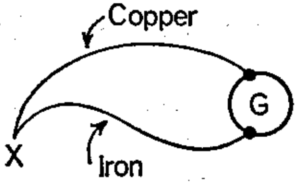

Fig. 4

Fig. 4 shows a simple thermoelectric thermometer. With junction X at room temperature, there is no deflection on the meter. When junction X is placed successively in melting ice and in the steam above boiling water, the deflections are +12·5 and −73·0 divisions respectively.

(*a*) Why is there a deflection when X is immersed in melting ice, and why is the deflection in the opposite direction when X is placed in steam? [2 *marks*]

(*b*) If the readings quoted above are used to define a centigrade scale of temperature, find room temperature on this scale. [2 *marks*] (*c*) Explain why this value does not agree exactly with room temperature as measured with a mercury thermometer. [2 *marks*]

(*d*) Discuss qualitatively whether you would expect to obtain the same readings in ice and steam as those above if the experiment were carried out with much thinner wires. [3 *marks*]

6 Explain why there is a difference between the heat capacity of a mass m of gas measured at constant pressure and at constant volume. Derive an expression relating this difference to the gas constant R and the mass of one mole M_m for an ideal gas. Name a consistent set of units for the quantities involved. [8 *marks*]

A sample of an ideal gas, originally occupying a volume of $3{\cdot}0 \times 10^{-3}\ \text{m}^3$ at 17 °C, was subjected to the following changes.

A The temperature was increased to 27 °C at constant pressure. The heat required was 20·5 J.

B The temperature was reduced to the original value of 17 °C, the volume remaining constant. The heat given out was 14·6 J.

C The gas then underwent a slow adiabatic compression until its volume was $2{\cdot}0 \times 10^{-3}\ \text{m}^3$.

(*a*) Illustrate these processes on a sketch graph of pressure against volume. [3 *marks*]

(*b*) Find the ratio, γ, of the specific heat capacity of the gas at constant pressure to that at constant volume. [2 *marks*]

(*c*) What was the volume of the gas at the end of *A*? [3 *marks*]

(*d*) What was the temperature of the gas at the end of *C*? [4 *marks*]

7 Explain the *principle* of an experiment to measure the thermal conductivity of a metal. [3 *marks*]

Draw a labelled diagram of the apparatus and list the quantities to be measured. [6 *marks*]

Show how the thermal conductivity would be calculated from these readings. [2 *marks*]

A theory suggests that the thermal conductivity λ and the electrical conductivity σ of a metal at temperature T are related by

$$\lambda = \frac{\pi^2 k^2 \sigma T}{3e^2}.$$

Values of λ and σ for a number of metals at temperatures T are tabulated below:

Metal	T/K	λ/W m^{-1} K^{-1}	σ/Ω^{-1} m^{-1}	σT/K Ω^{-1} m^{-1}
Tin	373	60	$0{\cdot}63 \times 10^7$	$2{\cdot}4 \times 10^9$
Nickel	273	91	$1{\cdot}64 \times 10^7$	$4{\cdot}5 \times 10^9$
Rhodium	273	152	$2{\cdot}33 \times 10^7$	$6{\cdot}4 \times 10^9$
Aluminium	273	238	$4{\cdot}08 \times 10^7$	$11{\cdot}1 \times 10^9$
Gold	373	310	$3{\cdot}52 \times 10^7$	$13{\cdot}1 \times 10^9$
Copper	273	385	$6{\cdot}41 \times 10^7$	$17{\cdot}5 \times 10^9$
Silver	273	418	$6{\cdot}62 \times 10^7$	$18{\cdot}1 \times 10^9$
Silver	373	417	$4{\cdot}70 \times 10^7$	$17{\cdot}5 \times 10^9$

(*a*) Using a graphical method, or otherwise, investigate the extent to which these figures support the proposed relation. [7 *marks*]

(*b*) Suggest a reason for the observation that, at a given temperature, a metal with a high electrical conductivity also has a high thermal conductivity. [2 *marks*]

[$k = 1{\cdot}38 \times 10^{-23}$ J K^{-1}; $e = -1{\cdot}60 \times 10^{-19}$ C.]

Section C

8 (*a*) Use the principle of superposition of waves to explain what happens when two sound waves of frequency 254 Hz and 256 Hz produce beats. [4 *marks*]

(*b*) Describe how you would use a cathode ray oscilloscope and associated apparatus to demonstrate your answer to (*a*) above. [3 *marks*]

Sketch the traces which would be observed on the screen. [3 *marks*]

How you would measure the frequencies of the waves? [3 *marks*]

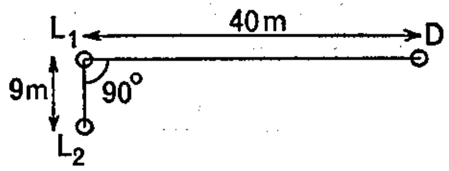

Fig. 5

(*c*) Two loudspeakers L_1, L_2, driven from a common oscillator and amplifier, are set up as shown in Fig. 5. A detector is placed at D. It is found that, as the frequency of the oscillator is gradually increased from zero, the detected signal passes through a series of maxima and minima. Explain this, and find the frequency at which the first maximum is observed. [7 *marks*]

[Speed of sound = 330 m s^{-1}.]

9

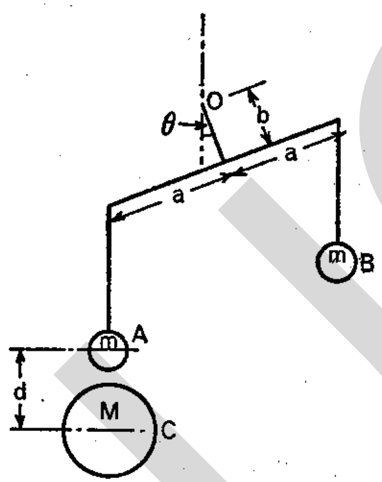

Fig. 6

Fig. 6 illustrates a possible method for determining the gravitational constant G. Two spheres A and B each of mass

m hang from the arms of a beam balance, which pivots about the point O. Another sphere C of mass M is placed under A, and, in the new equilibrium position, the beam is deflected through an angle θ, when the centres of A and C are d apart. The mass of the beam may be neglected in comparison with m.

(*a*) When the balance is in equilibrium, what is the moment about O of the gravitational attraction between A and C? [4 *marks*]

(*b*) Explain qualitatively why there is an equilibrium position. [4 *marks*]

(*c*) The quantities d and θ might be about 300 mm and a few seconds of arc respectively. Suggest methods by which they might be measured. [5 *marks*]

In a calibration experiment, C is removed and the mass m' is found which, when added to A, produces the same deflection θ.

(*d*) Show that $G \approx m'gd^2/(Mm)$. [2 *marks*]

(*e*) This expression is inaccurate because no account has been taken of the attraction between B and C. If $d \approx 300$ mm and $2a \approx 400$ mm, estimate the percentage error in G which is introduced by neglecting this attraction. [5 *marks*]

[$\approx$ means 'approximately equal to'.]

10 Give a brief description of evaporation in terms of a molecular model, and discuss the extent to which it provides a good analogy for thermionic emission of electrons. [7 *marks*]

Electrons may also be ejected from a metal by photo-electric emission. Discuss whether you would expect there to be an analogous process of photon-induced emission of *molecules* from a liquid. [3 *marks*]

Draw the following labelled sketch graphs:

(*a*) two curves of current versus p.d. in a thermionic diode, one showing *space-charge limitation* and the other *saturation*; [4 *marks*] (*b*) two curves of current versus p.d. in a vacuum photoemissive cell, one for illumination by monochromatic light of wavelength λ_1, and the second for light of wavelength λ_2, where λ_1 is greater than λ_2;

(Include positive and negative p.d's.) [4 *marks*]

(*c*) a curve of current versus light intensity in a vacuum photoemissive cell, the applied p.d. remaining constant. [2 *marks*]

[No explanation of the shapes of the curves is required.]

PHYSICS 861/2

ADVANCED LEVEL

PAPER 2

(*Two hours and a half*)

Candidates must answer **five** *questions, including at least* **one** *from* **each** *section.*

Mathematical tables and squared paper are available.

Marks indicate the relative credit for the various parts of the questions.

N.B. In tables of data in this question paper, the *italic* symbol for a physical quantity may be separated by an oblique from other letter symbols in upright type, e.g. time, t/s. The symbols in upright type indicate the units in which the quantity is expressed, e.g. time, t, in seconds.

SECTION A

1 What do you understand by the *magnifying power* of an optical system? Consider the cases where the object is (*a*) distant, and (*b*) very close. [4 *marks*]

Derive a formula for the magnifying power of a simple hand lens of focal length f when the final image is very distant. [4 *marks*]

Why are large magnifying powers unobtainable from a

single lens? [2 *marks*]

A camera with a lens of focal length 5·0 cm is used to take a colour slide of a distant scene. The slide is viewed with the naked eye from a distance of 25 cm. What overall magnifying power is obtained? [4 *marks*]

By examining the slide through a hand lens, it is possible to achieve an overall magnifying power of unity. Describe how this may be done and calculate the focal length of the lens required if the final image is to be

(*c*) 25 cm from the eye, [3 *marks*]

(*d*) very distant. [3 *marks*]

2 Draw a ray diagram to illustrate the functions of the optical components of a spectrometer, showing the passage of red and blue light. [10 *marks*]

In a Young's double slit experiment, monochromatic light of 600 nm wavelength produces fringes 0·75 mm apart on a screen 25 cm away. A diffraction grating, with elements separated by the same distances as the double slits, is placed on the table of a spectrometer and illuminated with light of the same wavelength at normal incidence. Through what angle would the telescope have to be turned for the zero order maximum to be replaced on the cross-wires by the first order maximum?

How would you attempt to identify the zero order maximum if the various orders were very close together? [10 *marks*]

3 Describe an accurate, terrestrial method of measuring the speed of light. Show clearly how the result is calculated from the observations actually made.

Explain how light may be refracted at an interface and deduce a formula relating the angles involved and the speeds of light in the media. [12 *marks*]

Lenses are often coated with a thin film of fluorite to reduce surface reflection: light reflected at the air/fluorite interface is made to interfere destructively with that reflected at the fluorite/glass interface. Discuss the factors that determine the thickness of the film. Calculate a suitable value for the thickness. Why do coated lenses often seem to be purple in colour? [8 *marks*]

[Refractive index of fluorite = 1·4; speed of light in air = $3{\cdot}0 \times 10^{8}$ m s^{-1}; frequency of green light = $6{\cdot}0 \times 10^{14}$ Hz.]

SECTION B

4 Discuss the meaning of *magnetic flux* and *magnetic flux density*. Your discussion should include fundamental definitions, formulae – with units, and diagrams.

Describe an experiment to measure the horizontal component of the Earth's magnetic flux density in terms of the quantities mentioned in your definition. Show clearly how your result is calculated from the readings actually taken. [12 *marks*]

A small circular coil of wire is suspended by a thread at the centre of a large circular coil. The planes of the coils are at all times vertical and initially at right angles. Direct current is now made to flow through both coils. Explain why the small coil oscillates and eventually comes to rest. Draw a diagram showing the coils and the current direction in the rest position. (Ignore the Earth's field.)

Discuss whether the oscillations are simple harmonic. [8 *marks*]

5 Describe, with the aid of a labelled diagram, a simple moving-coil galvanometer. State the design features that give it (*a*) high sensitivity, and (*b*) good linearity.

What is a *ballistic galvanometer*? What design features render it ballistic? Why are ballistic galvanometers usually very sensitive when used as ordinary galvanometers? [12 *marks*]

A 10 V battery was connected in series with a 50 MΩ resistor, a very large capacitor and a switch. The switch was closed for various times t and the capacitor subsequently discharged through a ballistic galvanometer. The deflections ϕ recorded were as follows:

t/s	5	10	15
ϕ/scale divs.	7·1	14·1	20·9

Estimate the charge that flowed on each occasion and determine the ballistic sensitivity of the galvanometer. Explain your calculation, give units clearly, and state any assumption you are making. [8 *marks*]

6 Define the *volt* and deduce from first principles a formula for the power dissipated when a potential difference V is maintained across a resistance R.

How is the r.m.s. value of an alternating current defined? Why are a.c. meters normally calibrated in r.m.s. values? [10 *marks*]

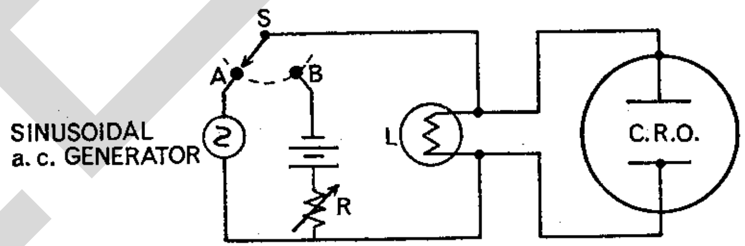

Fig. 1

In the circuit in Fig. 1 above, the rheostat R is adjusted until the lamp L seems equally bright when the switch S is at A or B. When the switch is connected to A the trace on the c.r.o. screen is a line of length y_a: when the switch is connected to B, there is merely a spot deflected from its zero position by a distance y_b. Explain these observations, sketch the appearance of the c.r.o. screen in each case, and give the ratio y_a/y_b. Also sketch the appearance of the screen in each case if an appropriate timebase were turned on. [10 *marks*]

7 What do you understand by *resistivity* and *temperature coefficient of resistance*? Discuss whether these quantities can ever have negative values. [7 *marks*]

What length of wire of cross-section 0·50 mm² and resistivity $2{\cdot}5 \times 10^{-7}$ Ω m is required to make a heater rated at 72 W to operate from a constant 12 V supply? If the material has a positive temperature coefficient of resistance, how does the power change with time while the heater is being used to melt a mixture of ice and water and to bring it to boiling point? [6 *marks*]

Another wire of the same material, but different diameter, is used to make a standard resistor. In order not to overheat it, the current density (i.e. the current per unit cross-sectional area of the wire) should not exceed 15 mA mm^{-2}. What is the maximum potential gradient which may safely be applied to the wire of the resistor? Explain your calculation carefully. [7 *marks*]

SECTION C

8 Draw a labelled diagram of the tube of a cathode-ray oscilloscope (c.r.o.) employing electrostatic deflection. Indicate typical operating potentials, polarities and any electrodes that are usually earthed.

Describe how this instrument may be used to measure the speed of sound in air. You may assume that you have a microphone, a loudspeaker and **either** an oscillator of known frequency **or** a calibrated timebase circuit. Indicate the connections to the c.r.o. and sketch the appearance of the trace from which you take your readings. Explain the physical principles involved and show clearly how you calculate the result from the measurements actually made. [11 *marks*]

In a cathode-ray tube with magnetic deflection, a deflecting field of 1×10^{-3} T is applied uniformly over a cylindrical volume of radius 5 cm in a direction parallel to the axis of the cylinder: elsewhere, the field is zero. The electron beam enters the field along a radius of the cylinder.

Describe, with the aid of a diagram, the subsequent path of the electrons: calculate their speed if the beam suffers a total deflection of 20°. [9 *marks*]

[Specific charge for the electron, $e/m_e = 1{\cdot}8 \times 10^{11}$ C kg^{-1}.]

9 In an experiment to detect gravitational *progressive waves*, a cylindrical aluminium alloy bar of mass $1{\cdot}40 \times 10^3$ kg and length 1·50 m is suspended at its mid-point. The waves would cause *longitudinal standing waves* in the bar at its fundamental *resonant frequency* of $1{\cdot}67 \times 10^3$ Hz. The maximum *amplitude* expected is 10^{-13} mm. Explain the meaning of the words *in italics*.

Calculate the speed of sound in the alloy, assuming that the point of suspension is a node. [10 *marks*]

The speed of sound, c, is related to the Young modulus, E, and the density, ρ, by the formula

$$c = \sqrt{(E/\rho)}.$$

Show that the formula is dimensionally consistent and calculate the steady force that would be required to produce a length change of 2×10^{-13} mm in the bar. [10 *marks*]

10 What are α-, β- and γ-rays? Discuss whether the inverse square law applies to these radiations (*a*) in air, and (*b*) in vacuum.

Give a short account of three different ways of detecting α-rays. Details of the detectors are not required, but the physical principles on which they operate should be made clear. [11 *marks*]

Estimate the minimum energy required to create simultaneously an α-particle and an anti-α-particle. (An anti-particle has the same mass as its corresponding particle, but opposite charge.) Through what p.d. would a β-particle have to be accelerated from rest in order to have this energy?

When a matter particle annihilates an anti-matter particle, two γ-rays are produced. Calculate the frequency of the γ radiation produced when α-particles and anti-α-particles annihilate. [9 *marks*]

[Mass of α-particle, $m_\alpha = 6{\cdot}7 \times 10^{-27}$ kg; speed of light, $c = 3{\cdot}0 \times 10^8$ m s^{-1}; charge on the electron, $e = -1{\cdot}6 \times 10^{-19}$ C; the Planck constant, $h = 6{\cdot}6 \times 10^{-34}$ J s.]

PHYSICS

861/0

SPECIAL PAPER

(*Two hours and a half*)

Answer **five** *questions.*

Mathematical tables are available.

The marks indicate the relative credit given for the various parts of the questions.

[Acceleration of free fall, $g = 9{\cdot}81$ m s^{-2}.]

1 Discuss, in terms of quantitative relationships where possible, the factors that determine the acceleration of a skier on a ski slope. [8 *marks*]

A small sphere is released from rest and, after falling a vertical distance of 0·5 m, bounces on a smooth plane which is inclined at 10° to the horizontal. If the sphere loses no energy during the impact, why do its directions of motion immediately before and immediately after the impact make equal angles with the normal to the plane? [4 *marks*]

Find the distance, measured down the plane, between this impact and the next. [8 *marks*]

2 Show that the motion of a mass M performing small vertical oscillations on the end of a light vertical spring can be expressed by the equation $x = a \sin \omega t$. [4 *marks*]

Show from first principles that the total energy of an s.h.m. of the above form remains constant with time. [3 *marks*]

If the mass M collides elastically, when it is travelling with maximum velocity, with a stationary body, which is of mass $M/2$ and is free to move, what is the new amplitude of the motion of the mass M? [7 *marks*]

Explain, without attempting to solve the relevant equations, how the answer would be modified if the two masses had stuck together. [6 *marks*]

3 State the fundamental postulates of the kinetic theory of gases and show how they lead to an equation that is consistent with the ideal gas law. [7 *marks*]

In a low pressure mercury discharge tube, the vapour is effectively at 1000 K. What is the root mean square speed of the atoms? [5 *marks*]

If the lamp emits a green line at $5{\cdot}64 \times 10^{-7}$ m, estimate the spread in wavelength due to the motion of the atoms. [5 *marks*]

Why is the intensity of the line greatest at the centre? [3 *marks*]

[Assume that mercury vapour behaves as an ideal, monatomic gas.

Relative atomic mass (atomic weight) of mercury = 200:

the gas constant $R = 8{\cdot}31$ J mol^{-1}K^{-1}:

speed of light = 3×10^8 m s^{-1}:

the Avogadro constant = $6{\cdot}02 \times 10^{23}$ mol^{-1}.]

4 Suggest why the temperature of a body in equilibrium with its surroundings is independent of its colour. [6 *marks*]

A small, blackened copper sphere, 1·0 cm in diameter, is suspended in an evacuated vessel and is initially in equilibrium with its surroundings at 0 °C. If the sphere is heated to a few degrees above the temperature of its surroundings, show that its net rate of loss of heat is approximately proportional to the temperature difference. [4 *marks*]

Estimate the error involved in this approximation when the sphere is at 10 °C. [5 *marks*]

If no further heat is supplied, what will be the initial rate of fall of temperature of the sphere? [5 *marks*]

[Specific heat capacity of copper = $3{\cdot}76 \times 10^2$ J kg^{-1} K^{-1}:
density of copper = $8{\cdot}93 \times 10^3$ kg m^{-3}:
the Stefan constant = $5{\cdot}67 \times 10^{-8}$ W m^{-2} K^{-4}.]

5 Explain briefly the principle of reversibility in geometrical optics. [3 *marks*]

A converging lens forms a real image of an object (Fig. 1).

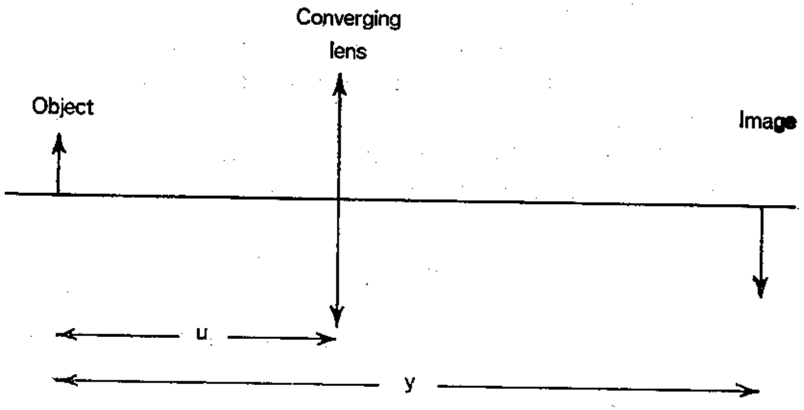

Fig. 1

Draw a ray diagram to illustrate the formation of the image and use it to derive an expression relating u (the object-lens distance), y (the object-image distance) and f (the focal length of the lens). Explain your sign convention clearly. [7 *marks*]

Measurements were made, using an inaccessible, thin, converging lens, of x, the distance from an object to an arbitrary fixed plane in front of the lens, and y, the separation of the object and its real image formed by the lens. The following values were obtained.

x/cm,	13·9	15·5	16·9	21·9	26·3	37·9
y/cm,	81·0	70·0	63·8	57·2	57·0	63·8

Deduce the focal length of the lens and its distance from the arbitrary fixed plane. [10 *marks*]

6 Solutions of certain sugars rotate the plane of polarisation of a beam of plane polarised light. How would you investigate this phenomenon quantitatively? [7 *marks*]

After a beam of unpolarised light has passed through two perfect, loss-free sheets of polarising material, it is noted that the light intensity has fallen to 12·5%. What is the orientation of the second sheet relative to the first? [6 *marks*]

A piece of quartz 5 mm thick is now inserted between the sheets of polarising material. The quartz rotates the plane of polarisation of the light according to the equation

$$\rho = \frac{8{\cdot}4\times10^{-12}}{\lambda^2} - 3{\cdot}3,$$

where ρ is the number of degrees of rotation per mm of quartz, and λ is in metres.

Which wavelengths in the range 4×10^{-7} m to 8×10^{-7} m may not be present in the light transmitted by the system? [7 *marks*]

7 State the laws that are used to determine the flow of current in a network of resistors.

To what extent do you consider them to be particular examples of more fundamental laws? [7 *marks*]

A known resistance R (of 1200 Ω) and an unknown resistance R_x are connected in series with a cell of negligible internal resistance. When a certain voltmeter is connected across R, it reads 0·6 V and when it is connected across R_x, it reads 0·9 V. Find the resistance R_x.

When the voltmeter is connected *in series* with R and R_x, it reads 0·8 V. What can you deduce about the cell and the voltmeter? [13 *marks*]

8 Explain how (*a*) the potential, (*b*) the electric field, at a point due to a number of point charges can be obtained by summing the effects of the individual charges. [4 *marks*]

Equal and opposite charges $+Q$ and $-Q$ are a distance $2a$ apart. Taking the mid-point between them as the origin O, find the potential and the field at a point P which is a distance r ($r \gg a$) from O

(*c*) when P is on the line joining the charges,

(*d*) when P is on a perpendicular bisector of the line joining the charges. [6 *marks*]

Equal and opposite charges separated by a small distance constitute a dipole. A hydrogen chloride molecule may be treated as a dipole in which an electron is separated from an equal positive charge by 2×10^{-11} m. Calculate the work required to turn a hydrogen chloride molecule which is lying parallel to a field of 3×10^5 V m^{-1} through 180°. [5 *marks*]

Suggest an explanation for the fact that the number of hydrogen chloride molecules lying nearly parallel to an applied field increases if the temperature is reduced.

[Electronic charge $e = -1{\cdot}6 \times 10^{-19}$ C] [5 *marks*]

9 Describe briefly three experiments, one in each case, which are fundamental to our knowledge of the given topics. Explain clearly, in each case, the significance of the observed results.

(*a*) The size of the atomic nucleus. [7 *marks*]

(*b*) The size of the atom. [6 *marks*]

(*c*) Energy levels for electrons in atoms. [7 *marks*]

10 How would you determine the count rate due to γ-rays from radium-226 a few centimetres away from a mixed source of radium-226 and strontium-90? Strontium-90 is chemically similar to radium but emits only β-particles. [7 *marks*]

What factors determine the health hazard associated with a particular radioactive isotope? [6 *marks*]

A convenient unit for measuring radiation exposures is the röntgen, symbol R.

The exposure rate 1 cm away from a 1 mg point source of radium is 8·4 R h^{-1} (röntgens per hour). A certain needle contains 2 mg of radium spread uniformly over its length of 4 cm. By first considering the effect of a small element dx of the needle at a distance x from the mid-point, or otherwise, estimate the exposure rate at a point 2 cm from the middle of the needle, measured along a perpendicular bisector. [7 *marks*]

(Candidates may wish to use the substitution $x = d\tan\theta$, where d is the distance from the mid-point of the needle to the point of measurement.)