

Examiners' Report January 2007

GCE

GCE Physics (8540/9540)

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Examiners Report

6731 Unit Test PHY1

There were very few candidates who did not make some attempt at all parts of each question. An encouraging aspect was an improvement in the clarity of the answers given to those questions requiring extended writing such as 2(c), 4(c) and 8(c). The answers were not necessarily correct, but at least their descriptions were easily followed. A disappointing aspect was the drawing of diagrams such as in 2(a).

Question 1

Not many candidates recognised the force B to be the weight of the box, which of course does not change, and therefore there were very few perfect answers to this question. Virtually all candidates scored at least one mark and the most common mark was two.

Question 2

The drawing of the coin's path for part (a) was disappointing. Too few candidates exercised care over what they drew. Common errors were; paths that initially increased in height; paths that maintained a horizontal trajectory for several centimetres; and paths that began above, below and after the coin. The calculations requiring candidates to separate the horizontal and vertical motions raised familiar misunderstanding such as for part (b)(i) selecting $s = ut + 1/2at^2$ then using the horizontal velocity 1.5 m s^{-1} for u and then in (b)(ii) again selecting $s = ut + 1/2at^2$ and using $a = 9.81 \text{ m s}^{-1}$. There were also many correct answers to these calculations. Comparing the paths of the coins in part c produced some excellent answers. Candidates gave well reasoned accounts as to why the paths would be the same. A significant number however, argued wrongly, that the path of the coin of greater mass would fall to ground in less time because its larger weight would mean it would have a greater vertical acceleration and as a consequence would cover less horizontal distance.

Question 3

Nearly all candidates recognised the time interval of 0.8 s as the reaction time of the cyclist and car driver. Although most obtained the correct answer to (b)(i) there was a significant number who gave 6 s as the answer. The area under the graph being equal to the distance travelled was understood by most and this meant that provided some attempt was made to obtain the value of an appropriate area at least one mark was obtained. The velocity 9 m s^{-1} was sometimes misread as 8.5 m s^{-1} . Many different ways were used by the candidates for obtaining the area between the graphs. Sadly a few did the hard work and then lost a mark by giving the answer 18 m^2 .

Question 4

Part (a) was well answered and should have been, because this same type of question has been set frequently. However, candidates are still losing marks by not explaining their reasoning. 'Show that' questions require such explanation. Typically it was not explained that the mass must be multiplied by the gravitational field strength to obtain the weight. In (b)(i) some candidates lost a mark because they did not do what the question asked, which was 'show how the centre of gravity is located'. (b)(ii) was poorly answered with many just repeating the calculation 47.52 g or giving the answer $470 \times 0.6 = 282 \text{ N}$. 4(c) proved difficult even for some of the best candidates. Too often it was clear that candidates understood centre of gravity as though it was the weight of the slab. Although many realised the answer lay in the idea of perpendicular distance between the line of action of a force and the pivot, they could not apply this idea to this situation. The question can also be tackled in terms of work done, but few chose this route and those that did were generally unsuccessful.

Question 5

There were many excellent answers to this question. The parts that caused the most problem were (b) and (c)(i). In the former many did not prefix their answer 8.4 kg m s^{-1} with a minus sign and in the latter the momentum magnitudes or the speeds were subtracted leading to the incorrect solution 13.2 N .

Question 6

Nearly all candidates answered part (a) correctly. If they did make an error it was in not squaring the speed. There was much misunderstanding of the idea of kinetic energy being conserved and thus for (b)(i) answers such as 0 , $1.7 \times 10^{-15} \text{ J}$ and $4.8 \times 10^{-15} \text{ J}$ were quite common. In (b)(ii) most correct answers came from solutions involving conservation of momentum.

Question 7

(a)(i) and (a)(ii) were answered correctly by many candidates. In part (ii) if candidates described the mass of the nucleus in terms of it being massive or heavy or dense etc without any comparison made with the alpha particle's mass, and this was very rare, they obtained no marks. Part (b) was too much for most candidates. They were being asked to think a little beyond what they have read or been told. Again marks were available for a diagram but poor drawings, often revealing a disturbing appreciation of what causes the deflections, eg alphas actually hitting the nucleus, meant that in many cases no marks could be awarded.

Question 8

All parts of this question were generally well answered. In part (a) a fairly common error was to suggest that 'random' was really just another way of describing the process as spontaneous. Part (c) was generally well answered in terms of the requirements of the mark scheme. However, there was little appreciation of the need to keep the source and detector very close when introducing the absorbers. It was not uncommon for the distance of separation to be 20 cm or more even when using paper to show that there was no alpha present. The actual thickness of absorbers was not understood. This lack of understanding might be due to the fact that far fewer candidates have the practical experience of doing radioactivity experiments.

6732 Unit Test PHY2

Question 1

Most candidates scored reasonably well on this question but a lack of precision in their definitions meant that not many scored full marks. In the definition for pressure we did not expect candidates to define the area as being perpendicular to the direction of the force but we did insist on cross-sectional area in the definition of resistivity and a reference to absolute temperature or temperature in Kelvin for the pressure \times volume definition. The most common error other than these was confusion over the definition of n . It was sometimes referred to as a number of particles or particle number density.

Question 2

Part (a) was generally answered well with most candidates getting the correct answer. Some candidates tried to include the temperature in their power equation and consequently gained no credit. Part (b) was again well answered with most candidates being able to rearrange the equation and recognise the meaning of Q . Incorrect answers were mainly due to confusion over Q with some candidates merely omitting it whilst others made up a number. There is an expectation at AS level that candidates should realise that for a wire Q is the charge on an electron. Part(c) by its nature was a much more difficult part to the question and was generally badly answered. Hardly any candidates told us that resistance was due to collisions between electrons and ions/atoms. A reasonable number of candidates attempted to answer the question by correctly talking about collisions but their answers were often vague and not specific enough. "Atoms vibrate more" was a common statement as was "it is more difficult for the electrons to get through". A significant number did not relate an increase in resistance to an increase in the frequency of collisions merely stating that collisions started when the tungsten was hot.

Question 3

Part (a) many answered $E = V + Ir$ even though V was not on the diagram and the other common wrong answer was $E = IR + r$. Candidates who gave this answer were unable to get the second mark. The majority of candidates realised that to find the e.m.f. they needed to calculate the gradient but did not always consider the negative vertical intercept. Candidates who struggled with the graphical nature of this question were often able to score the marks for the power calculation. The common mistake here was to use $V = 1.5 \text{ V}$ with $R = 5 \Omega$ giving an answer of 0.45 W and saying that was approximately 0.3 W . Candidates need to know that in a "show that" question the difference will be in one more significant figure only. Three marks were rarely scored for drawing the graph for two cells in series. The -2 intercept was hardly ever seen and often the accuracy of the gradient being doubled was missed.

Question 4

It was good to see that more candidates attempted this question by the potential divider method rather than by calculating current but a common mistake was to find the potential difference across the 5Ω resistor rather than the 20Ω resistor. However the drawing of the potential divider diagram was very badly done with a significant number of candidates simply redrawing the previous circuit putting the two resistors in series. Of those who did attempt to put the resistors in parallel and so gain some credit, they often put the supply across the fixed resistor or drew circuits with short circuits in them. What this question demonstrated was that candidates are not able to draw potential divider circuits.

Question 5

The quality of the diagrams for the experimental determination of the specific latent heat of vaporisation of water was often poor. There were bunsen burners, candles, thermocouples and electrolysis arrangements. Also a lot of candidates did fusion experiments. Having said that, many got most of their marks for their diagrams because the standard of the methods was even worse with the greatest error being not realising that this experiment does not start until boiling has been established. Also vague statements like “measure the mass” are not creditworthy. Because the markscheme allowed any four out of six marking points, fairly weak candidates did sometimes score well. In future examinations the mark scheme is likely to be tighter. The two calculations that followed were generally well answered but candidates did struggle with the graphical representation of these values. Quite a few candidates did not score either of the marks. For those who did realise that they needed to draw a line joining (0,0) to (100,2) followed by a vertical line, many made the mistake of not making the vertical line long enough. The vertical line length needed to be their value for the energy change whereas commonly that was the point that they plotted the graph to.

Question 6

This was a question specifically about a heat engine and the symbols used for it. Surprisingly many failed to identify T as a temperature. We still see hot sinks and cold sources. Although W was often identified as work, in order to gain the mark, they needed to identify it as either mechanical work or the work done by the engine. Q was often loosely referred to as energy which is better than heat or charge but again not sufficient to gain the mark. Questions on heat engines and pumps appear regularly on this paper and still the majority of candidates do not use Kelvin temperatures in the efficiency equation. This was the most common mistake followed by using 24 instead of 0.24 for the efficiency and confusion between the temperatures. Candidates who realised that the thermal efficiency of a heat engine depends on the temperatures managed to score a mark but a significant number of candidates thought that it was to do with materials used or use of insulation.

Question 7

Many candidates scored full marks for the pressure calculation with the common error being to use a volume of 5 cm^3 instead of 15 cm^3 . Other mistakes were when candidates tried to convert (unnecessarily) cm^3 to m^3 or thought that they had to find a value for n from $PV = nRT$. The force calculation was generally well answered. For the pressure calculation a significant number of candidates did not realise that the initial temperature was given in the stem of the question and so again tried to use $PV = nRT$ usually ignoring n or inventing a value for it. Again many candidates lost marks because they failed to convert temperature to Kelvin. The graph generally scored well with many candidates showing familiarity with the pressure volume graph. The most common error was to draw the second graph so that it converged with the first at the end points.

6733/01 Unit Test PHY3

All topics started with a similar question, which allowed assessment across all areas of the specification and was tackled well by most candidates. Quite a few candidates did not follow the instructions given in part (a) - it is worth emphasising that if the instructions in any exam are not followed then marks will be lost as a result. Many of the keyword statements were based directly on the specification and it was clear when candidates were not familiar with this. Phonetic spellings were accepted, provided it was clear what the candidate meant, such as “britility” in Solid Materials; an exception to this was a “black hall” in Astrophysics.

Topic A - Astrophysics

Almost all candidates were able to correctly use Wien’s law, but the explanation of the two terms in part (b) (i) was not well tackled, with the exact meaning of the peak intensity wavelength and the Kelvin surface temperature of a star not being well explained. Marks were frequently lost for lack of attention to detail, such as missing the peak of the graph as being a little over one millimetre. In part (c), many candidates were able to use energy = power x time and attempted to convert years to seconds. The ratio of energies was occasionally given the wrong way round and some answers were left incomplete (for example, 250:3). Most candidates correctly identified neutron stars and black holes. A minority of candidates correctly quoted the mass limits of the remnants, so basic learning of specification is recommended here. Most candidates secured both marks for the density calculation in part (d), but had less success with explaining how neutrons were formed in a star, where the fusion process during main sequence and gravitational collapse afterwards were often omitted. Many candidates scored poorly in part (e) due to distances being used in kilometres: this is often the case in Astrophysics and candidates should be more familiar with this. Error carried forward into part (ii) here greatly helped many candidates and is a good illustration of the importance of showing full working.

Topic B - Solid Materials

The units in part (b) caused difficulties for many candidates. The best approach here is to clearly explain each part of the equation in turn in terms of its units; base units did not have to be used, but this usually provided a more secure route. Marks were frequently lost here since examiners could not understand what the candidate was actually referring to. The calculations in parts (ii) and (iii) highlighted that most candidates could substitute numbers into basics equations in part (ii) (with omitted prefixes being seen more often than might be expected), but an alarmingly large number of candidates could not relate energy density to the area under a stress-strain graph, in spite of this being quoted in the specification. The importance of basic definitions was highlighted in part (c): there are a lot of these in the Solid Materials topic and they need to be learned for success in this paper. Calculations were generally well done, although very few candidates extended the initial gradient of their graph when calculating the Young modulus; poor accuracy here was penalised. Again, prefix errors proved costly for some candidates. In (d), Quench hardening was well understood but work hardening was less well explained; “repeatedly beating with a hammer” was sufficient to illustrate the latter.

Topic C - Nuclear and Particle Physics

Most candidates scored well in part (a) and the calculations in (b), sections (i) and (ii). The calculation of a neutron radius caused more difficulties - perhaps taking a cube root combined with a conceptual understanding of a neutron star being like a single huge nucleus giving rise to this. Many promising answers were seen for part (v), although the fact that neutrinos only interact by the weak interaction was often omitted. A full justification of the double plus charge for the delta particle in part (c) required the charge of plus one for both the proton and π^+ to be linked with charge conservation and was successfully produced by most candidates. Whilst the quark composition of the delta particle was often stated, the cancelling of the down and anti-down quarks was rarely seen. The energy spectrum in part (d) was well known, but the explanation that followed was often poorly constructed, with several quoted statements that were not fully linked being seen by examiners. Energy conservation for the decay of a neutron to a proton was expected here. Good candidates mentioned both rest masses and kinetic energy as part of their explanation.

Topic D - Medical Physics

Part (a) was well answered, but the usefulness of Tc-99m for tracer investigations was not well tackled in part (b). Explanations were often lacking or inadequate: "pure gamma emitter" and "suitable half life" are common examples of statements that needed an explanation to support them. Question (b) (iii) was generally well done but the definition of biological half-life was often omitted or incorrect (several responses gave time taken to be absorbed or time to be excreted by organ). In part (c), a surprisingly large number of candidates had parts 2 and 3 interchanged, although this error was carried forward and marks could still be gained for correct functions. Other common errors included: "collimator only allows rays from underneath", "collimator absorbs scattered rays", "collimator collimates the rays", PM tubes "accelerate electrons" or "amplify flashes". None of these statements scored marks. Most candidates scored well with the calculations in part (d), although a sizable number used their value of specific acoustic impedance in bone for their calculation of the speed of sound in tissue. In (e) the vague statement, "MeV X-rays do not depend on proton number" was often seen with no reference to absorption or attenuation and hence did not score a mark. Diagrams in part (ii) were often very poor, with no labelling or beams not reaching the target. Several responses stated, incorrectly, that no damage was done to the surrounding tissue. The inverse square law calculation at the end of the paper was well answered by most candidates.

6733/2A Practical Test PHY3

Question A.

The majority of candidates could set up the circuit correctly, however in a minority of cases, problems were created by Supervisors not checking the circuit thoroughly enough. Supervisors are instructed either to correct or ignore meter polarity errors, however power supply polarity errors must be corrected. Where the power supply was reversed the currents and voltages appeared in a different order compared to the table shown in the published mark scheme. In such circumstances examiners gave full credit for the table in a different order but did not award the 2 marks for setting up the circuit correctly. Several candidates had current readings of 0.0 mA for all currents. This suggests that the voltmeter was connected in series with the hidden circuit, again this should have been a fault that was corrected by the Supervisor. Such scripts make it difficult to be fair to the candidates. For all currents equal to 0.0 mA, for example, examiners gave credit for circuit set up correctly (because the Supervisor had not reported otherwise) and units and precision of readings in the table. No credit was given for the 0.0 mA readings which meant the loss of 4 marks. Checking circuits, particularly in a large laboratory, can be time consuming but is a necessary part of the practical examination. Candidates should be encouraged to ask the Supervisor if they feel that there is something wrong with their circuit, e.g. all readings are 0.0 mA. Excluding these unusual cases, the majority of candidates obtained full marks for the table of current and potential difference readings. Weaker candidates:

- omitted units from the table;
- quoted the current reading as Amps;
- did not record some readings to the correct precision, e.g. 9 mA rather than 9.0 mA.

When discussing the circuit that was shown on the question paper, a very small minority of candidates realised the parallel nature of the circuit. The majority of candidates chose NM or MN because it had a single resistor whereas the other paths consisted of a resistor and a diode. Examiners gave some credit for this so that the majority of candidates gained 2 or 3 marks. A tiny minority, probably less than 1%, realised that there were two routes for the current if N was positive and M was negative.

Part (b) of question A gave much better discrimination; the full range of marks being obtained for all sections. Typical mistakes made by the weaker candidates included:

- not recording l , w and t to the nearest mm or better, e.g. $l = 10$ cm;
- not repeating readings of l , w and t ;
- obtaining an incorrect value for the density by incorrectly converting cm or mm to metres;
- using an inappropriate number of significant figures (usually too many) for both the density and the ratio of the depths;
- drawing a diagram that did not fully illustrate the correct positioning of the pins.

Question B.

Sections (a) to (d) produced good discrimination between candidates. Weaker candidates made the following errors:

- the heights of the blocks were sometimes quoted to the nearest cm;
- the unit of the angle was not quoted or the angle was quoted to too many significant figures;
- a number of candidates used m s^{-1} as the unit of acceleration;
- the value of R was frequently either quoted to 1 significant figure, e.g. 0.005, or given the unit of Newtons or turned out to be negative because of inaccurate measurements.

When determining the uncertainty in the time taken for the trolley to travel 0.800 m candidates should have looked at the range of their results. A number of candidates quoted the uncertainty as 0.01 s, which is the precision of the stopwatch and too small for the likely uncertainty in the reading. Also if the range of readings is very small, for example 0.03 seconds, then candidates ought to take account of the reaction time in starting and stopping the stopwatch. This is likely to be at least 0.1 seconds.

When determining the percentage difference between two values, the average value should be used as the denominator. Good candidates did this but a number of weaker candidates used one of the two values as the denominator. In the last part of section (f), examiners required some quantitative work. For example, if the percentage uncertainty in t was 9%, examiners expected a statement that the percentage uncertainty in t^2 was 18%. Too many candidates restated the question and gained no credit for this. Virtually no candidates commented on the fact that there were two values of R so that the percentage uncertainty in the difference between the two values would be doubled again i.e. 36% in the above example. Credit was given for any sensible comment comparing the percentage uncertainty and the percentage difference and drawing a sensible conclusion. A number of candidates gained this mark even though they had not scored the previous 2 marks.

Most candidates gained the vary θ measure t marks and the mark for plotting the correct graph. However despite stating that the intercept on the a axis was $-g R$, many candidates drew a straight line that had a positive intercept on this axis. A proportion of candidates did not answer part (iii) of the question i.e. did not state how the value of R could be found from the intercept. Weaker candidates sketched a against θ , drew straight lines through the origin or straight lines with a negative slope, stated that R was the gradient of the graph, etc. The general point is that candidates need to be able to recognise the variables and the constants in an equation and to be able to compare such an equation to $y = m x + c$.

General Comments.

The paper was accessible to candidates with no evidence of candidates being short of time. The electrical measurement section of question A proved to be relatively straightforward and this has given the paper a slightly higher mark than last January's paper.

6734 Unit Test PHY4

Like last June's, this was a relatively accessible paper with plenty of familiar questions and straightforward calculations. Most candidates seemed very well prepared for these, but they were much less successful with non-routine explanations and calculations which needed tackling from first principles. Basic skills of algebraic manipulation, unit conversion and drawing clearly labelled diagrams were also poor in many instances.

Question 1

This question about polarisation tested candidates' powers of expression severely, and it is likely that many understood the first part without earning the marks. Asking them to include a diagram was intended to help, but diagrams were often too poorly labelled to be any use. Whilst sloppy wording ("the motion is perpendicular to the motion") remains common, an encouraging number of candidates did manage to produce acceptable definitions of longitudinal and transverse waves, but they often stopped there, not seeing any need to explain what polarisation actually means. Those who tried had great difficulty in expressing clearly the fact that a transverse wave can vibrate in different planes; statements like "transverse waves travel in different planes, longitudinal travel in only one plane" were common.

In part (b) most candidates understood the effect of a single polaroid on light from a filament lamp, but when asked about rotating it they often slipped into describing the different experiment with two polaroids.

Question 2

This proved quite discriminating, because two of the three calculations had to be tackled from first principles. Weak candidates tried to use the formula $I = P/4\pi r^2$ in all three parts. In part (a) most people understood the required physics steps, but only a minority reached the correct answer because they could not convert 10 cm^2 to m^2 . Many treated the area as $(10 \text{ cm})^2$. A number had the efficiency formula upside down or tried to calculate the fraction of the energy wasted. In the next part the inverse square formula did apply, but many candidates failed to square the distance and only a minority could handle the units. In the last part the examiners were shocked by how few people could calculate the area of a circle. Many had no idea of the formula, and those who knew it substituted the diameter as often as the radius.

Question 3

Here, on more familiar ground, virtually all candidates performed strongly. Nearly everyone had learned an acceptable definition of s.h.m., although "acceleration is proportional to the negative displacement" was a common, not quite watertight, statement. In part (b) they tackled the sequence of straightforward calculations confidently. A few obtained the correct answers by using the circular motion formulae from the same section of the formula list; whilst they might have been thinking of the auxiliary circle, the examiners were not convinced. Some weak algebra marred the last part, with a significant number unable to rearrange the period formula to calculate the mass.

Question 4

Explaining how a cello bow causes a stationary wave was a tricky question, because it is not immediately obvious what the bow is doing (and the wave produced is in reality more complicated). Candidates were not expected to know about the stick-slip mechanism (though the few who did received credit), but nevertheless a good proportion realised that the bow was causing a vibration, and discussed the result in terms of either superposing waves or resonance. A few candidates thought the vibration was being driven by backwards and forwards movement of the bow. This part was hard, but candidates were compensated in part (ii) where virtually everyone scored two easy marks for reading the wavelength off the diagram.

In part (iii) most people could identify differences between the string and sound waves, but sometimes dropped marks needlessly. When asked to distinguish two things, they need to make a clear statement about each one, rather than leaving half the answer implied (as in “the sound wave is longitudinal”). When asked for two differences, they need to ensure that they are distinct: a candidate who had said that one wave was progressive and the other stationary would not earn a second mark for mentioning the presence or otherwise of nodes and antinodes. A surprising minority thought that the string waves travelled at the speed of light and could propagate in a vacuum.

In part (b) most candidates made a good job of transforming information from the unfamiliar format of a frequency spectrum to a waveform plot. Where errors were made, they were usually in the period of the waveform.

Question 5

Most candidates managed to suggest three conditions for observable interference, but they often lost marks through repetition (“same frequency” and “same wavelength”) or giving conditions specific to particular experiments. Coherence was often mentioned, though not always understood (“the waves must be coherent and of similar frequency”, “the waves must come from a coherent source”). Many said “the waves must be in phase”, suggesting that they were thinking about the sources rather than the waves themselves.

Part (b) was low scoring. Nearly everyone knew the basic arrangement for a two-slit interference experiment, but quite a few candidates did not seem familiar with the microwave version. The inclusion of screens, single slits and unsuitably small slit dimensions suggested that they were either confusing the microwave and optical experiments or trying to adapt the latter without real understanding. Very few stated that the plates used to construct the slits should be made of metal.

In part (b), only the best candidates knew how to find the wavelength when the formula $\lambda = xs/D$ is not valid. Many confused the experiment, explicitly or implicitly, with the one involving normal reflection from a metal plate, and stated that the spacing of maxima should be $\lambda/2$. Others suggested measuring the frequency and using $\lambda = c/f$, or ignored the question completely and proposed using $\lambda = xs/D$. A few good candidates suggested measuring θ and using $s \sin \theta = n\lambda$; unfortunately this is only valid if $D \gg s$, which is not usually the case in the microwave experiment. Throughout the question, candidates' use of “maxima” to denote the singular was a source of irritation.

Question 6

A few excellent answers were seen to part (a), but overall the response was weak. Answers were bedevilled by confused terminology as well as confused physics. Many candidates said that electrons were “emitted from the photocell”, and many others had them passing from the anode to the cathode. It was not always clear whether - in spite of the labels on the diagram - they were using “anode” and “cathode” to denote polarities rather than physical objects (a mistake the examiners treated sympathetically), or whether they genuinely thought the photocell was a two-way device which would pass current either way depending on the applied p.d.. Further confusion arose when candidates talked about the number of electrons “emitted” or “released from” the cathode when one suspected that they meant the number crossing the gap to the anode. A sizeable proportion of candidates had no idea at all and either wrote vaguely about the reverse p.d. “increasing the resistance” of the circuit, or more wildly about changes to the light intensity or work function. Only the best candidates identified the energy distribution of the electrons as the key to the explanation.

The gulf between superficial knowledge and understanding was apparent in part (b). Almost everyone correctly stated the effects of increasing intensity and frequency on the stopping potential, even when they had no idea what was happening in part (a).

Question 7

Although part (a) was quite a complicated calculation with several steps, candidates had clearly been well schooled in how to do it. They have also assimilated the need for sufficient significant figures in “show that” answers, so that a pleasing proportion scored full marks. Many solutions were poorly set out, but candidates were not helped by the limited space provided for their answer. A few chose the plausible, but incorrect, method of using $E = hf$ and $v = f\lambda$.

In parts (ii) and (iii) the majority of candidates identified the wavelength as that of X-rays and realised that this was suitable for diffraction, but they were often vague about why. Answers often compared the wavelength to “the gaps in the structure” or, worse, “the gaps between structures”.

The last part, on wave-particle duality, was capably answered and allowed most candidates to earn the clarity mark. The commonest omission was any example of electrons exhibiting particle behaviour. Some candidates regarded their particle nature as too obvious to need comment, whilst many others just mentioned a property like mass, rather than giving an example of behaviour. Quite a few suggested the photoelectric effect; this would have had merit if they had convinced the examiners that they were thinking about the electron and not the photon, but they rarely did.

Grade boundaries

The raw mark obtained in each Unit is converted into a standardised mark on a uniform mark scale, and the uniform marks are then aggregated into a total for the subject. The tables show the boundaries at which the raw marks are converted into uniform marks. Raw marks within each grade are scaled appropriately within the equivalent range of uniform marks.

Units converted to 90 uniform marks

Unit	Maximum mark	Grade				
		A	B	C	D	E
	<i>Uniform marks</i> 90	72	63	54	45	36
	<i>Raw marks</i>					
PHY1	60	43	38	33	28	24
PHY2	60	42	37	32	27	22
PHY4	60	46	41	37	33	29

Units converted to 120 uniform marks

Unit	Maximum mark	Grade				
		A	B	C	D	E
	<i>Uniform marks</i> 120	96	84	72	60	48
	<i>Raw marks</i>					
PHY3	96	70	63	56	49	43

Raw marks are obtained for PHY3 by multiplying the component mark for Paper 1 by 1.5 and adding it to the mark for Paper 2. Grade boundaries for the individual papers are not available.

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