A Level

Physics

Session: 1967 June
Type: Question paper
Code: 527/537

527/1

PHYSICS (Syllabus T)

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 provided.

[$g = 980$ cm. sec.$^{-2}$ or 32 ft. sec.$^{-2}$; 4·2 joules = 1 calorie.]

SECTION A

1 Explain what is meant by the *potential energy* and the *kinetic energy* of a body. Discuss the energy changes which take place when a rubber catapult is used to project a stone.

The Highway Code quotes the following figures for the overall stopping distance x of vehicles travelling at various speeds v:

v (m.p.h.)	20	30	40	50	60
x (ft.)	40	75	120	175	240

The overall stopping distance represents the distance travelled during the reaction time of the driver, before the brakes are applied, together with the distance travelled under the action of the brakes, which may be assumed to provide the maximum retarding force without causing skidding. From a graph of x/v against v, or otherwise, find the overall stopping distance of a vehicle travelling at 70 m.p.h., the reaction time of the driver and the coefficient of static friction between the tyres of the vehicle and the road.

[60 m.p.h. = 88 ft. sec.$^{-1}$.]

2 Assuming the earth to be perfectly spherical, give sketch graphs to show how (*a*) the acceleration due to gravity, (*b*) the gravitational potential due to the earth's mass, vary with distance from the surface of the earth for points external to it. If any other assumption has been made state what it is.

Explain why, even if the earth were a perfect sphere, the period of oscillation of a simple pendulum at the poles would not be the same as the period at the equator.

Still assuming the earth to be perfectly spherical, discuss whether the velocity required to project a body vertically upwards, so that it rises to a given height, depends on the position on the earth from which it is projected.

3 Give **two** practical examples of oscillatory motion which approximate to simple harmonic motion. What conditions must be satisfied if the approximations are to be good ones?

A point mass moves with simple harmonic motion. Draw on the same axes sketch graphs to show the variation with position of (*a*) the potential energy, (*b*) the kinetic energy, and (*c*) the total energy of the particle.

A particle rests on a horizontal platform which is moving vertically in simple harmonic motion with an amplitude of 10 cm. Above a certain frequency, the thrust between the particle and the platform would become zero at some point in the motion. What is this frequency, and at what point in the motion does the thrust become zero at this frequency?

4 Describe an experiment to determine the variation of pressure with depth in a liquid. Give sketch graphs of the form of this variation for (*a*) an incompressible liquid, (*b*) a compressible fluid (e.g. a gas).

A beaker containing a liquid rests on the pan of a compression spring balance. Immersed in the liquid is a solid block which is suspended by means of a light string from an extension spring balance so that the block does not touch the beaker. With the aid of diagrams indicating the vertical forces acting on various parts of the system, explain how the equilibrium of each part is maintained.

What would be the simplest way of modifying the system so as to change the reading of the compression balance without changing that of the extension balance?

Explain qualitatively how, if at all, the readings of the two balances would change if a denser block of the same volume were substituted for the original block, no other changes in the system being made.

Section B

5 Distinguish between *heat* and *temperature*, and explain what is meant by the statement that the temperature of a body is $T°$ C. on the scale of a certain thermometer.

Explain how you would use a piece of resistance wire as a thermometer, and describe how you would determine the readings corresponding to the fixed points of its scale.

A satellite orbits the earth outside its atmosphere. What factors determine the temperature of the outer shell of the satellite (*a*) on the side exposed to the sun, (*b*) on the side remote from the sun?

6 Discuss the reasons for preferring electrical methods to the method of mixtures in finding an accurate value of a specific heat.

A carbon block of mass 150 gm. was heated electrically in air. The equilibrium temperatures θ_e attained at each value of the heater power W were as follows:

W (watts)	0	25	50	75	100	150	200	250
θ_e (° C.)	25	190	240	285	325	390	440	480

The block was then allowed to cool, and the following temperature readings θ were obtained at intervals of time t:

t (min.)	0	2	4	6	8	10	12	14	16	18
θ (° C.)	500	395	315	265	230	200	180	160	145	130

Find the specific heat of carbon at 150° C., 250° C. and 400° C.

7 Explain what is meant by the *coefficient of thermal conductivity* of a substance, and describe an experiment to determine this quantity for copper.

A copper kettle has a circular base of radius 10 cm. and thickness 3·0 mm. The upper surface of the base is covered with a uniform layer of scale 1·0 mm. thick. The kettle contains water which is brought to the boil over an electric heater. In the steady state 5·0 gm. of steam are produced each minute. What is the temperature of the lower surface of the base, assuming that conduction of heat up the sides of the kettle can be neglected?

[Values of thermal conductivity:

Copper: $9{\cdot}1 \times 10^{-1}$ cal. cm.$^{-1}$ sec.$^{-1}$ deg.C.$^{-1}$.

Scale: $3{\cdot}2 \times 10^{-3}$ cal. cm.$^{-1}$ sec.$^{-1}$ deg.C.$^{-1}$.

Latent heat of vaporization of water = 540 cal. gm.$^{-1}$.]

8 Discuss the meaning of and relate where possible the terms *pitch* of a musical note, *quality* of a musical note, *frequency*, *harmonics*.

Why is it much easier to hear the sound produced by a vibrating tuning-fork if its base is placed in contact with the bench?

Describe how you would measure (*a*) the frequency of vibration of a tuning fork, and (*b*) the wavelength in air of the note emitted by the fork.

Section C

9 Describe and give the theory of an experiment to determine the value of e/m for an electron.

What is meant by the term *electrochemical equivalent*?

Given that e/m for an electron is $-1{\cdot}76 \times 10^8$ coulomb gm.$^{-1}$, and that the electrochemical equivalent of hydrogen is $1{\cdot}045 \times 10^{-5}$ gm. coulomb^{-1}, find the ratio of the mass of a hydrogen atom to that of an electron.

10 Summarize the experimental evidence for regarding light as behaving (*a*) as a wave, (*b*) as a stream of particles.

A rubidium surface was illuminated by light of different wavelengths. Values of the maximum kinetic energy of the emitted electrons were determined at each wavelength. The results obtained are tabulated below:

Wavelength (Å.)	3650	4047	4358	4797	5461
Max. K.E. (eV.)	1·32	0·98	0·77	0·50	0·19

Find the maximum wavelength for which photoelectric emission can be observed from rubidium.

11 Summarize the conclusions of Moseley's experiments on the X-ray emission spectra of the elements, and explain their significance.

The copper target of an X-ray tube contains manganese and certain other impurities, and the emission spectrum shows a strong K_α line due to copper at a wavelength of 1·541 Å. and a weak K_α line of manganese at 2·102 Å. Weak K_α lines of the other impurities are observed at 1·789 Å., 1·936 Å. and 2·289 Å. Find the atomic numbers of the impurities.

[Atomic number of manganese = 25; of copper = 29.]

12 Explain why diffraction effects may be observed when a beam of X-rays is incident on a crystal, and derive the Bragg relation between the X-ray wavelength, the crystal lattice spacing, and the scattering angle.

The density of sodium chloride is 2·17 gm. cm.$^{-3}$, and its molecular weight is 58·5. Each molecule consists of two ions, a sodium ion and a chlorine ion; in the solid state the ions are arranged alternately in a regular cubic arrangement. How many ions are there in a crystal in the form of a cube of side 1 cm.? What is the distance between adjacent ions? Find the smallest angle at which X-rays of wavelength 1·54 Å. could be reflected from sodium chloride. How many orders of reflection could be observed from these planes of atoms?

[Number of molecules in a gram-molecule (Avogadro's number) = $6{\cdot}03 \times 10^{23}$.]

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PHYSICS (Syllabus T)

ADVANCED LEVEL

PAPER 2

(*Two hours and a half*)

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Mathematical tables and squared paper are provided.

Section A

1 Draw and label a full-page diagram of the optical components of a prism spectrometer. Indicate the passage of a mixture of monochromatic red and blue light through the instrument, including the final images observed.

A simple telescope is made of two converging lenses of focal lengths 55·0 cm. and 5·00 cm. when measured in yellow light. If the final image of a distant yellow object is to be formed 25·0 cm. from the eyepiece, calculate the necessary lens separation.

Describe, and explain very briefly, how your solution would be modified if a distant blue object were to replace the yellow one, the final image being formed in the same place.

2 Draw large, well labelled diagrams to illustrate:

(*a*) refraction, total internal reflection and critical angle;

(*b*) the refraction of a wide, plane wave train according to Huygens' principle.

The thin layer of calm air immediately above a hot, flat desert is at the same temperature as the desert. Above this layer the temperature of the air changes abruptly to a uniform cooler value. A man with eyes 2 metres above the ground has the impression that he is standing at the centre of a circular 'island' of sand, surrounded by a mirror-like surface, reminiscent of water. Explain this mirage, and calculate the critical angle for the interface between the warm and cold air if the distance from the man to the rim of this 'island' is 720 metres.

Discuss what effect increase in temperature must have on the velocity of light in air to account for this.

3 What do you understand by: (*a*) diffraction, (*b*) interference, and (*c*) the Doppler effect?

A beam of infra-red radiation from a distant stationary source falls normally on a fine wire grid. A strong beam of infra-red radiation is subsequently detected along a line at an angle of 10° 57′ to this normal. The source now begins to move along the line of the normal to the grid, and the angle at which the strong beam is detected changes to 10° 22′. Describe the motion of the source as fully as possible.

[The velocity of *e–m* waves = $3{\cdot}00 \times 10^{10}$ cm. sec.$^{-1}$.]

Section B

4 Define the ampere. Describe an experiment by which you would determine the horizontal component of the earth's magnetic field (magnetising force), if the only calibrated equipment available were a metre rule and an ammeter.

Write down the equations which predict:

(*a*) the magnetic field (magnetising force) inside a long solenoid carrying a current;

(*b*) the force on a moving charge in a magnetic field. In each give the meaning and units for the symbols you employ.

An electron is projected from the centre of a large current-carrying solenoid with a speed of $1{\cdot}00 \times 10^9$ cm. sec.$^{-1}$ at right angles to the axis of the solenoid. It follows a circular path of radius 1·42 cm. Calculate the product of the current and the turns per centimetre in the solenoid, and draw a diagram showing the direction of the conventional current in the solenoid and the path of the electron.

(Candidates employing the rationalised M.K.S. system of units may wish to be reminded that the numerical value of μ_0 is $4\pi \times 10^{-7}$, those using C.G.S. E.M.U. of the fact that 1 C.G.S. E.M.U. of current is 10 amp.)

[e/m for the electron = $1{\cdot}76 \times 10^8$ coulomb gm.$^{-1}$.]

5 What do you understand by: (i) **either** the dyne **or** the newton, (ii) the joule, (iii) the watt, (iv) the volt, (v) the kilowatt-hour, (vi) the megawatt-day?

The core of a fast nuclear reactor is cooled by a stream of molten sodium–potassium alloy. The specific heat of the alloy is S joule kg.$^{-1}$ °C.$^{-1}$ and the temperatures at which the molten metal enters and leaves the reactor are θ_1° C. and

θ_2° C. respectively. Deduce an expression for the rate of flow of metal in kilogrammes per second M/t through the core if the reactor generates W watts of heat. Calculate M/t if

$$S = 1{\cdot}4 \times 10^3 \text{ joule kg.}^{-1}\ {}^\circ\text{C.}^{-1},$$
$$\theta_1 = 50^\circ \text{ C.},$$
$$\theta_2 = 600^\circ \text{ C.},$$
$$W = 6{\cdot}5 \times 10^7 \text{ watts.}$$

The molten metal is pumped by passing direct current through the alloy in a strong magnetic field (magnetising force). Draw a diagram to show the direction of the field, the direction in which the metal flows, and the current. Use the symbol ⊙ to indicate conventional current flow from the plane of the paper towards the reader.

6 What do you understand by *resistivity* and *temperature coefficient of resistance*?

A long metal rod, of 1·50 cm.² area of cross-section, carries a current of 10·0 amp. Leads are clipped to points 20 cm. apart along the rod and connected to a galvanometer with a 960 ohm resistor in series. The sensitivity of the galvanometer is 40 mm. per microamp. and its internal resistance is 40 ohm. If the galvanometer deflection is 8·0 cm., calculate the resistivity of the metal. Justify any approximations in your calculation.

Discuss the merits, or otherwise, of using currents (*a*) much larger than 10 amp., (*b*) much smaller than 10 amp., when using this apparatus for measuring resistivity.

7 Describe how you would measure a thermo-electric E.M.F. as accurately as possible, using a standard cell.

The E.M.F. of a thermocouple, when one junction is kept at 0° C. and the second junction is maintained at T° C., is given by the relation $E = 8 \times 10^{-6}T - 2 \times 10^{-8}T^2$ volt. Above what temperature T will the E.M.F. E

(*a*) begin to decrease as the temperature rises;

(*b*) reverse in polarity as the temperature continues to rise?

(You may, if you wish, employ a graphical method of solution.)

In what circumstances is a thermocouple more suitable than a mercury-in-glass thermometer for temperature measurement?

8 Summarise the essential features of electro-magnetic induction. Describe **one** experiment to demonstrate each feature.

Sketch a graph showing how the potential difference E generated by a coil of wire rotating in a uniform magnetic field varies with time t. Write down the equation for this potential E in terms of t and the period T of rotation of the coil. Explain any other symbol you employ.

Draw four diagrams showing the relative positions of the plane of the coil and the magnetic field when $t = 0$, $T/4$, $T/2$, $3T/4$.

Describe and explain how a simple fixed magnet dynamo can be modified so as to give short, sharp, high voltage pulses, rather than the A.C. you have previously described.

9 Draw clear, well labelled, circuit diagrams to show how you would:

(*a*) effect full wave rectification of A.C.;

(*b*) obtain approximately steady direct current from such rectified A.C.;

(*c*) measure the static grid characteristics of a triode valve;

(*d*) use a diode valve as a detector of radio-frequency signals.

SECTION C

10 What do you understand by (*a*) an α particle, (*b*) a proton, (*c*) a perfectly elastic collision?

The range of an α particle, R micron, in Ilford G5 photographic emulsion, is related to its initial energy E, in meV., by the equation $E = 0{\cdot}25R$. Radium emits α particles which are observed to have a range of 19·2 micron in this emulsion. Calculate their initial velocity.

If an α particle moving at this speed in this emulsion makes a perfectly elastic head-on collision with a stationary proton, calculate the direction and the length (in cm.) of the subsequent track of the α particle.

[1 a.m.u. $= 1{\cdot}7 \times 10^{-24}$ gm.,
1 eV. $= 1{\cdot}6 \times 10^{-12}$ erg or $1{\cdot}6 \times 10^{-19}$ joule,
1 micron $= 10^{-6}$ metre.]

11 What do you understand by a radio-active decay constant λ, and the radio-active half life of an element $T_{\frac{1}{2}}$? Show that $\lambda \times T_{\frac{1}{2}} = \log_e 2$ for any particular radio-active element.

Describe how you would determine $T_{\frac{1}{2}}$ for a radio-active gas whose half life is of the order of twenty minutes.

12 Give an account of the theory of the measurement of the charge on the electron by Millikan's method.

Give an account of the experimental evidence for the existence of quanta of energy.

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PHYSICS (Syllabus T)

SPECIAL PAPER

(Two hours and a half)

Answer **five** *questions.*

Mathematical tables and squared paper are provided.

[$g = 980$ cm. sec.$^{-2}$.]

1 Explain carefully what is meant by *mass*, *weight*, and *inertia*. How should your explanation be modified to include cases when bodies are immersed in a fluid whose density may not be neglected?

An open tube of radius $2a$ is inclined at an angle α to the horizontal while completely immersed in liquid helium of density ρ_1. A sphere of radius a and density ρ_2 ($\rho_2 > \rho_1$) rolls, starting from rest, down the tube. Find the time taken for the sphere to descend a vertical distance h, the viscosity of the liquid helium being negligible. Indicate any approximations you have made. (Moment of inertia of a sphere of mass M about a diameter is $\frac{2}{5}Ma^2$.)

2 Define Young's Modulus and explain how it might be measured for a steel rod 1 metre long, having a square cross section area of 0·25 cm.^{2}.

The same rod is bent to form a circle and the two ends are welded together. The circle is heated until its temperature is raised by 180° C. when it is slipped over a wheel which it then fits exactly. Estimate the pressure exerted on the wheel when the circle cools to its original temperature.

[Young's modulus for steel $= 1{\cdot}95 \times 10^{12}$ dyne cm.$^{-2}$.
Coefficient of linear expansion $= 1{\cdot}10 \times 10^{-5}$ °C.$^{-1}$.]

3 Answer **all** the following:

(*a*) Explain why it is difficult to see near objects when the eye is immersed in water.

(*b*) Account for the shape and colour of the setting sun.

(*c*) Explain the formation of colours seen in a film of oil, floating on water.

(*d*) Account for the difference between the colours of objects viewed in artificial light and in daylight.

(*e*) What limits the intensity of sound waves that may be transmitted through air?

4 Explain what is meant by Brownian motion and show how it provides evidence in favour of the Kinetic Theory.

State a relationship connecting the pressure of a gas with its density and the mean square velocity of its molecules, and indicate how Avogadro's hypothesis may be derived using this expression. State the assumptions that are required.

Find the root mean square velocity of molecules of hydrogen at 100° C., if the density of hydrogen at s.t.p. is $8{\cdot}9 \times 10^{-5}$ gm. cm.$^{-3}$. (Density of mercury = $13{\cdot}6$ gm. cm.$^{-3}$.)

Outline briefly an electrical method which may be used to derive Avogadro's number.

5 Give the simple theory of a diffraction grating, and describe how you would use it to measure the wavelength of monochromatic light.

What factors determine the number of orders that may be seen when the light is incident normally?

The diffraction grating in a simple spectrometer has 5000 lines cm.$^{-1}$. If the telescope of the spectrometer is replaced by a camera having a lens of 40 cm. focal length, what will be the separation in the second order spectrum of the sodium D lines on the photographic plate?

[Wavelengths of the D lines are $5{\cdot}890 \times 10^{-5}$ cm. and $5{\cdot}896 \times 10^{-5}$ cm.]

6 Indicate how the concepts of a Black Body and of Black Body Radiation are derived from Prévost's theory of exchanges.

Draw curves to illustrate how the energy radiated at different wavelengths varies with the Black Body temperature.

The cathode of a diode valve consists of a cylinder $2{\cdot}0$ cm. long and $0{\cdot}10$ cm. diameter, and is surrounded by a coaxial anode of diameter large compared with that of the cathode. The anode remains at 127° C. when 4 watts are dissipated in heating the cathode. Estimate the temperature of the cathode. List the assumptions you have made in arriving at your estimate. Discuss whether the estimate is realistic.

[Stefan's constant = $5{\cdot}74 \times 10^{-12}$ watts cm^{-2}. °K.$^{-4}$.]

7 Derive an expression for the e.m.f. induced in a coil rotating about a diameter which is perpendicular to a uniform magnetic field (magnetising force).

Such a generator is connected in turn to a resistor, an inductor having negligible resistance, and a capacitor. Discuss with the aid of diagrams (*a*) the relationship of the current flowing and voltage across each in turn, and (*b*) how the current flowing will vary in each case with the speed of rotation. The resistance of the generator coil may be neglected.

8 Explain what is meant by (*a*) the anode resistance, (*b*) the mutual conductance and (*c*) the amplification factor of a triode valve, and deduce the relation between them.

Draw the circuit of a single triode valve arranged as an amplifier for audio frequencies from 20 to 15000 cycles sec.$^{-1}$.

Estimate the transit time for electrons passing between the grid (when at zero potential) and the anode of a triode if the anode voltage is 50 and the grid-to-anode separation is $2{\cdot}0$ mm. Hence deduce approximately the highest frequency at which the triode will act as an amplifier.

[e/m for an electron = $5{\cdot}27 \times 10^{17}$ e.s.u. gm.$^{-1}$
= $1{\cdot}76 \times 10^{11}$ coulomb kgm.$^{-1}$.]

9 Describe a method by which the masses of the nuclei of the elements may be compared.

Accurate mass-spectrometric determinations show that such masses expressed in atomic mass units are not exactly whole numbers. Comment on the significance of this observation. What can be deduced from the magnitude of the mass defect? Explain what significance, if any, can be attached to the fact that with the mass of C^{12} = $12{\cdot}000$ a.m.u., the mass of H^1 = $1{\cdot}008$ a.m.u.

10 Give an account of the explanation which has been offered for the occurrence of line spectra.

Discuss what atomic and other fundamental constants you would expect to influence the relationships between these lines in any one spectrum.

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PHYSICS (Syllabus N)

ADVANCED LEVEL

PAPER 1

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[60 m.p.h. = 88 ft. sec.$^{-1}$.]

2 Give **two** practical examples of oscillatory motion which approximate to simple harmonic motion. What conditions must be satisfied if the approximations are to be good ones?

A point mass moves with simple harmonic motion. Draw on the same axes sketch graphs to show the variation with position of (*a*) the potential energy, (*b*) the kinetic energy, and (*c*) the total energy of the particle.

A particle rests on a horizontal platform which is moving vertically in simple harmonic motion with an amplitude of 10 cm. Above a certain frequency, the thrust between the particle and the platform would become zero at some point in the motion. What is this frequency, and at what point in the motion does the thrust become zero at this frequency?

3 Describe an experiment to determine the variation of pressure with depth in a liquid. Give sketch graphs of the form of this variation for (*a*) an incompressible liquid, (*b*) a compressible fluid (e.g. a gas).

A beaker containing a liquid rests on the pan of a compression spring balance. Immersed in the liquid is a solid block which is suspended by means of a light string from an extension spring balance so that the block does not touch the beaker. With the aid of diagrams indicating the vertical forces acting on various parts of the system, explain how the equilibrium of each part is maintained.

What would be the simplest way of modifying the system so as to change the reading of the compression balance without changing that of the extension balance?

Explain qualitatively how, if at all, the readings of the two balances would change if a denser block of the same volume were substituted for the original block, no other changes in the system being made.

4 Explain what is meant by the *viscosity* of a liquid, and define the *coefficient of viscosity*. What phenomena suggest that viscosity is exhibited by gases as well as by liquids?

The following figures were obtained in an experiment to determine the coefficient of viscosity of water by measuring the rate of flow through a horizontal capillary tube:

Diameter of capillary tube = 1·40 mm.
Length of capillary tube = 21·0 cm.
Pressure difference between ends of tube = 18·5 cm. water.
Rate of flow of water = 0·74 $cm.^3$ $sec.^{-1}$.

Give a diagram of the apparatus which would be used for this experiment, and explain how each measurement would be made.

If the diameter of the tube was measured to ± 0·05 mm., the length to ± 1 mm., the pressure difference to ± 2 mm. water, and the rate of flow to ± 0·01 $cm.^3$ $sec.^{-1}$, calculate the percentage error which the uncertainty in each of these factors introduces into the value obtained for the coefficient of viscosity.

Section B

5 Distinguish between *heat* and *temperature*, and explain what is meant by the statement that the temperature of a body is T° C. on the scale of a certain thermometer.

Explain how you would use a piece of resistance wire as a thermometer, and describe how you would determine the readings corresponding to the fixed points of its scale.

A satellite orbits the earth outside its atmosphere. What factors determine the temperature of the outer shell of the satellite (*a*) on the side exposed to the sun, (*b*) on the side remote from the sun?

6 Discuss the reasons for preferring electrical methods to the method of mixtures in finding an accurate value of a specific heat.

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Find the specific heat of carbon at 150° C., 250° C. and 400° C.

7 What do you understand by an *ideal gas*? Discuss the extent to which the behaviour of (*a*) real gases, and (*b*) saturated vapours can be represented by relations derived for an ideal gas.

Describe an experiment to investigate the relation between the pressure and the temperature of a sample of air maintained at constant volume over the temperature range from 0° C. to 100° C.

A tube of length 40 cm. and uniform area of cross-section of 1·0 $cm.^2$, held vertically, is pushed downwards into a trough of mercury until its top is 15·0 cm. above the mercury level. An airtight cap is placed over the top end of the tube and the tube is very slowly raised, keeping its axis vertical, until the bottom end of the tube is 1·0 cm. below the level of the mercury in the trough. What is the new height of mercury in the tube, assuming that the temperature of the air in the tube remains constant? Take the atmospheric pressure as 760 mm. Hg., and neglect surface tension effects.

8 Explain what is meant by the *coefficient of thermal conductivity* of a substance, and describe an experiment to determine this quantity for copper.

A copper kettle has a circular base of radius 10 cm. and thickness 3·0 mm. The upper surface of the base is covered with a uniform layer of scale 1·0 mm. thick. The kettle contains water which is brought to the boil over an electric heater. In the steady state 5·0 gm. of steam are produced each minute. What is the temperature of the lower surface of the base, assuming that conduction of heat up the sides of the kettle can be neglected?

[Values of thermal conductivity:

Copper: $9 \cdot 1 \times 10^{-1}$ cal. cm.$^{-1}$ sec.$^{-1}$ deg.C.$^{-1}$.

Scale: $3 \cdot 2 \times 10^{-3}$ cal. cm.$^{-1}$ sec.$^{-1}$ deg.C.$^{-1}$.

Latent heat of vaporization of water = 540 cal. gm.$^{-1}$.]

9 Discuss the meaning of and relate where possible the terms *pitch* of a musical note, *quality* of a musical note, *frequency*, *overtones*.

Why is it much easier to hear the sound produced by a vibrating tuning-fork if its base is placed in contact with the bench?

Describe how you would measure (*a*) the frequency of vibration of a tuning-fork, and (*b*) the wavelength in air of the note emitted by the fork.

537/2

PHYSICS (Syllabus N)

ADVANCED LEVEL

PAPER 2

(*Two hours and a half*)

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SECTION A

1 Draw and label a full-page diagram of the optical components of a prism spectrometer. Indicate the passage of a mixture of monochromatic red and blue light through the instrument, including the final images observed.

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Discuss what effect increase in temperature must have on the velocity of light in air to account for this.

3 What do you understand by 'the standard candle' and 'the foot candle'? Comment on the statement 'the inverse square law always applies in photometry'.

A simple car headlamp is made from a paraboloidal reflector with a small 120 candle power lamp at its focus. The shortest distance from the lamp to the reflector (i.e. the distance from the focus to the vertex of the paraboloid) is 3·0 in. If the reflection factor is 80 % calculate a value for the intensity of illumination on a small plane surface on the axis of the reflector and perpendicular to it (*a*) 1 ft., (*b*) 50 ft., (*c*) 100 ft. from the lamp. State any assumptions you make.

Describe briefly one electrical device you might use to measure this intensity of illumination.

Section B

4 Either (*a*) Define the C.G.S. electro-magnetic unit of current. Deduce a formula for the magnetic field at the centre of a circular coil of wire carrying a current i amp.

When a tangent galvanometer is set in the usual way, the needle makes 10·0 oscillations in 5·0 seconds before settling down to a steady deflection of 45° with the current switched on. How many oscillations will it make in 5·0 sec. when the current is switched off?

[One C.G.S. E.M.U. of current is 10 amp.]

Or (*b*) (Alternative based on the rationalised M.K.S. system of units.)

Define the M.K.S. unit of current. Deduce a formula for the magnetic flux density near a long straight wire carrying a current i amp.

A long solenoid is arranged with its axis North–South and carries a current which nullifies the horizontal component of the earth's field (magnetising force) at its centre. While still carrying this current, the solenoid is rotated about a vertical axis through this centre, until its axis lies East–West. The resultant flux at the centre of the solenoid is again reduced to zero, but this time by means of a horseshoe magnet, which produces a flux density of $2{\cdot}5 \times 10^{-5}$ weber metre^{-2} between its pole faces. Calculate the value of the horizontal component of the earth's magnetising force.

[The numerical value of μ_0 in the rationalised M.K.S. system is $4\pi \times 10^{-7}$.]

5 What do you understand by: (i) **either** the dyne **or** the newton, (ii) the joule, (iii) the watt, (iv) the volt, (v) the kilowatt-hour, (vi) the megawatt-day?

The core of a fast nuclear reactor is cooled by a stream of molten sodium–potassium alloy. The specific heat of the alloy is S joule kg.$^{-1}$ ° C.$^{-1}$ and the temperatures at which the molten metal enters and leaves the reactor are θ_1° C. and θ_2° C. respectively. Deduce an expression for the rate of flow of metal in kilogrammes per second M/t through the core if the reactor generates W watts of heat. Calculate M/t if

$$S = 1{\cdot}4 \times 10^3 \text{ joule kg.}^{-1}\text{° C.}^{-1},$$
$$\theta_1 = 50\text{° C.},$$
$$\theta_2 = 600\text{° C.},$$
$$W = 6{\cdot}5 \times 10^7 \text{ watts.}$$

The molten metal is pumped by passing direct current through the alloy in a strong magnetic field (magnetising force). Draw a diagram to show the direction of the field, the direction in which the metal flows, and the current. Use the symbol ⊙ to indicate conventional current flow from the plane of the paper towards the reader.

6 What do you understand by *resistivity* and *temperature coefficient of resistance*?

A long metal rod, of 1·50 cm² area of cross-section, carries a current of 10·0 amp. Leads are clipped to points 20 cm. apart along the rod and connected to a galvanometer with a 960 ohm resistor in series. The sensitivity of the galvanometer is 40 mm. per microamp. and its internal resistance is 40 ohm. If the galvanometer deflection is 8·0 cm., calculate the resistivity of the metal. Justify any approximations in your calculation.

Discuss the merits, or otherwise, of using currents (*a*) much larger than 10 amp., (*b*) much smaller than 10 amp., when using this apparatus for measuring resistivity.

7 Describe how you would measure a thermo-electric E.M.F. as accurately as possible, using a standard cell.

The E.M.F. of a thermocouple, when one junction is kept at 0° C. and the second junction is maintained at T° C. is given by the relation $E = 8 \times 10^{-6}\,T - 2 \times 10^{-8}\,T^2$ volt. Above what temperature T will the E.M.F. E

(*a*) begin to decrease as the temperature rises, (*b*) reverse in polarity as the temperature continues to rise?

[You may, if you wish, employ a graphical method of solution.]

In what circumstances is a thermocouple more suitable than a mercury-in-glass thermometer for temperature measurement?

8 Summarise the essential features of electro-magnetic induction. Describe one experiment to demonstrate each feature.

Sketch a graph showing how the potential difference E generated by a coil of wire rotating in a uniform magnetic field varies with time t. Write down the equation for this potential E in terms of t and the period T of rotation of the coil. Explain any other symbol you employ.

Draw four diagrams showing the relative positions of the plane of the coil and the magnetic field when $t = 0$, $T/4$, $T/2$, $3T/4$.

Describe and explain how a simple fixed magnet dynamo can be modified so as to give short, sharp, high voltage pulses, rather than the A.C. you have previously described.

9 Draw clear, well-labelled, circuit diagrams to show how you would

(*a*) compare two low resistors using a potentiometer;

(*b*) estimate the E.M.F. of a high tension battery using a potentiometer;

(*c*) measure the static grid characteristics of a triode valve;

(*d*) use a diode valve as a detector of radio-frequency signals.

537/0

PHYSICS (Syllabus N)

SPECIAL PAPER

(*Two hours and a half*)

Answer **five** *questions.*

Mathematical tables and squared paper are provided.

[g = 980 cm. sec.$^{-2}$.]

1 Explain carefully what is meant by *mass*, *weight*, and *inertia*. How should your explanation be modified to include cases when bodies are immersed in a fluid whose density may not be neglected?

An open tube of radius $2a$ is inclined at an angle α to the horizontal while completely immersed in liquid helium of density ρ_1. A sphere of radius a and density ρ_2 ($\rho_2 > \rho_1$) rolls, starting from rest, down the tube. Find the time taken for the sphere to descend a vertical distance h, the viscosity of the liquid helium being negligible. Indicate any approximations you have made. (Moment of inertia of a sphere of mass M about a diameter is $\frac{2}{5}Ma^2$.)

2 Define Young's Modulus and explain how it might be measured for a steel rod 1 metre long, having a square cross-section area of 0·25 cm.^{2}.

The same rod is bent to form a circle and the two ends are welded together. The circle is heated until its temperature is raised by 180° C. when it is slipped over a wheel which it then fits exactly. Estimate the pressure exerted on the wheel when the circle cools to its original temperature.

[Young's modulus for steel = $1{\cdot}95 \times 10^{12}$ dyne cm.$^{-2}$. Coefficient of linear expansion = $1{\cdot}10 \times 10^{-5}$ °C.$^{-1}$.]

3 Answer **all** the following:

(*a*) Explain why it is difficult to see near objects when the eye is immersed in water.

(*b*) Account for the shape and colour of the setting sun.

(*c*) Explain the formation of colours seen in a film of oil, floating on water.

(*d*) Account for the difference between the colours of objects viewed in artificial light and in daylight.

(*e*) What limits the intensity of sound waves that may be transmitted through air?

4 Derive an expression connecting the pressure of a gas with its density and the mean square velocity of its molecules. State the assumptions that are required in the derivation of this expression.

Show that this expression is consistent with the gas equation pv/T = constant, provided a certain assumption is made. State this assumption.

Find the total kinetic energy per unit volume in a monatomic gas at standard temperature and pressure. Deduce an expression for the variation of this kinetic energy with temperature if the pressure is maintained constant.

[Density of mercury = 13·6 gm. cm.$^{-3}$.]

5 Give the simple theory of a diffraction grating, and describe how you would use it to measure the wavelength of monochromatic light.

What factors determine the number of orders that may be seen when the light is incident normally?

The diffraction grating in a simple spectrometer has 5000 lines cm.$^{-1}$. If the telescope of the spectrometer is replaced by a camera having a lens of 40 cm. focal length, what will be the separation in the second-order spectrum of the sodium *D* lines on the photographic plate?

[Wavelengths of the *D* lines are $5{\cdot}890 \times 10^{-5}$ cm. and $5{\cdot}896 \times 10^{-5}$ cm.]

6 A metal hemisphere of radius 10 cm. is immersed near the centre of a large conducting tank containing a liquid having

resistivity 6×10^3 ohm cm. The plane surface of the hemisphere is level with the surface of the liquid.

(*a*) Derive an expression for the resistance between two hemispherical shells within the liquid, concentric with the centre of the metal hemisphere, having radii a and $(a+da)$ respectively when da is very small.

(*b*) Hence calculate the resistance between the hemisphere and the tank.

(*c*) When a potential difference of 1000 volts is applied between the hemisphere and the tank, where will the initial rate of rise of temperature be greatest? Estimate its value if 1·70 joules are required to raise the temperature of 1 cm.^{3} of the liquid by 1 deg. C.

7 Indicate how the concepts of a Black Body and of Black Body Radiation are derived from Prévost's theory of exchanges.

Draw curves to illustrate how the energy radiated at different wavelengths varies with the Black Body temperature.

The cathode of a diode valve consists of a cylinder 2·0 cm. long and 0·10 cm. diameter, and is surrounded by a coaxial anode of diameter large compared with that of the cathode. The anode remains at 127° C. when 4 watts are dissipated in heating the cathode. Estimate the temperature of the cathode. List the assumptions you have made in arriving at your estimate. Discuss whether the estimate is realistic.

[Stefan's constant = $5{\cdot}74 \times 10^{-12}$ watts cm.$^{-2}$ °K.$^{-4}$.]

8 Derive an expression for the e.m.f. induced in a coil rotating about a diameter which is perpendicular to a uniform magnetic field (magnetising force).

Such a generator is connected in turn to a resistor, an inductor having negligible resistance, and a capacitor. Discuss with the aid of diagrams (*a*) the relationship of the current flowing and voltage across each in turn, and (*b*) how the current flowing will vary in each case with the speed of rotation. The resistance of the generator coil may be neglected.

9 Explain what is meant by (*a*) the anode resistance, (*b*) the mutual conductance and (*c*) the amplification factor of a triode valve, and deduce the relation between them.

Draw the circuit of a single triode valve arranged as an amplifier for audio frequencies from 20 to 15000 cycles sec.$^{-1}$.

Estimate the transit time for electrons passing between the grid (when at zero potential) and the anode of a triode if the anode voltage is 50 and the grid-to-anode separation is 2·0 mm. Hence deduce approximately the highest frequency at which the triode will act as an amplifier.

[e/m for an electron $= 5{\cdot}27 \times 10^{17}$ e.s.u. gm.$^{-1}$
$= 1{\cdot}76 \times 10^{11}$ coulomb kgm.$^{-1}$.]