UNIVERSITIES OF MANCHESTER LIVERPOOL LEEDS SHEFFIELD AND BIRMINGHAM

Joint Matriculation Board

General Certificate of Education

PHYSICS

SCHOLARSHIP

WEDNESDAY 3 JULY 1957, 2-5

Answer **five** *questions, including* **at least two** *from* SECTION (1).

Answers to Sections (1) and (2) must be written in different answer-books.

The books must be marked clearly either SECTION (1) *or* SECTION (2) *and handed in to the Supervisor separately.*

For full credit it is not sufficient to obtain correct results to numerical questions ; the principles involved and their bearing on the question must be clearly stated.

2 sheets of graph paper supplied. Additional sheets will be supplied on request but **all** *sheets issued must be placed within the answer-book and handed in to the Supervisor.*

Assume that the acceleration due to gravity is 981 cm. sec.$^{-2}$.

SECTION (1)

Answer **at least two** *questions from this section.*

1. Describe how a block which is suspended by long strings of equal length and is free to swing in a vertical plane may be used to find (*a*) the speed of a rifle-bullet, (*b*) the speed of a jet of water. State the physical principles involved and the assumptions made in calculating the speeds from the observations.

What observations would be expected if the block had a mass of 10 kgm., the supporting strings were 4 m. long and (*a*) the bullet had mass 10 gm. and speed 300 m. sec.$^{-1}$, (*b*) the jet had a cross-sectional area of 2 sq. cm. and speed 25 m. sec.$^{-1}$?

2. Discuss in some detail the effects of temperature changes on the accuracy of clocks and watches and the steps taken to eliminate such effects.

An iron band, 0·50 sq. cm. cross section, when heated to 120° C. just fits round a wheel at 20° C. What is the tension in the band when it cools to 20° C. if the diameter of the wheel remains constant? Assume that Young's modulus for iron is 21×10^{11} dyne. cm.$^{-2}$ and that the coefficient of linear expansion of iron is 12×10^{-6} deg.$^{-1}$ C.

If the band is 2·0 cm. wide and the wheel has a diameter of 50 cm., what pressure does the band exert on the rim of the wheel at 20° C.?

✓ **3.** Explain how the radius of curvature of a surface of an equi-convex lens (refractive index 1·50) may be determined (*a*) from measurements with a spherometer, (*b*) by an optical bench method.

Discuss the suitability of the methods described for finding the radius of curvature to an accuracy of 1 per cent. if the lens has a focal length of (i) 15 cm., (ii) 100 cm.

It may be assumed that the experimenter is able to reproduce settings with a spherometer, whose inner and outer legs are 1·50 cm. apart, to within 0·005 mm., and on an optical bench to within 1 mm.

4. Either, (*a*) The current flowing in a circuit is measured by means of a tangent galvanometer, which is incorrectly placed with the plane of the coil at 5° to the magnetic meridian and with the axis of the coil directed 5° N. of E., the needle being deflected through 50° in a clockwise direction.

Draw to scale on squared paper a vector-diagram of the forces acting on the north pole of the needle. Represent the force due to the horizontal component of the earth's magnetic field by a line 5 in. long. Use the diagram, explaining any construction, to find,

(i) the apparent deflecting field (i.e., the field which would have produced the same deflection had the plane of the coil been placed in the meridian) and thence the percentage error in the measured current,

(ii) the deflection produced if the current through the galvanometer is reversed.

Hence find the percentage error in the value found by assuming that the actual current is that obtained

(1) from the mean of the apparent deflecting fields which act for the two directions of flow of the current,

(2) by applying the tangent law to the mean deflection.

Or, (*b*) It is required to produce a magnetic field of about 50 oersteds (4,000 ampere-turns per metre) inside a straight solenoid 50 cm. long wound on a former 2 cm. in diameter. Two coils of enamelled copper wire of 18 and 28 S.W.G. are available, together with two 2 volt. accumulators. Design the solenoid, showing that only one gauge of wire is suitable.

Copper wire.

S.W.G.	Resistance ohm per metre	Turns per cm.	Maximum safe current (amp.).
18	0·0145	7·80	1·80
28	0·153	24·2	0·172

Indicate briefly how the variation of the magnetic field along the axis of the solenoid might be investigated.

5. Describe an experiment to measure accurately a small resistance of the order of 0·01 ohm, giving reasons for your choice of method. Assume that any standards required are available.

Find the ratio of the lengths of two wires of the same metal, but of different radii, which are heated to the same steady temperature when the same potential difference is applied in the same circumstances. Find also the ratio of the powers dissipated.

A wire is heated to whiteness *in vacuo* by an electric current, the surroundings being kept at a constant temperature. In course of time, owing to the evaporation of the metal, the wire gets thinner. Show that its temperature will remain constant if V^3i is kept constant, where V is the potential difference applied to the wire and i the current passing through it.

Or, (*b*) It is required to produce a magnetic field of about 50 oersteds (4,000 ampere-turns per metre) inside a straight solenoid 50 cm. long wound on a former 2 cm. in diameter. Two coils of enamelled copper wire of 18 and 28 S.W.G. are available, together with two 2 volt. accumulators. Design the solenoid, showing that only one gauge of wire is suitable.

Copper wire.

S.W.G.	Resistance ohm per metre	Turns per cm.	Maximum safe current (amp.).
18	0·0145	7·80	1·80
28	0·153	24·2	0·172

Indicate briefly how the variation of the magnetic field along the axis of the solenoid might be investigated.

5. Describe an experiment to measure accurately a small resistance of the order of 0·01 ohm, giving reasons for your choice of method. Assume that any standards required are available.

Find the ratio of the lengths of two wires of the same metal, but of different radii, which are heated to the same steady temperature when the same potential difference is applied in the same circumstances. Find also the ratio of the powers dissipated.

A wire is heated to whiteness *in vacuo* by an electric current, the surroundings being kept at a constant temperature. In course of time, owing to the evaporation of the metal, the wire gets thinner. Show that its temperature will remain constant if V^3i is kept constant, where V is the potential difference applied to the wire and i the current passing through it.

SECTION (2)

Answers to be written in a separate answer-book.

Not more than **three** *questions may be answered from this section.*

6. Explain in general terms how the force F on a liquid molecule varies with its position along a line drawn normally through the liquid surface. Hence explain and indicate on a graph (having energy as ordinate and distance as abscissa) how the potential energy V of the molecule varies along the same line.

A molecule approaches the surface normally within the liquid, with total energy E just sufficient to allow it to escape completely. Indicate by a line on the graph already drawn the constant value of E for all positions of the molecule. What is the significance of the vertical separation of the lines representing E and V and its variation? Discuss what happens when the total energy is less than E.

Comment on **either** the relevance of these considerations in the explanation of surface tension, **or** the similar nature of the conceptions involved in accounting for the photoelectric effect.

7. Explain how the phenomenon of interference of waves is illustrated by the production of stationary waves.

A sonometer wire of adjustable length passes a small alternating current from the mains, and a horseshoe magnet is arranged with its poles astride the wire. Describe and explain the effects which occur as the wire is gradually lengthened, and give details of the procedure you would adopt to find the frequency of the mains by this means. Suggest, with reasons, approximate values for the dimensions and tension of a wire suitable for the experiment.

✓ **8.** Heat is supplied at the constant rate of 40·0 cal. min.$^{-1}$ to 39·0 gm. of a liquid of density 1·30 gm. cm.$^{-3}$ contained in a calorimeter of water equivalent 10·0 gm. The calorimeter is provided with a means of removing any vapour produced, and after 30 min. 5·18 gm. of vapour have been removed.

In a separate experiment 30·0 gm. of water are heated by the same supply in the same calorimeter, the temperature of the surroundings being 20·0° C. in the two experiments. The rise in temperature with time in each instance is recorded in the table.

Time (min.) ..	0	2	4	6	8	10	12	14	16
Liquid temp. (deg. C.)	20·0	23·9	27·7	31·3	34·8	38·1	41·3	44·4	46·0
Water temp. (deg. C.)	20·0		23·9		27·7		31·3		34·8

Time (min.) ..	18	20	22	24	26	28	30	32	
Liquid temp. (deg. C.)	46·0	46·0	46·0	46·0	46·0	46·0	46·0		
Water temp. .. (deg. C.)		38·1		41·3		44·4		47·4	

Assuming that Newton's law of cooling holds and that a negligible mass of vapour is produced below the boiling point, calculate values of the specific heat and latent heat of vaporization of the liquid.

State, with reasons, whether you consider an experiment performed to obtain the above data would yield reliable values of the specific and latent heats.

9. (*a*) An object is moved along the axis of a thin convergent lens. Show by reference to diagrams that the refracted image (whether real or virtual) moves in the same direction as the object, except when the object is moved through the focal plane of the lens. Show further that this also occurs for divergent lenses.

(*b*) Show that, for any thin lens, the distance between the object positions such that the image is the same size as the object and (i) inverted (ii) erect, is equal to twice the focal length of the lens. Draw diagrams illustrating this for a divergent lens.

(*c*) An enlarging lens focusses on a screen an image of a negative, the linear magnification being 5 times. When the lens is moved 9 inches relative to the screen and the negative is suitably adjusted, a focussed image of magnification 3 times is obtained. Find the focal length of the lens, and the alteration in distance of the negative from the screen between the two adjustments.

(*d*) Explain briefly the function of the condensing lens of an enlarger.

✓ **10.** What are the essential processes involved in the communication of speech (or music) by radio?

Explain in detail any arrangement used in **either** the generation **or** the reception of radio signals.