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Physics (9540/8540)

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Examiners' Report

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6731 Unit Test PHY1

Most candidates made some attempt at all parts of every question. In general they performed better doing calculations than in writing explanations or defining laws.

Question 1

The average mark on this question was 3. Mostly the mark lost was for part iii, where 'impulse' was the most frequent wrong answer given.

Question 2

Completing Newton's third law was generally well done. The word 'same' for 'equals' and omitting the fact that the force acts on 'body A' were the main reasons why candidates lost a mark here. The bodies upon which the Newton third law pair forces acts was poorly answered. The question, in different guises, has been asked many times before and therefore it was disappointing to see so many wrong answers e.g. the newtonmeter instead of the Earth. It should be noted that the ground is not acceptable as an equivalent for the Earth.

Question 3

Part A was well answered. Most candidates favouring the more direct route to the answer using $s = ut + 0.5at^2$, rather than using 2 equations such as $v^2 = u^2 + 2as$ then $v = u + at$. Part b proved difficult for many. A popular wrong solution was to work out the vertical (downward) velocity at impact and to then assume that this was the initial vertical (upward) velocity as it left the surface on its rise to the top of the wicket. Also many used $s = ut + 0.5at^2$ using $g = 9.81 ms^{-2}$ and $u = 0$. However, unless it was clear from a candidate's working that they were considering the fall of the ball from the wicket, as this would mirror the rise to the wicket, they did not obtain any marks for this. The horizontal velocity was generally calculated correctly allowing for error carried forward. However, there was a minority of candidates who thought that 'g' played some part in this solution. Virtually all candidates achieved the mark for part d. However, mention of gravitational force negated any mark they would otherwise have obtained.

Question 4

The definition of Newton's second law in terms of momentum was not well done. 'Force is proportional to change in momentum' was typical of the sort of inaccurate response candidates gave and very often reference to the direction in which the rate of change took place was not given. It should be noted that it is acceptable to define the law in terms of an equation provided all symbols are defined. This might help those candidates who struggle with English. The calculations were generally well done. Oddly, there was a significant number of candidates who, having given a correct answer for the rate of change of momentum in part c, then divided this value by 2 to obtain the value of the force for the last part of the question.

Question 5

In all recent papers the definition of the principle of moments has been required and yet, despite easy access to mark schemes etc., the number of candidates who define this accurately has not improved. The same errors occur such as, omitting references to equilibrium (or balance) and/or total (or sum) when describing the moments equality. Weaker candidates confuse moment and momentum. The calculations for (b)(i) and (b)(ii) were generally well done and many scored full marks. Part (b)(iii) on the other hand resulted in a tiny percentage of candidates achieving both marks. Most thought the force produced by the newtonmeter increased or decreased and gave spurious reasons why such as; 'the gravity is less because the bar has been raised so the force is less'; 'All the distances are reduced so the force is greater'. Part(b)(iv) was well answered and many candidates obtained 3 or 4 marks. The most common point not included in descriptions was the fact that the anti-clockwise moment (or the moment of the newtonmeter) increases. It was not sufficient to simply say 'the moments must be equal therefore T must increase', thus leaving it to the examiner to deduce that the anti-clockwise moment must therefore increase.

Question 6

Many candidates obtained full marks for the calculations in (i), (iii) and (v). There were some precise definitions of the principle of conservation of energy, but in general the response of candidates was disappointing. The simple statement 'energy cannot be created or destroyed' would gain full marks. Most candidates lost marks in part (iv). The energy transfer from chemical to gravitational potential energy was rarely seen in describing the lifting of the bar. The transfer from gravitational potential energy to kinetic energy as the bar falls was generally understood, but candidates that omitted the word 'gravitational' lost this mark. There were few answers that explained that the loss in gpe was equal to the gain in ke. Obviously, correct references to energy transfer into thermal energy were also accepted, but to gain marks kinetic energy had to be mentioned.

Question 7

Most candidates were able to plot the points accurately on the graph. However, 'line of best fit' seems to many candidates to mean a straight line only. This misconception then led to other marks being lost. For instance in part v when asked for a difference between the model and radioactivity they gave the fact that the graph was a straight line as a difference. The definition of half life contained the usual inaccuracies e.g. 'the time it takes the nucleus to halve', 'the time it takes the mass of a radioactive substance to halve'. Mention of 'average' time was rare even though this has been mentioned in previous reports.

Question 8

Parts (i) and (ii) were generally well answered with many candidates gaining all three marks. In part (iii), candidates who indicated the changes in A and Z with numbers, but did not assign a plus or minus sign to them, lost marks.

6732 Unit Test PHY2

Question 1
The definition of potential difference was badly answered with *V* = *IR* being the most common answer. Weaker candidates then proceeded to use ohms and amps to try to express the volt in base units without realising that the ohm is defined from the volt. It was interesting how many of the more able candidates were able to express the volt in base units starting from the volt as a joule per coulomb without actually scoring the mark for the definition of the volt. A significant number of candidates scored full marks for the energy calculation. Providing the correct equation had been remembered marks were generally lost by candidates forgetting to convert minutes into seconds.

Question 2
The definitions were not as well known as they should be especially *n*, number of charge carriers per unit volume. It is the per unit volume that is frequently omitted and some candidates seem to think that it means all of the electrons per unit volume. Of great concern are the candidates who do not seem to realise that some symbols are used to define more than one quantity and so a not insignificant number of candidates refer to *n* as number of moles and *v* as a volume or potential difference. A number of candidates misinterpreted part (b), not seeming to realise that a comparison between conductors and insulators was required. Section (c) proved to be a good discriminator with competent candidates coming to the correct conclusion by careful reasoning and others getting part way there or arriving at entirely the wrong answer. For candidates who did realise there was in inverse relationship the common error was to work with a factor of 2 instead of 4. Some candidates lost a mark by not identifying the terms that remain constant.

Question 3
Good candidates were able to score full marks on this question however most struggled with this question. The majority correctly calculated the potential difference across the parallel combination but then proceeded to use the full 6 V for calculating the current through the 4 Ω resistor. This demonstrates a lack of understanding about potential differences in a circuit.

Question 4
A number of weaker candidates made errors reading the scales on the graph, resulting in a lot of lost marks. Most candidates did know how to extract emf and internal resistance from the graph. However most did not realise that the working current was the intersection of the two graphs and for the resistance calculation took random points from the curve, the most popular one being the top of the curve at 9 V. Most candidates were able to score some marks for the experimental description but slightly alarming were the candidates who had a battery, wire, ammeter and voltmeter with no resistive load. Candidates need to realise that in order to obtain a graph, a range of readings are necessary and so a means of varying the resistance is essential. Candidates did not always think about what they had drawn and what the question asked for. They often included two resistive components e.g. a light bulb and a variable resistor and put their voltmeter across one of these so that they would not be measuring the terminal potential difference of the cell.

Question 5

Part (a) required factual recall and while a significant number did score full marks the majority did not with the most common errors being with *n* given as the number of molecules being the commonest wrong answer and *T* where ^{O}K or ^{O}C were common. Part (b) was another good discriminator with only a minority of candidates scoring all four marks. Two common mistakes were made, forgetting to convert the Celsius temperature to Kelvin and misreading the question by using the given increase in volume as the final volume. A number of candidates worked from $pV = nRT$ and whilst this is possible it does make the calculation more difficult than simply using V/T = constant.

Question 6

Many candidates scored the full three marks for the graph with common mistakes for those candidates who did have the correct shape graph being starting the graph at 550 ^{O}C instead of 600 ^{O}C and not being able to correctly identify 660 ^{O}C on axis. The last part was very difficult because it needed both knowledge and clear expression. Whilst accepting that there is a continual interchange of KE and PE between molecules in any state, candidates need to realise that there is a link between the average temperature and the average KE of the molecules. Answers to this question demonstrated that most candidates do not understand the energy changes that occur. Many think that in order to change from a solid state to a liquid state, molecules actually need more KE. At the change of state stage, candidates forgot that energy was still being supplied and whilst they knew that energy was needed for the change of state they had the molecules converting energy from one form onto another.

Question 7

Most candidates were able to work out the correct answer for the first part. Many candidates do not realise that the first law of thermodynamics is an application of the principle of conservation of energy. The calculation of energy was often well done but a significant number of candidates subtracted their two values instead of adding them. Predictably, some changed 20 ^{O}C to 293 K while others, unpredictably chose a temperature change of 100 – 20 ^{O}C. In the last part of this question some candidates were obviously convinced that fins was a misspelling of fans. Others thought they were some sort of air vent by which warm air could escape. Whilst some of the marks were easily scored very few candidates realised that the convection process was established by the positioning of the fins. Many thought that convection was already occurring and so the sensible place to remove energy was from where the air was hottest.

6733/01 Unit Test PHY3

Topic A - Astrophysics

Two common mistakes were often seen by examiners in the y-axis additions in parts (i) and (ii) of section (a): luminosity was often quoted in watts (even when solar luminosities had already been mentioned) and the middle value of the scale was often incorrectly given as either 10 or zero. The temperature scale was often quoted correctly. Part (iv) was usually well answered, as was the calculation in part (v), although marks were sometimes lost as a result of an incorrect substitution or failure to square the distance value. Candidates who were able to calculate a ratio in part (vi) had more difficulty in converting their answer to standard from in order to identify star A.

The mass / energy calculations in part (b) often scored full marks, with common errors being to miss out the x 10^{-27} or a unit (either kg or J). Despite (c) (i) indicating that there were four options to be underlined, it was common to see only three options chosen: the neutron star was almost invariably underlined, but the minimum mass was less well known. Responses to part (ii) were mixed. Some of these went into detail about how pulsars worked, which is not what the question had asked for. In part (d), it is worth reminding candidates that the formula for the volume of a sphere is given at the end of the exam paper; sphere (or even circle) areas were quite common incorrect responses. In part (ii), many candidates neglected to use the graph scales and hence only scored one of the three marks available. In part (iii), a significant number of responses incorrectly implied that a white dwarf was still undergoing fusion, or that it became a brown dwarf, which is a quite different sort of 'star' altogether.

Topic B – Solid Materials

Almost all candidates were able to correctly add to the graph in part (i). In part (ii), a value of strain was often used that was beyond the linear region of the graph. Some scales were added to the graph that went up in steps of 0.975: this did not gain a mark as a **suitable** scale. The ultimate tensile stress in (iii) was sometimes quoted as the yield stress. Despite yield stress being defined explicitly in the specification only about 50% of all candidates could quote its meaning: this indicates that many candidates need to become more familiar with the single A4 sheet of the specification for their topic. Parts (v) and (vi) were well answered by many, although in part (vii) many candidates did not score any marks since they were unable to equate energy density to the area under their graph.

In part (b), very few candidates could explain how dislocations could make plastic deformation easier. There was little reference to a half plane of atoms or to bonds being broken one at a time. Part (c) (i) was very poorly answered, with numerous vague references to potential energy being made, whereas 'chemical energy', 'strain energy' and 'gravitational potential energy' are expected at this level. Parts (ii) and (iii) usually scored well. Composites were sometimes described vaguely in part (d) with many answers make statements that did not gain any marks, such as, 'composites are stronger' or 'brittle means easy to break'. There are standard definitions for this topic that should be learnt.

Topic C – Nuclear and Particle Physics

Most candidates recognised the energy spectrum graph in (a) (i) and could add the MeV unit, although very few labelled the x-axis as kinetic energy. Part (ii) worked well as an exam question, with a very even spread of scores from zero to all four; as ever, those candidates who knew their topic could give brief and accurate statements that gained marks. Quark compositions in part (b) (i) were well known, although common mistakes in part (ii) involved repeating that a neutron changed to a proton for beta-plus decay (the correct answer is the opposite of this) or producing an antineutrino instead of a neutrino. Part (iii) proved to be one of the tougher questions in the topic since full marks required mention of both (anti)neutrinos and the change in quark flavours for both beta-minus **and** beta-plus decays. The exchange particles for part (iv) were often correctly identified, although examiners saw a diverse range of particles mentioned here.

The calculations that comprised part (c) were mostly done well, although quite a few candidates do have problems with $A^{1/3}$ (i.e. taking a cube root), sometimes multiplying by a third instead. In part (e) on antimatter it is worth noting that charges need to have a magnitude: in (ii) a statement that 'positrons are positive, antiprotons are negative' did not gain credit since a value was also required. Although the actual value is plus/minus *e* (electronic charge), examiners accepted +1 and –1 here. The spelling of 'annihilation' has improved much over recent years.

Topic D – Medical Physics

The time axis in (a) part (i) was correctly labelled by almost all candidates, except for a few who chose 'half-life' instead. Although most scored both marks in part (ii), a sizable minority did not follow the instruction to show how graph R was used **on the graph**: an indication of one half-life equating to six hours needed to be shown. A large number of candidates gave their answer to part (iii) as simply four hours; having read a value of the effective half-life from their graph, they did not actually go on and use this to calculate the biological half-life. In part (b), about two thirds scored the mark for the nuclear equation, but the opposite was true for the source of the molybdenum, where 'in an illusion cell' was an novel (and quite incorrect) suggestion. Some referred to neutron bombardment but did not actually answer the question and say where this happened. Some very good answers were seen in part (iii). Part (iv) illustrated whether an understanding of metastability was grasped (not the case for most candidates), and some interesting (incorrect) answers were seen in part (v) where many thought that a long half-life for the technetium daughter product would be useful for future tracer studies and save the patient having to be injected with any additional technetium.

Part (c) showed a real confusion between X-ray diagnosis and ultrasound imaging, with only about half of all candidates identifying proton number as the important factor for absorption of keV X-rays (this is stated explicitly in the specification). In part (ii) many candidates discussed what happens to the photographic film without actually tackling the question itself and referring to the proton number of different parts of the human body. In part (iii) it is worth noting that examiners accepted any spelling of vacuum that was phonetically correct, which helped a large number of candidates. As has been seen in previous papers, the high voltage function was often described as 'to **attract** electrons', which did not gain credit (a low voltage would also attract them). The function of the anode was usually described as to rotate to dissipate heat; whilst this is true it is not the primary purpose of the anode, which is to be the source of X-rays. A few candidates mentioned that electrons could turn into X-rays, as opposed to the **energy** change. Part (d) scored well for many candidates; common errors were to describe acoustic impedances in (i) of surfaces as opposed to media, or to give the reflection coefficient a unit in part (iii). Only a minority could relate the figure for reflection with that of transmission in part (iv).

6733/02 Practical Test PHY3

General Points

In order to improve marks on this paper, candidates need to take more care when describing experimental techniques. For example in paper 2A, question 1 (a) (i) very few candidates described how they would ensure that the metre rule was either parallel or perpendicular to the edge of the foil. Similar problems were encountered in the planning section of the paper where the majority of candidates did not describe how to make the string horizontal, etc. despite the fact that they had done this part of the experiment in the previous sections.

Group 1 (2A)

Question 1A
Most candidates could successfully determine the values of *l* and *w* and repeated their measurements. As stated in the opening remarks few candidates could describe successfully how it was ensured that the metre rule was perpendicular or parallel to the edge of the foil. A diagram showing the rule along the edge of the foil or with a set square at the edge showing the rule perpendicular to the edge of the foil would have been sufficient to score the mark.

Most candidates obtained a value for 16*t* that lay in the expected range and often repeat readings were shown. The better candidates checked the zero error of the instrument or explained how the foil was smoothed to exclude air or folded to avoid creases.
The percentage uncertainty in *t* proved a major obstacle for E grade candidates. It is important for candidates to realise that the percentage uncertainty in *t* is exactly the same as the percentage uncertainty in 16*t*. If the **percentage** uncertainty in *16t* is found, it is not necessary to divide this figure by 16 in order to find the percentage uncertainty in *t*. In order to answer this question it was simply necessary to estimate the percentage uncertainty in 16*t*. In the majority of cases candidates had a range of 16*t* that was greater than the instrument precision of 0.01 mm. In such cases it is important that candidates use the range or ½ the range of their results in order to estimate the uncertainty in their result. In these circumstances the precision of the instrument must not be used. The precision of the instrument should only be used if all the repeated measurements are the same or if only one measurement has been taken.

Most candidates knew that density = mass/volume, however the volume calculation proved difficult for some candidates. There were those who mixed units of cm for *l* and *w* with mm for *t* and those who used 16*t* instead of *t*.

Virtually no candidates had difficulty setting up the circuit. Because of problems with contact resistance and variations in foil properties virtually any values for the p.d. across the foil were allowed provided they were measured to a precision of 0.1 V. Voltmeters of this precision had been specified in the instructions to Supervisors. Because of the problems of contact resistance, examiners had anticipated that candidates would repeat their measurements of the p.d., however this was rarely seen.
The resistance *R* was usually calculated correctly. A number of candidates thought that, because *I* was measured in mA and *V* was measured in mV, the answer was in mΩ, this was not correct because the milli factors cancelled out.

In determining the resistivity weaker candidates made the following mistakes:

- measured the width of the strip of foil to the nearest cm,
- mixed units of mm, cm and metres in the formula,
- gave the incorrect unit for the resistivity.

A very small number of candidates confused the width of the strip of foil with the width of the foil measured in the first part of the question.

Question 1B

Good candidates showed, on the diagram, the vertical metre rule with the set square between it and the bench. Many candidates showed this in two positions and gained the two marks without the need for a description. If it is suggested that candidates may add to the diagram if they wish, then often full marks can be obtained simply by adding full details to the diagram.

Most candidates obtained a correct value for the angle. Typical errors from weaker candidates included:

- quoting the heights to the nearest cm,
- obtaining a height difference that was outside the expected range because candidates had not followed the instruction to set the angle at approximately 30°.

Most candidates obtained a correct value for *W*. Typical errors from weaker candidates included:

- only recording the Newton meter reading to the nearest Newton,
- quoting the calculated value of *W* to an inappropriate number of significant figures.

Calculating the weight of the metre rule by balancing the rule on the knife edge produced a wide range of marks. Good candidates obtained all 5 marks, but weaker candidates made the following errors:

- not showing the measurements on the diagram with sufficient precision,
- calculating the mass of the rule rather than the weight,
- obtaining a value outside the expected range, in most cases because the distances on the rule had not been measured to the centre of mass of the 100 g mass,
- unit problems such as quoting the weight of the rule as 1.2 kg rather than 1.2 N.

Many candidates omitted the required detail in the planning part of the experiment.

Candidates should not be afraid to describe the techniques that they have used in the first part of the second experiment in order to answer the planning part. The major weakness of all candidates is not explaining how procedures are carried out, for example most candidates stated that the string needed to be made horizontal but few went on to say that this could be achieved either by increasing the separation of the stands, or by changing the height of the nail, or by changing the height of the Newton meter. Despite hints in the stem of the question, weaker candidates had difficulty identifying the variables in the given equation. Many plotted T against m without stating that θ would need to be held constant. Such a graph could not score marks for an intercept of ½ W because the intercept is now ½ $W / \cos\theta$, hence candidates who plotted such a graph rarely gained any marks for the processing of the results.

Group 2 (2B)

Question A in group 2 proved to be more straightforward the A question in group 1. However this was compensated for by a more difficult question B. The mean marks and standard deviations for the two groups were approximately the same.

Question 2A

The measurement of the diameter of the wire proved to be more straightforward than the measurement of the thickness of the foil. Sufficient precautions were allowed to enable most candidates to score full marks in the section. In the same way the measurement of the percentage uncertainty was straightforward and the majority of candidates scored the full 2 marks for this section.

The volume calculation did not have the problem of the confusion between 16*t* and *t*, however weaker candidates still had expressions that contained a mixture of units, normally *l* in metres and *d* in mm. This lead to a density value which had an incorrect power of 10 but the majority of candidates could obtain the first of the two value marks.

Contact resistance was less critical in this group but examiners still expected candidates to repeat their measurement of *V*, few did this. The calculation of resistance produced similar problems to those described in group 1. The calculation of resistivity lead to the same problems as described in group 1. Most candidates determined a correct value for *R* but weaker candidates mixed units of mm and cm in the formula and did not give the correct units for resistivity. Because of the problems of the foil in group 1, any correctly calculated value of resistivity was allowed, here candidates had to obtain an answer within a range of about $\pm$ 10% of the true value, good candidates had no difficulty with this but weaker candidates often obtained values outside the range.

Question 2B

Sections (a) to (d) in this group have comparable sections in group 1 and the comments made there are equally valid in this group.

In the calculation of the percentage difference examiners insisted that the average value of the weight of the rule was used in the denominator of the percentage difference calculation, this meant that only a small proportion of candidates gained the mark. The second part of this section did not discriminate between candidates. Most thought, incorrectly, that the horizontal metre rule with the Newton meter attached would give the most accurate value because it was more stable, they ignored points such as

- the mass of the rule had a very small effect on the Newton meter reading because the 1 kg mass was so much greater than the mass of the rule.
- the Newton meter could only be read to a precision of 0.1 N in about 6.0 N.
- the Newton meter is far less accurate than the metre rule.

Candidates were clearly worried about the fact that it was difficult to balance the metre rule on the knife edge. There was no appreciation of the fact that, say, a 1 mm movement of the pivot could produce a change from a resultant clockwise moment to a resultant anticlockwise moment so that the distance measurements were very precise, say, a 1 mm error in 200 mm. Candidates do not need to waste time achieving perfect balance, in fact a 1 mm movement of the pivot will change from resultant clockwise to resultant anticlockwise moment. Also the calibration of the metre rule is likely to be far more accurate than that of the Newton meter.

6734 Unit Test PHY4

Question 1

Most candidates were familiar with the kinematical explanation of the acceleration in terms of changing direction and changing velocity, and many earned three marks in this way. However the question required some reference to the free-body force diagram and the essential point – that the forces are unbalanced – was less often made. The word “centripetal” was not accepted as implying “resultant”, because of the frequency with which students misunderstand the concept of centripetal force. A full answer to the question as posed would also have included a dynamical explanation of why the speed remains constant, but this was very rarely seen.

Question 2

Whilst almost everyone gave the correct time interval between wavefronts in the first part, many did not appreciate that the time interval “between successive slits” was the same. They seemed to misinterpret the question as asking for the time interval between successive appearances of a given slit in front of the eye. Despite this, a good proportion of candidates calculated the correct angular speed, and nearly everyone got the correct velocity of point A. Success with the ratios in part (iv) was more mixed.

Question 3

The experiment descriptions in part (a) were usually very good – one felt this was something the candidates had learned carefully – and very detailed. Many could have earned the “precaution” mark several times over, although they sometimes omitted the more obvious things, such as any mention of the equipment used or a clear statement of the need to measure the period for a range of masses. Another common error was failing to specify that the straight line graph must pass through the origin. Perhaps partly because the candidates were on familiar ground, the quality of communication was high and the QOWC mark could nearly always be awarded.

Virtually everyone managed the calculation in part (b) successfully, and in part (c) resonance was well understood, although only a small minority of candidates pointed out that at resonance the amplitude is a maximum, as opposed to just being large. They found “natural frequency” much more difficult to explain, many saying merely that it was the frequency at which resonance occurred. A significant number of candidates talked about standing waves and resonance at multiples of the natural frequency; they had clearly not read the question correctly and were writing about a stretched string rather than a mass on a spring.

Question 4

In part (i) a pleasing number of candidates managed to give sensible values for the apparatus dimensions, but in finding the fringe separation in part (ii) quite a few did not realise that they were to make measurements from the diagram, and tried instead to use the formula $x = \lambda D/s$, substituting either their own suggested dimensions, or even measurements off the apparatus diagram. A further misunderstanding was to take “separation” to mean the width of the “dark strips”, rather than the distance s between fringe centres. Because of the way the diagram had been drawn, candidates received some credit for this interpretation. Most candidates got sensible answers, although the standard of explanation, particularly regarding the use of the scale, was poor. Part (b) - drawing the blue fringes - proved discriminating, with a correct, carefully drawn diagram the mark of a good candidate. The most common error, apart from incorrect spacing, was to draw the bright bands wider than the dark gaps.

Part (c) was the most poorly answered question on the paper. It seemed that most candidates had not learned about white light fringes. Interestingly, some did seem familiar with the single slit diffraction pattern for white light, talking here about a central maximum twice as wide as the others and flanked by spectra. Only a small minority of candidates scored any marks.

Question 5

The two calculations discriminated well. In part (a), weak candidates used $4\pi r^2$ for the area. Stronger ones realised that they should use πr^2, but often took the wrong component of the intensity. Only the best scored 3 marks. Part (b) was usually answered correctly, but a disappointing minority of candidates still do not know the relationship between energy, power and time.

Question 6

Most candidates drew a straight line graph with a positive gradient, but it often passed through the origin, had a positive intercept, or extended to physically unrealistic negative kinetic energies. Fully correct graphs, with the threshold frequency labelled, were quite rare. However, provided they had drawn a rising straight line, the majority gained the marks for parts (b) and (c).

Question 7

Part (a) was a standard calculation for which candidates were well prepared and produced many fully correct answers. That a number forgot the 10^3 factor from keV was not surprising; what was more worrying was how many of them nevertheless claimed to have obtained the correct answer! Identifying the correct part of the electromagnetic spectrum should have been straightforward but proved otherwise, with every possible type of electromagnetic wave putting in an appearance.

Question 8

In the first part, nearly everyone knew that the gradient of the graph was required, though quite a number made no attempt to convert light years to metres. Even for those who did, the powers of ten appearing on each graph axis caused many errors. A pleasing majority of candidates knew that measuring the distances to galaxies is the major source of error in determining *H*, though quite a few tried to hedge their bets by mentioning the velocity as well.

Answers to part (b) were often disappointingly vague, with many candidates just writing in a general way about the Big Bang and the expansion, or quoting "speed = distance / time" without saying precisely to which quantities it referred. A clear algebraic derivation of $t = 1/H$, using the symbols defined in the question, was not very common. Part (c) was another standard calculation, excellently done except by the minority who used the wrong wavelength in the denominator of the formula. Full marks on part (d) were rarer than expected. A surprising number of candidates got the situation the wrong way round, arguing that a high mass-energy density would lead to an open universe. Perhaps "high energy" suggests fast particles more likely to fly apart? Others, who clearly understood the physics, unfortunately failed to use the terms "open" or "closed" in their answer. Only a minority tried to explain what was happening in terms of gravitational attraction. Sloppy expression – "mass" instead of "density", or "gravity" instead of "gravitational force" - cost many marks.

6735/01 Unit Test PHY5

Question 1

Most students correctly stated the relationship, either as an equation or a proportionality. Significant flaws were the confusion of 'sum' with 'product', equalities that lacked a constant of proportionality, and the inappropriate suggestion that the term in the denominator was the square of a radius. A few students, perhaps flustered at the start of the examination, gave their answers in terms of mass. The base units of the constant were successfully arrived at by fewer than half the candidates. Many failed to recall that the coulomb is not a base unit and substituted only for the newton. Where a substitution for the C^2 term was attempted, a favourite error was to suggest $(As^{-1})^2$ instead of $(As)^2$. Some of those who did clear this hurdle successfully were then prone to carelessness in tidying their powers, erroneously cancelling s^{-2} in the numerator with s^2 in the denominator to throw away the final mark. A minority approached the problem using Fm^{-1} as their starting point. Belief that this 'F' was a force usually barred further progress.

Question 2

Most candidates seemed to know the direction of the current in L, though the ambiguous use of 'downwards' - seen quite often - suggested a gravitational context for the diagram not implied in the stem of the question. The perfect, undistorted circular pattern was recognised by the majority as indicative of the absence of any other fields, though a significant minority incorrectly suggested the field was radial, uniform, or, more mysteriously, featured equipotentials. The explanation part of the question was not generally well done. The fact that fields had cancelled was conveyed at length by some, without ever identifying how or why. Credit for the neutral point 'label' was the sole mark many ultimately achieved, with 'null point' a novel term often seen. Better candidates correctly identified the need for fields of equal strength and opposite direction, though few added correct detail to this by stating it occurred mid-way between the wires, or required the currents to be in the same direction. Indeed, the majority were driven by instinct to claim that the currents were in opposite directions, a conviction that did not affect contrary subsequent statements about field directions. Significant confusion was caused where arguments included conflicting claims that fields were both 'in the same direction' (rather than both 'clockwise') and at the same time 'in opposite directions'. This arose because candidates were making general initial statements about the overall field arrangement, then particular statements about the detail at the point in question, without ever indicating that they had tightened the focus of their argument. The language of interference phenomena was evident in too many answers. Diagrams sometimes added clarity to otherwise vague responses, but were often too sketchy to convey clear detail.

Question 3

All but a very few candidates were successful in Q3 (a), an exercise in which they have clearly had plenty of practice. Where credit was lost it was often due to an answer being given inadequately to just 1 s.f., presuming the result, or incorrectly as 4.1 instead of 4.2, the result of careless rounding of the true 4.19. At Q3 (c) there were many entirely successful efforts, though some false starts and scruffy layouts made following of the steps in solutions less than straightforward. The main weakness lay in finding the value of '*t*', with candidates who had already found a value for '*a*' often trying to force it into an equation of motion, rather than recalling that they already had a horizontal velocity and plate length from which to deduce a transit time. Weaker candidates were prone to mix quantities belonging distinctly to the horizontal and vertical parts of the electron's motion. A resourceful minority, whose mathematical route was clearly taking them into uncharted waters, took the value of *h* suggested on the diagram to be an accurate scale representation. The near-magical appearance of a ‘2cm’ value for *h* was, in the scripts of these candidates, quite a feat. The electron beam paths produced with smaller potential differences were often correctly shown, though beams that anticipated the deflecting effects of fields before they reached them, or ignored them for some time after entering them, were not uncommon. It was evident, in a good many examples, that candidates had not given as much care to the drawing of these beam paths as they might. Some very approximate attempts could gain little credit. Unlabelled efforts gained none.

Question 4
The foundation for this question was laid effectively by the majority in their statement of Newton’s law, though the same looseness in language was apparent here as in the corresponding Coulomb’s law statement at Q1(a). Having been obliged to give the latter as a word equation, most candidates elected to use the same format here, though it was not necessary. At Q4b(i) the best candidates produced a succinct and purposeful argument in support of the inverse square law relationship, following one of a number of routes to demonstrate the consistency of data from the graph with this physical reality. Weaker candidates often arrived at the same end point, though by roundabout routes. Almost all candidates successfully seized the opportunity to gain an easy mark at 4(c), though a few misinterpreted the question and answered it in terms of the effect of the Earth’s field on an object on the Moon’s surface. A small minority believed the Earth’s field to have no effect whatsover at this distance.

Question 5
Many candidates found it easy to arrive at the correct force value at Q5 (a) (i), though failure to convert grams to kilograms introduced an error factor here that would prove disconcerting later. Perhaps because the initial calculation was relatively straightforward, many candidates did not seem to have taken the time to understand the context of the question before attempting the explanatory part. Fundamentally flawed responses thus set out to explain why the rod experienced a downward force. Other candidate suspected that electromagnetic induction processes were the key to the argument, prompting elaboration of complex interactions of induced fields, e.m.f.s and currents. Other common weaknesses included the belief that the force on the balance itself could be justified as a Newton third law pair of the force on the rod, or suggestions that the current in the rod produced a magnetic field within it - or even an electric field around it. Despite the invitation to win credit through clarity, this injunction was ignored by many. Answers that hinted meanderingly at key points, without ever quite making them, were seen all too often. The use of a bullet-point strategy for picking off individual target points is again recommended.

Addition to the diagram at Q5(b)(i) was unsuccessful in the majority of cases, perhaps a carry-over of the misinterpretation of the effect of the interaction on the rod. Despite the emboldened text requiring labelling of the poles, some merely added field lines or, strangely, suggested the presence of positive and negative charges.

The calculation exercise at Q5(b)(ii) should have proved entirely straightforward, but undue haste prompted too many candidates to forget the meaning of ‘l’ in $F = BIl$. Merely working with a value of 20cm flagged up this significant misunderstanding. A minority bizarrely subtracted 5cm from 20cm and used the difference of 15cm in their calculation. Correct conversions of field and length values to a consistent set of units gave most who had started out correctly a plausible 2.6A value for I, though currents of several kA were required by an unabashed few.

6735/02 – Practical Test PHY5

Group 1 (2A)

Question A was a good test of candidates' techniques for taking straightforward measurements and of simple analysis of uncertainties. Unfortunately, many candidates were somewhat lacking in these basic skills expected at A2 level. Indeed, some candidates seemed to have forgotten what they had done at AS level, for example they were not able to measure the dimensions of the sheet of paper with either the accuracy and/or precision that was expected. Many did not take repeat readings, neither were they able to measure the thickness by folding the paper to give several layers.

The general attention to precision and significant figures was poor. Even quite good candidates often quoted the width of the paper as 21 cm (i.e. 2 sf) and then were quite happy to quote density as, for example, 821.3 kg m^{-3} (i.e. 4sf). In doing so, they lost two marks – one for the precision of the width and the other for too many sf in their density value.

A significant number of candidates lost marks for the timing part of the question as they did not time at least 15 oscillations. They should understand that if the oscillations die away fairly quickly, then more repeats are needed, e.g. at least 3 × 5 oscillations. The importance of using a marker at the *centre* of the oscillations is still not understood, despite this appearing in virtually every report.

Again, marks were lost by many candidates by not recording the lengths $l_1$and l_2 to a precision of 1 mm. It was common to see these distances given as 78 cm and 48 cm and then the ratio as 1.625, showing no understanding of significant figures. As candidates were told to assume that the uncertainty in $l_1$and l_2 was negligible, this ratio should have been taken as the denominator when determining the percentage difference between the two ratios and not the average value. This was a common mistake. Only the A grade candidates performed well in this section, getting 3 or 4 marks. Many candidates got no marks at all.

Most candidates performed very well in Question B, which was a straightforward electrical experiment, capable of yielding accurate results. It was pleasing to see even the E grade candidates taking at least 6 readings for line X, although only the better candidates also took 6 readings for line Y. The graph plotting was generally good, although a lot of candidates lost marks by only drawing small triangles when calculating the gradients. Grade A candidates extended their lines to the edge of the paper, which gave large triangles and made it easy to read off the co-ordinates.

Most candidates correctly calculated the ratio of the gradients, but made errors in comparing their values with the stated value of 0.360. Only the best candidates found the percentage difference using 0.360 as the denominator and the discussed whether this percentage difference was reasonable experimental error in the light of their measurements.

The answers to Question C were disappointing. It would appear that candidates had very little understanding of the basic experimental techniques when taking measurements of radioactivity, or had forgotten their AS work. Answers such as 'measure the background count at different parts of the laboratory' showed that they did not appreciate that it was important to measure the background count *where the experiment was to be conducted.* Neither did they know that the background count was small and random, therefore requiring that this be taken for *several minutes* to give an average value. Many descriptions lacked detail, such as recording the activity of the protactinium every 20 s, say, for two or three minutes.

Most candidates could derive the logarithmic equation, but invariably lost the 'units' mark by not writing the logarithm unit in the form ln(A/min^{-1}). Candidates must be taught that this is the correct way of expressing such a unit. As is usual with logarithmic plots, only the best candidates chose a large scale for the graph. It is disappointing that the above two errors are repeated year after year despite comments to this effect in the examiner's report.

Group 2 (2B)

This paper tested similar skills to paper 6735/2A and so many of the above comments also relate to this paper. It was interesting that candidates were better at describing *how* they would determine the thickness of the sheet of paper in Question A than they were in actually *doing* it in paper 6735/2A. Many candidates said that they would fold the paper several times and measure the thickness in different places in 6735/2B, but only the best candidates actually did this in 6735/2A.

In Question A it was not easy to get exactly reproducible values for the oscillations, which caused problems in the subsequent analysis of the uncertainties. Candidates, in the main, showed a poor understanding of uncertainties. A common error was to quote the uncertainty in the timings as 0.1 s (human reaction time) when their range, or half range, was significantly greater than this. Worse still was to quote an uncertainty of 0.01 s in the *period*. This suggested that they thought that they could time to the precision of the stopwatch, which is clearly not possible, and that they did not understand that the uncertainty should be as a percentage of the *actual timing*, not the calculated period. Most candidates did, however, realise that the two percentage uncertainties had to be added to find the percentage uncertainty in the ratio T_2 / T_1.

In question 2, most candidates were able to measure the diameter correctly, although only the better candidates took repeat measurements. Most were also able to set up the fairly complex circuit without assistance and take at least six sets of measurements. Some candidates had problems converting their meter readings of mA and mV into A and V, but managed to fudge their values to give the correct R/x values. Weak candidates did not convert their diameter into metres in the equation for resistivity and a significant number of candidates did not know that the units of resistivity were Ωm.

In question C, candidates were much better at describing the discharge of a capacitor than candidates were in tackling radioactivity in 6735/2A. As a consequence many candidates got all 6 marks for this section. However, the same errors occurred in the subsequent graph drawing and analysis as in 6735/2A.

In summary, as in Paper 2A, whilst candidates on the whole showed competent practical skills in taking and recording measurements, their processing and analysis of data was in many cases below the standard expected at A level. In particular they showed a lack of understanding of significant figures and uncertainties. These are clearly areas for Centres to work on.

6736 Unit Test PHY6

Question 1
The passage was more accessible than that of last June and, although the Millikan experiment is no longer mentioned in the specification, may have got candidates off to a 'happier' start than usual. The overall mark for question 1 was high, errors often resulting from a lack of care in reading the stem, e.g. 'sketch *and label*' the graph in part (a)(i); a drop 'of radius 7.9×10^{-5} *cm*' in part (b)(i). In part (d) it was pleasing to see that most candidates appreciated how to test the curve, but equally surprising that a small number, having calculated three or four values for the product *Wt* differing by as much as 20%, claimed that the product was approximately constant. In this part the examiners demanded that the points chosen to test for inverse proportion were widely separated on the graph, as the products for a pair of adjacent points are almost bound to be equal whatever the shape of the graph. The marks for 'suggest why' in part (f) asking the candidate to appreciate that a suitable radioactive ß source would *weakly* ionise the air in the Millikan cell were rarely gained, and in the final part (g) the quality of the diagrams often made it difficult for the examiners to award full marks.

Question 2
A good answer to the type of question asked in part (a) requires some planning. A bullet-point list of the key issues is often the best approach and is also entirely acceptable for gaining the 'clarity' mark, e.g.

- Protons move at a constant velocity in the tubes
- Protons accelerate between the tubes, etc., etc.

The impression gained here was that weaker candidates spent far too many words describing what they believe occurs as a proton accelerates from A to B to C to D etc.
There were several correct routes through the calculation in part (b)(i) and for those who were unsure how to calculate the gain in kinetic energy the second half of the calculation can be achieved using the 5×10^{-11} J given. It was perhaps unfortunate that the question asked the answer to be expressed as a fraction. The rather obvious advantage in part (c)(i) that it is easy to hit a fixed target was not credited.

Question 3
Parts (a) and (b) were generally well done, there being a wide variety of suggestions in the latter as to why the temperature rise does not continue, the better ones focusing on the evaporation of water molecules thus reducing the number remaining to oscillate. Very few candidates knew in (a) that at resonance, i.e. when forced at f_0, there is maximum energy/power transfer. The concept of superposition examined in part (c)(ii) involved establishing what $(SQ + QP) - SP$ was, expressed in terms of λ. Many candidates gave a general description of the principle of superposition, but few were able to relate such a description to this situation. A mention of path difference was limited to the best candidates.

Question 4
The descriptions in part (a) were extremely disappointing, the commonest fault being to quote speed as distance ÷ time without defining just what distance and/or time was involved. By contrast the homogeneity in part (b)(i) was very well done by a wide range of candidates and a pleasing proportion teased out the doubling of k in (ii). The key to explaining the shape of the pulse in part (c)(ii) was that of a changing magnetic flux through the short coil. Many answers described the cutting of magnetic field lines – an approach that is not part of the specification but which often led to a discussion of an induced e.m.f. and thus gained some credit.

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
	Uniform marks 90	72	63	54	45	36
	Raw marks					
PHY1	60	43	38	33	28	24
PHY2	60	43	38	33	29	25
PHY4	60	47	42	38	34	30
PHY5	96	77	71	65	59	54

Raw marks are obtained for PHY5 by multiplying the component mark for Paper 1 by 1.2 and adding it to the mark for Paper 2. Grade boundaries for the individual papers are not available.

Units converted to 120 uniform marks

Unit	Maximum mark	Grade				
		A	B	C	D	E
	Uniform marks 120	96	84	72	60	48
	Raw marks					
PHY3	96	70	61	53	45	37
PHY6	80	57	51	46	41	36

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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