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PHYSICS

ADVANCED LEVEL

Paper 9240/1

The paper produced a very good dispersion of marks, ranging from 0 to 96. The average mark scored was about 44. The compulsory Section A questions tested a wide range of syllabus topics, and it was pleasing that most candidates were able to make an attempt at the majority of these questions. In Section B it was noticeable that one question (*Q.18*) was very popular indeed, while another (*Q.17*) was very unpopular. The Section B questions appeared to be rather more testing than those set in the 1983 examination.

In many Centres, although the standard in Physics was satisfactory, the presentation of the work was poor. Often spelling was incorrect, expression slipshod, slang common, and handwriting a mere scrawl. No penalty was applied for these faults, but it is regretted that so many candidates fail to realise that they can gain a positive advantage by laying out their work carefully and neatly.

Section A

Q.1 To score full marks on this question, the statement that the indicated speed was greater than the actual speed had to be supported by a clear explanation. Many candidates failed to provide this.

Q.2 The calculation of the mass of the Moon gave some difficulties. Many candidates took the centre of mass of the Earth–Moon system as being the point at which the gravitational fields, or potentials, are equal. Although many obtained the correct answer by applying the principle of moments, the critical issue is that the gravitational force between Earth and Moon provides equal centripetal forces towards the common centre of mass, and the angular velocity about this point is the same for both Earth and Moon. Very few appreciated the significance of the common centre of mass as the centre of rotation.

Q.3 This question involved simple applications of the lens and magnification formulae. The most common error was to substitute v = 360 mm (instead of $360 - u$).

Q.4 Instead of the amplitude graph, many candidates drew the looped standing-wave pattern. While most were aware of the existence of the end-correction, a surprising number related it to the distance of the tuning-fork from the end of the tube.

Q.5 Only a few sketches showed the intensity graph in its correct proportions. Important points to note include the facts that the distances between minima should be approximately constant and equal to the distance between the central maximum and first minimum, and that the intensity of the first subsidiary maximum is less than one-twentieth of that of the central maximum. A surprising number of candidates stated that the effect of decreasing the slit width would be to concentrate the intensity into a bright, narrow central line.

Q.6 Many candidates gave clear and convincing arguments against classifying the electron beam as an electromagnetic wave.

Q.7 The answers to this question showed that the majority appreciated the function of the galvanometer protective resistor. However, it is incorrect to suggest that the series resistor lowers the galvanometer sensitivity, as its response to a given current is unchanged. An appreciable number confused the resistor with the one which may be connected in series with the slide-wire in order to reduce the potential drop across the wire.

Q.8 The deduction of the relation between field strength and surface density of charge was unfamiliar to a number of candidates. However, many of these were able to recall the result, and continued to obtain the correct answer to the problem.

Q.9 It had been expected that many candidates would derive the expression $B = RQ/nA$ from the first principles. In the event, most candidates scoring full marks for this question recalled the formula.

Q.10 Some good answers were received. However, many candidates failed to appreciate that the insertion of the iron core would cause a permanent reduction in the brightness of the filament: it was common to state that a change would be observed only while the rod was in motion.

Q.11 A common error in calculating the rate of rise of temperature was to give the full rise over the period of 150 s.

Q.12 A number of candidates included an electron in the deuterium nucleus. The most common error in the calculation of the binding energy was to fail to convert from m_u into kg.

Section B

Q.13 Most candidates were able to expand on the lead given in the question, and gave more or less convincing explanations of the reasons for abandoning the old definition of the metre and adopting one in terms of the wavelength of light. However, many hold exaggerated ideas about the variability of the ice-point. The effects of making the measurements under non-standard conditions were usually well understood. In part *(b)*, sketches of the experimental arrangement often incorrectly showed a point source of light, instead of an extended source or a broad parallel beam. If, as in this case, normal incidence is required, a reflecting plate is necessary in order to avoid obstruction of the beam by the observer's head. While most candidates correctly stated that interference arose between light reflected at the lower surface of the top plate and at the upper surface of the bottom plate, many gave an incorrect explanation of 'coherent', stating that it meant that these waves were in phase. Rather few candidates made it clear that, in the absence of the phase change on reflection, it would be expected that the apex of the wedge should be a bright fringe. The very simple measurement of the thickness of the wedge (by counting the dark fringes and multiplying by $\frac{1}{2}\lambda$) was often complicated by travelling microscope measurements of distance along the wedge and calculation of the wedge angle.

Q.14 A few candidates confused angular acceleration with centripetal acceleration. While it is natural that this syllabus topic should be taught by analogy to linear motion, it is not correct to explain torque as 'an angular force': this statement was offered more often than the correct one. Not many candidates correctly identified the factors upon which the moment of inertia depends: a common error was to deal only with a point mass, or to confuse the axis of rotation with the centre of mass. In part *(a)* of the problem, many candidates failed to give numerical values for the magnitudes of the forces. The upward force of the table on the particle was often omitted. In part *(b)* the explanation was very often an account of *how* the angular momentum remains constant (i.e., 'the radius decreases so the angular speed must increase to compensate') instead of *why* (e.g., 'because the force applied to the string does not cause a torque', or an equivalent statement such as 'because no external torque acts'). An appreciable number of candidates gave incorrect expressions for angular momentum, the most popular being $mr\omega^2$. A common error in part *(c)* was to attempt to calculate the work done by 'force x distance', ignoring the fact that the force is not constant, or recognising it and taking an average force. The most direct method of calculation is to find the change in kinetic energy of the particle.

Q.15 While many candidates had a good idea of a perfect absorber, attempts to explain the perfect radiator were poor. It was very common to regard the emission process solely as a consequence of absorption: thus, 'a perfect radiator emits all the radiation it absorbs'. Most candidates made a good attempt at explaining the action of the hole in the container as an absorber, but were less happy at discussing its efficiency as a radiator. Most candidates employed the correct principles in estimating the equilibrium temperature of the element of the fire, but errors were made in using the volume instead of the surface area. Many candidates lost a mark for expressing their 'estimate' as 1046.1 K. Most appreciated that the effect of the element not being a perfect radiator, and of neglect of the radiation absorbed from the room, was in each case to make the real temperature higher than their estimate, but clear explanations were rare.

Q.16 The derivation of the expression for the difference in the molar heat

capacities was well done. In discussing the degrees of freedom of the diatomic molecule, few candidates recognised the possibility of vibration. In part *(c)* it was very common to leave the answer as the energy of one molecule. There were a number of spurious derivations of the value of γ, involving expressions such as '$C_V = 5kT/2$'. In the last part of the question only a few candidates compared the numerical values of C_V given in the graph with the theoretical values of $3R/2$ and $5R/2$.

Q.17 This question proved to be much less popular than the other five in Section B. Few candidates attempting it could give even approximate wavelength limits for the X-ray region; surprisingly, there was also considerable difficulty with the visible. In part *(a)*, many candidates sketched a complete spectrometer, instead of only the collimator. In part *(b)* most could make an estimate of grating spacing consistent with their idea of visible wavelengths. Visible and X-ray detectors were well known. The explanation of line spectra in terms of electronic transitions between energy levels was generally good. Not many candidates appreciated that directions of strong scattering in the von Laue method correspond to solutions of the Bragg equation over the range of values of λ and of d available.

Q.18 In the definition of stress, candidates were expected to make it clear that the cross-sectional area of the wire was involved: 'stress = force/area' was not sufficient. Candidates should be aware that a single wire, suspended from a clamp-stand, and with extensions measured on a metre rule, is not a suitable experimental arrangement to investigate the strain-stress relation for a steel wire; nevertheless, this version of the apparatus was frequently offered. Sketches of a more acceptable apparatus were often very poor, with the two scales of the vernier system not in contact. It was rare to indicate the measurement of the original length of the wire. Some errors were made in the very simple calculation of the extension due to loading, mainly in the conversion of 0.1 mm^2 to m^2. Candidates found considerable difficulty in using the data on the fractional increase in length to deduce the extension due to thermal expansion. Too often the discussion on the importance of temperature changes was merely along the lines of 'it is important to maintain constant temperature conditions (or to record the temperature) when measuring the Young modulus, as otherwise an error will be made'; it had been hoped that candidates would make some comment on the relative magnitudes of the extensions they had just calculated, or on the design of the apparatus they had just described.

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Answer Key

1.	E	2.	E	3.	A	4.	A	5.	A
6.	E	7.	E	8.	A	9.	C	10.	B
11.	D	12.	C	13.	D	14.	E	15.	D
16.	A	17.	C	18.	D	19.	C	20.	A
21.	B	22.	E	23.	C	24.	B	25.	C
26.	E	27.	D	28.	C	29.	C	30.	E
31.	D	32.	C	33.	C	34.	A	35.	D
36.	A	37.	C	38.	D	39.	A	40.	D

Paper 9240/3

With few exceptions the candidates had sufficient time to complete the answers to the three questions required. The overall mark distribution reflected a very wide range of achievement. *Question 6* proved most popular, *Questions 2* and *3* least.

Q.1 Candidates often failed to suggest displacement is measured from some reference point, but it was pleasing to see less confusion between the mathematician's modulus λ and the physicist's force constant k. The Doppler effect was appreciated qualitatively, but the mathematics of the small fractional change in frequency proved difficult to many. Some used the velocity of sound instead of e/m waves, and some assumed the frequency of the γ radiation to be 10^4 Hz, the audio frequency of the loudspeaker. The concept of resonance absorbtion was generally appreciated, but the final graph was often inverted.

Q.2 There were some good, concise accounts of the measurement of the maximum energy of photoelectrons, but in many the electrical circuit was incomplete. The examiners were happy to accept a 'black box' for detection of small currents – labelled perhaps 'D.C. amplifier' – but a simple practical circuit to vary and measure the stopping potential was expected. Answers to the electron diffraction question were often confused, the Bragg equation sometimes being substituted for the de Broglie relationship. In the final calculation a common error was to equate the electron energy to the energy of the X-ray photons, instead of equating the X-ray wavelength to the de Broglie wavelength of the electrons.

Q.3 Candidates who described a simple Wheatstone circuit generally performed better than those who attempted the alternative potentiometric method:– these often produced diagrams of circuits which simply would not work. The final section on systematic error was poorly answered, many confusing systematic with random errors. The error calculations often contained ten factor mistakes. Many of the suggested systematic errors betrayed a lack of practical experience with such circuits.

Q.4 The capacitor 'bookwork' was usually well remembered, though candidates often failed to offer any justification for the equality of charges on capacitors connected in series. In sections *(c)* and *(d)* many omitted any mention of electrons, despite the instruction in the question. The phasor diagram was generally disappointing, but the final calculations produced some clear and concise solutions.

Q.5 A common fault in the first section was to omit all consideration of the length of the conductors, and the logic connecting the definition of the ampere and the value of μ_0 was not always clear. Diagrams were generally poor and few explained how radial field leads to linearity in galvanometers. The required deflection ratio was correctly deduced by the majority, but few could explain how to make a suitable choice of meter.

Q.6 Again, the elementary bookwork was well known. However, a remarkably large number explained a "β emitter" as "... a substance which emits β particles ...". Few candidates realised that since two types of α were produced in the Plutonium problem, the Uranium produced must also be of two types, with differing nuclear potential (binding energies) and different mass. This mass difference being the mass difference in the α particles, which most had just calculated successfully. However, most completed the penultimate calculation correctly, and some gave admirable solutions to the final problem.

Overall, the quality of the scripts was similar to that in previous years. If anything, the level of explanation given in calculation and the clarity of argument was even less adequate than usual. Much hard work is obviously done both by students and teachers, but this section of the syllabus may need more time to master than that allocated to it at some centres.

Paper 9240/4

Q.1 Most candidates could establish the diameter of the rod within the limits expected, but their technique left a lot to be desired. The majority were content to quote readings to 3 significant figures when 4 should have been investigated (and this even when the candidate pointed out that the dimension was being used to the fourth power in the final equation). Zero error was largely ignored. In consequence many scored but one mark of the available four here.

Mass calibration was well done, records were carefully and fully reported, and many candidates gained the maximum of four marks for this part of the experiment.

In the vibration part of the experiment, whilst results were reasonably well tabulated, few candidates recorded the measurements from which they deduced the length of the vibrating rod. This was not recognised as the important value it was. Most candidates provided just one value assuming that the length remained constant. Many said that they adjusted the apparatus so that the length was the same, but they provided no supporting figures, and so did not receive any credit. Marks were allotted for tabulation; for recording readings taken to determine l; for determining l each time a new, different sized, lump of plasticine was used. When timing the vibration, faults reported on in previous years continued to appear. Whilst most candidates measured and recorded intervals to better than a second, too few vibrations were counted, and then not checked. A significant number of candidates appeared to have no technique for dealing with rapid vibrations. Marks were given for counting at least 20 vibrations a trial, and for checking at least once. Extra checking received additional marks. A significant number of candidates chose to vary the number of vibrations in order to obtain similar intervals so trying to maintain a constant error. Such candidates were not penalised provided that they used time intervals large enough to invoke an adequately small error. Most candidates could calculate the frequency, though too many threw away accuracy by rounding down these values to 1 or 2 significant figures.

Three marks were available for drawing the graph: credit was given for choosing suitable scales; accurate plotting to the accuracy of the scale used; drawing a fair line through the trend of the plots (too many candidates ignored completely one of the plots in order to draw a straight line, so losing a mark). The trend showed a fair curve from the upper three points leading to a linear lower half, intercepting on the mass axis between 0.15 and 0.20 kg. Two marks were scored for a correct trend, and a further mark for an acceptable extrapolation.

In calculating a value for the Young modulus, credit was given for reading off a value for M_0 to the accuracy of the scales used (often lost due to the candidate's inability to read his/her own scales); calculating an average value for l (rarely done); substituting correctly into the given formula and calculating an answer for E to a justifiable number of significant figures; obtaining an acceptable answer of the correct order of magnitude; and quoting the correct SI unit.

Q.2 Several centres reported difficulties with the preparation and use of the tubes. This is regretted by the examiners as this pattern of behaviour had not been observed during trials, including sessions of high ambient temperatures.

Examiners thank Supervisors for their efforts in coping with this problem and ensured that candidates did not lose credit as a result of such a problem.

Many candidates lost an initial mark by failing to record temperatures as requested. Tabulation of results was usually good, though a significant number did not/could not record a unit for the reciprocal of the gas space length, a. Credit was given for an adequate number of observations, ten scoring full marks and other quantities in proportion. Some candidates took far more, which led to wide scatter of plots on the graph indicating that they had not left sufficient time for the apparatus to regain steady state conditions after an alteration. Credit was given also for recording the actual rule readings from which the required values were obtained, (these were expected to be read to a millimeter or better); for calculating the reciprocals of a, and the values of cos θ without throwing away accuracy; for examining the range of values suggested in the question.

Graphwork continues to cause problems to candidates who do not use sharp pencils, who cannot choose suitable scales (the usual crop of 3:1 and 6:1 ratios was observed); and who insist on rounding values to 1 or 2 significant figures, presumably to make the plotting easier.

The calculation of gradient was generally better done, though candidates are still failing to choose suitable points from their line from which to read off the coordinates. Far too many candidates, having indicated suitably separated points, lost credit by reading the values inaccurately, rounding to the nearest printed line in many cases. The intercept caused problems to many. Many candidates chose to read off the point where the line crossed the left hand edge of the graph graticule instead of using the cos $\theta = 0$ axis in the middle of their plot. Few gained credit for quoting units for the gradient and intercept.

Calculating the air pressure required finding the average value for the length of the mercury column (which caused little problem) but many lost the next mark by ignoring the units they had been using, and failing to substitute the average length in to the equation in the units named (viz: mm). A large number had trouble with the arithmetic at this stage. Far too many candidates were unable to read off p_y accurately because (i) they could not read the scale of the temperature axis and (ii) they tended to round off the values they were using. One decimal place was possible and expected. Most could do the simple addition to yield p_0, but not many obtained an answer within 5% of the Centre value returned to the examiners. Candidates showed some confusion over the choice of the number of significant figures in their answer. It was not an easy decision, but 4 or 5 significant figures are difficult to justify.

Q.3 Similar comments apply here as in *Question 1* to the use of a screw gauge to measure the diameter of the wire, and not many candidates scored the 4 marks available here, for stating and using the zero error; working to 3 significant figures; taking at least 4 readings in different positions; and obtaining a satisfactory answer.

The determination of the resistance per unit length had a maximum of 4 marks allocated also. These were for recording a balance length to a millimeter or better, checking this value (not just repeating it) and calculating an acceptable value for the value r, i.e. within the range 4.00 to 4.80 $\Omega\ m^{-1}$.

When working with the iron wire, credit was given for recording and tabulating values required; measuring lengths to the nearest mm or better; checking values of the length q, and sensibly averaging these; calculating q^{-1} without loss of accuracy; examining a satisfactory range of values of p (taken as between 0.300 m and 0.850 m, as many Centres reported problems with low current capacity cells used

in position E in the experiment); and obtaining a minimum of 6 different sets of readings.

Graph work was a little better in this question though blunt pencils, and slack work in plotting lost marks as did failing to read off values to the accuracy of the scales used, and not considering the units involved. This particularly led to loss of marks in the calculation. In the graph, credit was given for accurate plotting on suitably chosen scales, with a well-judged straight line through the trend (though a curve trend correctly drawn for short lengths p was not penalised). Graph deductions were scored according to how far apart points for gradient calculation were chosen, how accurately the coordinates were read off, how accurately the calculation was completed (at this stage provided accuracy is not lost, penalty is not exacted for excessive significant figures). Further credit was given for accurate read-off of intercept, and for quoting the units of the two quantities. The calculation scored three marks: the candidate who substituted correctly, worked an answer with acceptable significant figures, and obtained a value of the correct order of magnitude scored all three.