GCE A LEVEL EXAMINERS' REPORTS

PHYSICS
A LEVEL

SUMMER 2022

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PHYSICS

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COMPONENT 1 – NEWTONIAN PHYSICS

General Comments

The questions on Newtonian mechanics and the kinetic theory (questions 1– 4 and 6) were very well done by most candidates. Oscillations proved a little less straightforward. The weakest answers were for the QER (on thermodynamics) and the comprehension. These were at the end of the paper, but there was not much evidence of candidates running out of time.

Comments on individual questions/sections

Q.1 (a) (i) Only a handful of candidates failed to show the plank's weight by a vertical arrow through its centre.

(ii) Most candidates realised that the easiest way to find the force of the wall on the ladder was to take moments about the ladder's foot, B. This was usually done successfully, though occasionally moments were confused with forces. One mark was reserved for the brief explanation requested. "Moments about B" was enough, and the mark was usually given.

(iii) Most candidates correctly calculated the magnitude and direction of the contact force on the ladder's foot from its horizontal and vertical components, though a small minority, recalling that sines and cosines might be relevant, tried to incorporate those of the ladder's angle of lean.

(b) About half the candidates realised that the main thing they needed to do to investigate the ladder's stability at an angle of 45° was to repeat (a)(ii) using the new angle. Other approaches were possible. A fairly common mistake was to try to use values computed in part (a) that were not applicable to the new angle.

Q.2 (a) Most candidates gained the mark for pointing out that $a = \frac{g}{M}m$ followed from $F = mg$ and $F = Ma$.

(b) A few candidates drew single lines of best fit, and therefore couldn't calculate uncertainties; they could still score 3 marks. The great majority drew lines of maximum and minimum gradients consistent with the error bars, though occasionally a line going near the tops of all the error bars and another near the bottoms were drawn. Gradients were generally calculated accurately. Almost, but not quite, everyone could work out M from the mean gradient, and there was a very pleasing level of success in calculating the uncertainty in M.

(c) A minority of candidates ignored the context of the question and described how the acceleration could be found from the applied force. Most gave a kinematic method as required, though sometimes marred by vagueness, as in claims that measured values of displacement and time should be inserted into “an equation of motion”.

Q.3 (a) (i) Despite occasional claims that it applied only to elastic collisions, the principle of conservation of momentum was usually stated correctly.

(ii) Most candidates applied the principle successfully to the collision and correctly calculated the loss of kinetic energy. Mistakes were usually arithmetical. How does conservation of energy apply? Most candidates gained the first mark for some mention of transfer of kinetic to thermal, but for the second mark we needed more precision, such as transfer of kinetic energy to (random) internal energy in the discs, or, in time, as heat from the discs to the surroundings.

(b) 3 of the 4 marks were available for showing that a slope-length of 0.70 m would give an ‘ideal’ final speed of 2.4 $m\,s^{-1}$, or vice versa. Many candidates succeeded, using energy conservation. The less popular method, using acceleration, tended to be less successful. The last mark was reserved for explaining why the actual slope-length needed to be greater than 0.7 m. A surprising number of candidates didn’t cite friction.

Q.4 (a) We needed to be told that an object moving in a circular path is continuously changing its direction, so it is changing its velocity, or is accelerating, and that this requires a (resultant) force to act on it. The first point was often not made clearly.

(b) (i) Almost everyone could calculate the greatest force the rod could exert, given its diameter and the breaking stress of the metal.

(ii) Calculating the greatest rotation frequency was also done very well. The commonest mistake was failure to divide a calculated value of ω by 2π.

(iii) Only a minority of candidates pointed out that they had ignored the mass of the rod itself, or the rod’s elongation. Air resistance was commonly offered, but it would not contribute a radial force.

Q.5 (a) About half the candidates found the ratio of periods correctly. Many candidates did not realise that the two springs in series would have half the spring constant of one of them. Sometimes, also, the square root caused trouble.

(b) (i) Almost everyone checked the maximum velocity convincingly.

(ii) In the velocity–time graphs we were looking for correct maximum and minimum, period and phase. There was a good success rate. Shapes of curve had to be fairly bizarre to incur a penalty in this two mark question part, but candidates should be aware that it is not safe to draw a ‘triangle wave’ as a substitute for a sinusoid.

(iii) The graph did not extend as far as 3.50 s, so candidates were expected to find the speed from the equation (in the data booklet). Many candidates managed this, but there were the inevitable slips over radians and degrees. Another approach, sometimes carried out successfully, was to read the velocity from the graph at 2.3 s or 1.1 s.

(iv) The first mark, usually gained, was for showing that 1.67 Hz is double the oscillation frequency. The second mark was deliberately harder to obtain: we needed to be told that this 'double frequency' was to be expected because both peaks and troughs in the velocity graph would give peaks in the KE graph – or equivalent.

(c) (i) Most candidates correctly suggested using a piece of paper or card as a damper, but an appreciable minority suggested a stiffer spring.

(ii) The easiest way of checking for exponential decay was to look for near-equality of ratios of successive amplitudes. Many candidates did this well. Some correctly pointed out that logarithms of amplitudes had equal differences between them. The commonest failing was just to remark that the differences between successive amplitudes decreased.

(d) Most candidates gained 2 marks for stating that damping in car suspensions suppressed oscillations or 'bouncing' and that damping in pedestrian suspension bridges reduced the amplitude of oscillations caused by pedestrians walking. The third mark was reserved for some extra detail, such as that in car suspensions we are dealing mainly with natural oscillations set off by single events like bumps, whereas in the bridge we are mainly controlling forced oscillations (and possibly resonance). This mark proved harder to get.

Q.6 (a) Most candidates, but not all, were able to quote "$\text{pressure} = \dfrac{\text{force}}{\text{area}}$".

(b) (i) The ratio of pressures for the O_2 and the N_2 was more often than not calculated correctly using the ideal gas equation, though some candidates tried misguidedly to introduce the molecular masses.

(ii) The ratio of rms speeds proved more difficult to determine. Many candidates didn't seem to know that $\frac{1}{2}m\overline{c^2}$ was the same for both gases, and some of those who *did* know made mistakes in the algebra.

(c) (i) Candidates bravely applied $p = \frac{1}{3}\rho\overline{c^2}$ to the centre of the Sun, almost everyone gaining the 2 marks available.

(ii) There was rather less appreciation that most of the assumptions of the ideal gas kinetic theory wouldn't hold in that region, though sometimes, no doubt, the assumptions were simply not known.

Q.7 (a) The great majority of candidates knew how to use the ideal gas equation to calculate temperatures using data from the graph grid.

(b) Few candidates made mistakes in calculating the work done at constant pressure.

(c) Bearing in mind their success in part (b), it was surprising that many (perhaps most) candidates didn't point out that less work was done by the gas over AY than over AX. It was noted rather more often that the internal energy increases over AX but doesn't change over AY. Some candidates deduced that more heat flows in over AX than AY, but we were very seldom told that this was because both ΔU and W are greater for AX than AY. Admittedly making both these points would have been exemplary. For AZ an explicit *work* comparison with AX was often not made. Sometimes the absence of heat flow was confused with constant temperature, but some candidates did realise that work done with no heat flow implied a drop in internal energy, contrasting it with the rise over AX. Answers to this QER were in general disappointing.

Q.8 (a) More than half the candidates explained that the negative sign was needed because if the wavelength went up the frequency had to go down or equivalent. The commonest mistake was to think that the sign had something to do with direction of travel.

(b) (i) Most candidates understood that the blue shift would make the photon the right frequency to be absorbed…

(ii) … but that if the photons and atom are moving in the same direction, the photon will be red shifted, making its frequency *further away* from that needed.

(iii) To explain cooling we were hoping that candidates would tell us that *only* photons that could slow down the atoms would be absorbed, but the mark was not often awarded.

(c) The change in wavelength, $\Delta\lambda$, of photons as 'seen' by helium atoms moving towards them was calculated directly by many candidates. Sometimes $\Delta\lambda$ was found, with more labour, by first calculating the frequency shift. Candidates then needed to realise that the laser wavelength needed to be *greater* by $\Delta\lambda$ than the helium absorption (or emission) wavelength, so that blue-shifted photons would be absorbed by approaching atoms. Many candidates subtracted rather than added $\Delta\lambda$. They lost one mark.

(d) Most, but not all, candidates realised that to find the decrease in the atom's velocity, they needed to apply conservation of momentum. The photon's momentum was usually found correctly. Most candidates calculated the atom's initial momentum (sometimes making mistakes with mass units) and then its final momentum, hence the new velocity. A minority saw that the change in velocity was simply equal to the photon momentum divided by the atom's mass.

(e) Candidates could gain 2 out of the 3 marks by calculating the number of photons emitted by the laser in a millisecond and pointing out that this is far larger than 26 000, making the photon *supply* ample for 26 000 to be absorbed in a millisecond. Many candidates missed these easy marks; perhaps some had been thrown by being told that the lifetime of the excited atom was a few nanoseconds. One way of using *this* information was to show that for 26 000 photons to be absorbed in a millisecond, the mean time between absorptions was 38 ns, so there was plenty of 'spare time' when the atom was not excited and so able to absorb, making it *capable* of absorbing several times more than 26 000 in a millisecond. A significant number of candidates did present this argument in some form.

(f) Most candidates sensibly chose to use $\frac{1}{2}m\overline{c^2} = \frac{3}{2}kT$, but many did not substitute the value from the bottom of paragraph 13 as the mean square speed (to get a temperature of 0.36 μK). There were also some mistakes handling units for mass and speed.

Summary of key points

Answers to the first four questions revealed a generally excellent understanding of basic statics and dynamics.

- Candidates had evidently been very well trained in calculating a gradient together with its uncertainty from a straight line graph and correlating it with the equation of the graph.
- The variation of kinetic energy with time for a body in SHM was a weak area.
- Few candidates distinguished between natural and forced oscillations in the question part about damping in car suspensions and pedestrian suspension bridges.
- The assumptions made in deriving $p = \frac{1}{3}\rho\overline{c^2}$ did not appear to be well known.
- Thermodynamics was (again) a weak area. Qualitative comparisons of work could have been made by inspecting p–V graphs but were often omitted. Heat and internal energy were sometimes confused with each other, and, occasionally, constant temperature with no heat entering or leaving.
- Most candidates seemed to grasp the principle of laser Doppler cooling as explained in the article for comprehension. Calculation of number of photons emitted per (milli)second from a laser, and minimum temperature achievable (using kinetic theory) were poorly done. More careful study of the paragraphs mentioned in the questions might have helped.

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COMPONENT 2 – ELECTRICITY AND THE UNIVERSE

General Comments

Candidates showed a good appreciation of all the physics tested in the paper with some areas scoring better than others. Responses to gravitational and electric field questions were strong with candidates scoring particularly well in questions testing equations related to gravitational fields. Questions related to electric circuits were adequately answered with many candidates showing a good basic understanding of the concepts involved, but many were unable to apply their knowledge to higher level concepts such as power calculations involving different circuits.

Practical analysis questions, including the determination of emf, internal resistance and uncertainty calculations were carried out well. However, questions testing experimental technique were poorly answered. The core skills of literacy and numeracy were displayed to a high standard, as would be expected at this level, with algebraic skills in particular demonstrated to a very high standard. Once again however, many candidates lost marks for confusing surface area with cross-sectional area in questions testing stellar physics. Candidates are reminded that these expressions are provided in the data booklet. Responses in general were often not well presented, with work seemingly rushed and set out in an ad-hoc manner. More so than in previous years, examiners found difficulty in deciphering many responses. Is this a reflection of the fact that these candidates have had little exam technique practise?

Synoptic questions involving combined magnetic and electric fields and the determination of rms speeds of molecules were very well answered. However, definition-based questions were not well answered.

Comments on individual questions/sections

Q.1 (a) Nearly all candidates applied the concept of conservation of charge at a junction correctly to find the required current and give its direction. Nearly all candidates were successful in calculating the number of electrons passing point Q in one second.

(b) (i) Most candidates applied $R = \frac{V}{I}$ correctly to determine a value for R ($330\,\Omega$), with many stating that this also represented the resistance of each of the resistors. Those that did not make this distinction were not penalised with the assumption being made that the value calculated did indeed represent each of the resistors. A minority of candidates incorrectly manipulated the $330\,\Omega$ to determine the value of each resistor, e.g. by dividing 330 by 4, and were not awarded the second mark.

(ii) Candidates had to show the current increased with switch X closed and increased further with both X and Y closed. A significant number of candidates determined both currents correctly and provided a valid conclusion, that 'Charlotte was correct'. A common approach was to discuss in general terms the impact of resistors in parallel on the overall resistance and hence the current. Whilst this approach did gain some credit, very few candidates were able to clearly articulate the impact of the reduction in series resistance on the overall resistance of the remaining parallel resistors. Those candidates giving an algebraic solution in terms of R usually did so very well e.g. they showed, with switch X closed, that the overall resistance would become $\frac{2R}{3}$ (where R = original resistance), and so on.

(iii) Many candidates were able to determine and compare the power emitted when 2 and then 4 buzzers were operating and confirm the measurements made. Some candidates did not realise that the two buzzers had to be P and Q, with some choosing two buzzers at random. Many candidates failed to realise that the resistance of the circuit when only two buzzers were operating was half of the original value, and the current was twice the original value.

Q.2 (a) In general candidates made good attempts at describing and explaining the features of the I-V graph for the filament of a lamp. To access the higher marking band, it was expected that candidates distinguished (and explained) the difference between the drift velocity and random vibrational velocity of electrons. They were expected to discuss collisions between electrons and lattice ions and the effect of increasing temperature on the motion of the lattice and electrons, leading to the mean drift velocity decreasing and hence the resistance increasing at higher voltages. They were expected to understand that the increase in temperature is caused by the increased frequency of collisions, which many failed to do. They were expected to relate this back to the shape of the graph at higher voltages. Lower band responses typically outlined the initial straight line aspect of the graph as 'obeying Ohm's law' or equivalent and failed to refer to the motion of electrons. Middle band responses built upon this basic description by introducing the idea of collisions between electrons and the lattice, but then failed to provide any depth in terms of the effects of increased pd on the movement of electrons and the consequent effect on temperature for example.

(b) (i) Nearly all candidates were able to draw a suitable straight line between the points given, and then used this to determine both the emf and internal resistance of the cell. Nearly all responses were within the tolerances expected.

(ii) Very few candidates gave a correct response for the importance of the technique described when carrying out the experiment. Many discussed the effect of heat on the external resistor or the joining wires for example. Few referred to the impact on the cell or its internal resistance as required.

Q.3 (a) (i) Many candidates were able to show, through a variety of approaches, that the capacitor set-up would store the required charge. Candidates were provided with all the information related to the capacitor set up, and so had the option to determine one of Q, C, A, or d to answer the question.

(ii) Nearly all candidates stated that the charge stored could be increased by using a dielectric.

(b) There were impressive responses to this combination of capacitors question. Candidates displayed a good understanding of the effects of capacitors in parallel and series on charge and potential differences. Most candidates adopted the approach of determining the overall capacitance, and hence the overall charge and from there the charge on each capacitor. From there they determined the pd across each capacitor. A significant minority however determined the pds across each capacitor as a first step using appropriate ratios before proceeding to determine the charge on each capacitor. Both approaches are equally valid.

(c) Good attempts were made to show the given expression. Most candidates produced two separate decay equations, one for each of the capacitors before proceeding to manipulate the equations to show the given expression. Marks were awarded for the expressions and a further mark for correct algebra leading to the final expression. Many candidates were awarded 2 marks for providing correct expressions, however fewer were successful in gaining the third mark. A very few candidates opted for the logic-based approach, realising that the charge would halve through $\frac{R}{2}$ in $\frac{t}{2}$ and that to decay from 16 nC would require $3 \times \frac{t}{2}$ time periods.

Q.4 (a) Whilst many candidates were able to give a correct explanation for the term *ductile*, far fewer were able to describe the effect of adding carbon atoms to iron. In most cases this was due to candidates referring to the carbon atoms inhibiting the motion of whole planes of atoms rather than inhibiting dislocation movement. Reference to whole plane of atoms movement was not credited.

(b) (i) Many candidates were able to produce expressions for the extension of both copper and steel, identifying the common factors in both expressions. A significant number proceeded to successfully merge these expressions into the given equation for strain energy to derive the work done to stretch the combination of wires.

(ii)&(iii) Nearly all candidates were successful in carrying out the calculations.

(c) (i) Many candidates determined the Young modulus of the metal along with its absolute uncertainty correctly. A common reason for not achieving full marks was for incorrectly calculating the uncertainty in cross-sectional area, with a significant number of candidates omitting the factor ‘2’ in their calculations (leading to a % uncertainty of half the correct value). Many candidates also failed to give their final answers to an appropriate number of significant figures.

(ii) Many candidates identified the reduction in the uncertainty due to the increased diameter, however only a few candidates discussed the impact of the reduced extension on the final uncertainty.

Q.5 (a) Few candidates were able to give a correct definition for electric potential, with key words and / or phrases often being missed out. For example, the word '*unit*' (or one coulomb) was missed by many, as was the reference to moving the positive unit charge from *infinity* (to the point).

(b) (i) Most candidates were able to take appropriate readings from the graph and use them correctly to determine the charge Q.

(ii) Fewer candidates were able to take correct values of potential from the graph at the distances indicated. Those that did so correctly often placed the values the wrong way around in their equations, leading to a negative value for the work done. One mark was deducted for negative answers.

(iii) Many candidates drew an appropriate tangent and then determined the gradient correctly.

(c) (i) Many gave a correct expression for the magnitude of the force due to the magnetic field but omitted to give its direction as required in the question.

(ii) Nearly all candidates were able to derive the given expression.

(iii) Nearly all candidates were able to determine the correct value for V.

(iv) A majority also described the motion of the protons but fewer were able to give a convincing reason for this motion in terms of unbalanced forces.

Q.6 (a) Nearly all candidates referred to the peak wavelength and Wien's law. However, responses which referred to 'maximum wavelength' (instead of wavelength at maximum intensity, or peak wavelength) were not credited.

(b) (i) Candidates were required to use Stefan's law to determine the luminosity of the star as a first step followed by the inverse square law to determine the distance of the star from Earth. These processes were carried out correctly by many candidates, however a frequently seen error was to use the formula for the area of a circle (πr^2) rather than that for the surface area of a sphere ($4\pi r^2$) in both equations. Candidates should also consider the validity of their answers to questions such as these - does the answer make sense? Distances of a few km for example should indicate that an arithmetic error may have taken place and should encourage candidates to check their calculations.

(ii) Nearly all candidates were successful in calculating λ_{peak} as 240 nm, however some stated that this was in the blue part of the spectrum, rather than stating that it was less than blue, or in the UV.

(c) In this issues-based question it was expected that candidates focus their responses on scientific methodology rather than give specific physics-based responses. The mark scheme offered a range of responses, including ‘peer review’, ‘further independent verification’ and ‘comparison with historical data’ amongst them. Whilst many candidates identified one acceptable response, few were able to provide two suggestions as required.

Q.7 (a) (i) Many candidates were able to relate the age of the universe to the Hubble constant as required.

(ii) The majority of candidates used the Doppler and Hubble equations correctly to determine the age of the universe, however a few candidates failed to give an appropriate unit for their answers to the age of the universe and were deducted one mark.

(b) (i) Nearly all candidates were able to determine the theoretical orbital speed of dust particles.

(ii) Most candidates referred to ‘dark matter’, however fewer made the link between dark matter and additional mass for the second mark.

Q.8 (a) Nearly all candidates were successful in confirming the mass of the Moon.

(b) (i) Many candidates applied the principle of conservation of energy appropriately to derive an expression for escape velocity. Some candidates lost a mark for incorrect use of signs.

(ii) Those candidates who were able to derive a correct expression in (i) usually used it correctly to calculate the escape velocity in (ii).

(c) (i) As required, a percentage of each of the physics components should contain synoptic elements, testing aspects from all parts of the specification. This was one such part. The response in general was very good, with many candidates able to determine the rms speed required. Several approaches were possible, either using the mass of the gas, or the mass of individual molecules. Some candidates became confused with their approaches, using for example the Boltzmann constant instead of the molar gas constant, or vice-versa.

(ii) Many candidates focussed their answers on the 500 $m\,s^{-1}$ region of the speed distribution graph, whereas the focus should have been on the region which showed that a proportion of molecules had speeds greater than the escape velocity calculate previously in the question.

Summary of key points

Candidates would benefit from:

- Learning key definitions. Teachers should emphasise the need for complete and correct wording when answering definition-based questions. Examples of 'nearly correct' responses to the question, *define electric potential, V_E, at a point in an electric field* include:
  - The work done to move a charge from infinity to that point in the field.
  - The work done to move a positive unit charge.
  - The work done to move a positive unit charge from the point to infinity.

- Understanding concepts related to scientific methodology, especially when answering issues-based questions which test the role of the scientific community in validating new knowledge and ensuring integrity.

- Being aware that at least two marks are awarded in each component for the use of correct units to numerical answers. That is, if the unit is incorrect or omitted the mark is not awarded, even if the numerical answer is correct.

- Ensuring that they have a sound grasp of the importance of experimental technique. For example, very few candidates appreciated the significance of the technique for taking electrical readings in Q2 on the emf of the cell.

PHYSICS

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COMPONENT 3 - LIGHT, NUCLEI AND OPTIONS

General Comments

The general standard of performance of candidates is outstanding. Although this was a difficult paper, some of the questions were generously split into bite-sized chunks and the 6 mark QER question was on quite an accessible topic. These two points, combined with a strong candidature, are probably responsible for the increased mean mark this year. The statistics indicate that the paper was of an appropriate level of difficulty and provided good differentiation for the cohort of applicants. There was little or no evidence of candidates struggling with time restrictions and it would appear that 6 candidates attempted more than one of the options.

General Points
Topics: The weakest topics this year were electromagnetic induction (Q9), basic wave properties (Q1) and Energy and the Environment (Q13).

Language: Answers to the 6 mark QER were of a high standard this year and most candidates found no language difficulties when expressing difficult explanations. There was some evidence of candidates, whose first language is not English, using incorrect words from time to time but this tends to lose no marks unless fundamental terms are misused.

Mathematics: No particular mathematical weaknesses were apparent this year.

Comments on individual questions/sections

SECTION A

Q.1 (a) (i) Almost universally correct.

(ii) Only a small minority used more than one wavelength to improve the percentage uncertainty.

(iii) Generally quite poorly answered. Although most candidates were comfortable describing points in phase and in antiphase, very few were willing to discuss the relationship between phase angle and distance. The equation $\varepsilon = \frac{x}{\lambda} \times 2\pi$ is rather useful.

(b) (i) Generally well answered but few candidates used more than one period to improve the percentage uncertainty. There were quite a few power of ten mistakes here too due to the time in ms.

(ii) Again, one of the weak points of the paper. Obtaining the correct displacement proved to be slightly tough but this was more successful than the explanation.

Q.2 (a) Well answered.

(b) (i) Well answered. The most difficult step here was realising that the series of nodes and antinodes represented 1¾ wavelengths.

(ii) Candidates found it difficult to work out where the second mark was here. Most were able to state that the distance needed to be doubled but failed to go on to explain why this halves the percentage uncertainty.

(c) Very well answered.

Q.3 (a) Well answered in general. The most difficult mark to obtain seemed to be the link between path difference and constructive / destructive interference.

(b) Very well answered but this was a simple substitution. Nonetheless, very few power of ten mistakes were seen.

(c) Well answered with the vast majority realising that these sources would not be coherent.

Q.4 (a) (i) Quite poorly answered. Most candidates were unable to come up with two relevant points.

(ii) Well answered but a significant minority finished with just the photon energy or even subtracted the photon energy from E_3 (instead of adding it to E_2).

(b) (i) Not a particularly easy part question but extremely well answered.

(ii) Well answered in general but a significant number were unable to calculate the refractive index (either by the wavelength shortening route or using Snell's Law).

Q.5 (a) (i) Very well answered although a minority wanted to discuss photon energy rather than the momentum of a photon.

(b) (i)&(ii) Very well answered.

(iii) Well answered in general. A significant minority tried to obtain the answer assuming the same KE is transferred every time. Unfortunately, this gives a completely wrong answer.

(iv) Most candidates realised that conservation of energy was being violated but few were able to explain it completely. Although it was not required, some candidates realised that the red shift of the reflected light could explain this "contradiction".

Q.6 (a) These question types are not particularly easy but are always well answered.

(b) Explaining the previous answer in terms of binding energy proved to be more difficult than the previous calculation in terms of mass.

(c) Quite well answered with the majority of candidates being able to make two good, relevant points.

Q.7 (a) (i) Although well answered, one would expect the vast majority to score 3/3 here. This was not the case on this occasion.

(ii) Very well answered but this is to be expected when the answer is given in a “show that”.

(iii)&(iv) Very well answered with the majority of candidates making no mistakes and obtaining full marks. Calculating the number of nuclei is usually the most difficult step but this was given this time. Small minorities failed to obtain the correct decay constant or mixed up between 10% and 90%.

(b) This was a particularly fair and successful 6 mark QER with a mean score of nearly 4/6. The common methods of dropping marks were incomplete answers e.g.

- discussing one reaction fully but not the other;
- discussing conservation laws but not forces (and vice versa);
- not discussing enough conservation laws;
- discussing the force responsible for one reaction but not the other.

There were some mistakes present too e.g. stating that the lepton number of a positron is +1 (or -1 for the electron-neutrino). Some candidates believed that the photons were leptons.

Q.8 (a) Extremely well answered although some candidates used the reading on the screen of the mobile phone rather than the table.

(b) (i) Very well answered although the marking was not particularly strict this year. The main reason for losing this mark was forcing the line through the origin.

(ii) Once the candidates realised that this was the x-axis intercept the only possible mistake was reading the scale incorrectly e.g. 2 cm instead of 2 mm.

(c) For such a difficult part question, the mean mark was incredibly high. Some rare mistakes were:

- wrong numbers in gradient calculations;
- equating the gradient to the wrong expression;
- power of ten slips.

(d) Answers requiring the evaluation of data are traditionally of lower quality. Many candidates stated that their value in part (c) was within the range of uncertainty and said no more. This part question was worth 4 marks and candidates should have thought more carefully about what other things can be said about the quality of the data.

Q.9 (a) This part question possessed the lowest mean percentage mark. More candidates discussed air resistance than ohmic heating in the hoop.

(b) This was an alternative method of asking for the induced emf but most candidates saw through this by using $V = IR$ followed by Faraday's Law.

SECTION B – OPTIONS
OPTION A – ALTERNATING CURRENTS

Q.10 (a) (i) The majority of the candidates answered this correctly.

(ii) In part I most candidates answered this correctly. Some calculated Z incorrectly or treated the potential divider as resistors in series. Part II most candidates answered correctly.

(iii) Most candidates calculated part I correctly. In part II some candidates gave a confused explanation here with 'increased' and 'decreased' used incorrectly / confused throughout. Some candidates gained the first mark for stating that the reactance of the capacitor decreased with frequency, but were unable to link this correctly with a decrease in pd.

(iv) Most candidates answered this by calculating Q and f_0.

(v) Some good resonance curves seen with the majority of candidates calculating the current at resonance (50 kHz) in order to identify the peak.

(b) Most candidates calculated the peak pd and used the VOLTS/DIV setting to show that the plotted peak value was incorrect. Most candidates calculated the period and used the SEC/DIV setting to show that the period was plotted correctly.

OPTION B – MEDICAL PHYSICS

Q.11 (a) (i) This was well answered. A number of candidates quoted $V = \frac{hc}{e\lambda}$ at the start of the question and then went on to obtain full marks.

(ii) A number of poor / scruffy diagrams where the new diagram overlapped the original were seen, so the first mark was lost, also a number had the minimum wavelength in the same position as the original diagram again losing a mark.

(iii) Very well answered. The majority of candidates had learnt this derivation which was pleasing. A number used $\ln\frac{1}{2} = \ln 2$ which obviously was accepted.

(iv) Most candidates calculated μ = 0.495 and the majority went on to show that x = 0.87 cm or 8.7 mm or 8.7×10^{-3} m all including appropriate units which was excellent.

(b) (i) Not very well answered, many treated it similar to ultrasound A-scans and so described measuring reflection times, also a number thought that electrons were precessing.

(ii) Well answered. Many candidates stated $f = 42.6 \times 10^6 B$ which was accepted for the first mark, most then went on to calculate $B = 1.2\,\text{T}$ with units which was very pleasing.

(c) A number of candidates indicated that half-life was a factor stating either ‘long’ or ‘short’ half-life. This was not accepted unless explained e.g. doesn’t stay in body long / long enough so it can be detected. A large number of candidates stated that it must be a gamma emitter which was excellent.

(d) A surprising number of candidates thought tracers were a good option. Explanations were generally not very good with many fixated with cost, and also the ionising effect of CT scans which disregarded the urgent need of the investigation.

OPTION C – THE PHYSICS OF SPORTS

Q.12 (a) This was well answered by most candidates. The main reason many did not gain full marks was that they did not refer to the centre of gravity being lowered.

(b) The definition of coefficient of restitution was given by most of the candidates but they were not then able to use this to explain fully why hockey stick C is the preferred option. Some candidates attempted to use the equation based on heights which did not receive credit.

(c) (i) A significant number of candidates were not able to determine the angular velocity correctly from the data given or able to determine correctly the moment of inertia though the equation was given. Error carried forward was applied and many candidates were able to gain marks for determining the torque if the correct equation was used.

(ii) The linear and rotational kinetic energy and their use were well understood by all candidates and the majority were able to gain full marks with ecf from part (c)(i).

(iii) This was not answered well with many not being able to use the speeds correctly in the equation. The sign for the magnitude of the force was consequently omitted by the majority. A significant number then stated that protection was not advisable due to the high force though a minority did gain credit by saying that additional protection was required since the force was high.

(iv) In part I many candidates struggled and used the drag force equation rather than Bernoulli's equation. Also, the pressure difference was not calculated correctly with 2^2 rather than $22^2 – 20^2$ being used. Candidates did gain credit if they used either the surface area of a circle or hemisphere for determining the force. Also an ecf was applied if a correct comparison was made with the weight of the ball for the final mark. In part II most candidates were able to correctly base their answers on the drag force equation but did not give a full explanation e.g. factor of 4 in their final answer.

OPTION D – ENERGY AND THE ENVIRONMENT

Q.13 (a) (i) There were mixed responses for this question part. The majority of candidates were able to define intensity. We were not requiring the fact that the area was perpendicular to the radiation direction, however, it was noticeable that some candidates had knowledge of that level of detail. Not all candidates went on to state the correct units or incorrectly stated them.

(ii) Good attempts were made by most candidates here. $P = A\sigma T^4$ and $\lambda_{\mathrm{max}}= \frac{W}{T}$ were regularly seen and the orderly presentation of the algebraic steps was pleasing. A minority of candidates were unable to separate the surface area of the Sun with the surface area of the 'radiation sphere' created by the Sun considered at the Earth-Sun distance.

(iii) This was not answered as well as anticipated as a minority of candidates incorrectly transferred the powers in the given equation. There were also some clear calculator errors.

(b) (i) The majority of candidates were able to determine the mass per second and use $\mathrm{PE} = mgh$ per second. This often resulted in the correct answer of 153 MW. There were a minority of candidates who incorrectly rearranged the density equation or tried using $P = \frac{1}{2}A\rho v^3$ which did not gain any credit.

(ii) The discussion on greenhouse gas emissions was mixed. There were some very good responses. These candidates generally mentioned that the electricity generated from the hydroelectric power plant produces no greenhouse gases or more specifically, no CO_2. They would then go on to say when electricity is bought back for the pumping process, the electricity may have been created in, for example, a thermal power station. The hydroelectric power station using its own electricity to pump the water back up did not gain credit. A minority of candidates suggested that renewable resources are resources that do not produce greenhouse gases. These responses were often confused. A renewable resource can be replenished within a given timescale.

(c) (i) Only a small number of candidates were able to explain what is meant by the confinement time. It is the time that the fuel can maintain its internal energy. Some candidates were rewarded for responses that referenced ‘more energy produced from fusion than the energy put in to heat the plasma’.

(ii) Candidates in part I generally saw that the Boltzmann constant was the link between temperature and energy which was pleasing. Multiplying 1.1×10^8 K by k or dividing by e was required for the first mark. Multiplying by $\frac{3}{2}k$ was accepted as an understandable alternative. In part II the first mark was accessed by the majority of candidates where they had to manipulate the triple product into the form $\tau_E = \frac{nT\tau_E}{nT}$. Some did not consider the unusual unit for the triple product given in the question. A minority realised that the temperature was required to be in keV and used their value from part I to obtain a correct value. An alternative correct answer used the 10 eV approximation resulting in a confinement time of 4 seconds.

(d) This question was well attempted with a full range of marks awarded. The first marking point was generally achieved through implication within the second and third marking points. However, a noticeable number of candidates are now communicating that $\frac{\Delta Q}{\Delta t}$ is the same through both layers before they proceed with their calculations. There were different approaches used by candidates. The most common involved setting up a version of $0.1(20 - \theta) = 0.5(\theta - 5)$ for 2 marks and correctly determining θ as 7.5° for the third mark. Simply substituting 7.5 back into either side of the above equation would have achieved the fourth mark. The fifth mark usually followed. Some candidates incorrectly calculated the combined K value for the external wall and did not get past three marks. A minority of candidates implied an understanding of $\frac{\Delta Q}{\Delta t}$ being the same through both layers, correctly calculated the temperature at the boundary, but then incorrectly calculated $\frac{\Delta Q}{\Delta t}$ in the individual layers to be different values. This was somewhat contradictory.

Summary of key points

- The variation with distance of phase of a progressive wave (1(a)(iii)).
- Explanation of the percentage uncertainty should discuss the top and bottom of the fraction i.e. the absolute uncertainty and the value itself (2(b)(ii)).
- Explaining energy loss or energy conservation in unusual circumstances. Although these were tough applications this year (5(b)(iv) and 9(a)), there is room for improvement. Explaining damped oscillations incorporating Lenz’s Law and ohmic heating proved to be particularly difficult. Explaining the apparent contradiction in laser propulsion of a rocket also proved testing.
- In the medical physics option, the role of radio waves in MRI and the evaluation of imaging techniques.
- In the energy and the environment option, intensity and the solar constant.

PHYSICS

GCE A LEVEL

Summer 2022

COMPONENT 4 – PRACTICAL ENDORSEMENT

General Comments

The recent pandemic necessitated changes to the way in which monitoring of the Practical Endorsement was conducted. Monitoring was carried out remotely which meant that practical lessons were not viewed. All other aspects of the Practical Endorsement were monitored as they would have been if the monitor visited the centre. However, centres should note that we will be moving back to face-to-face monitoring from September 2022.

The pandemic also meant some requirements of Practical Endorsement were relaxed. The modification for summer 2022 allowed candidates to be awarded a Pass in Practical Endorsement if they had demonstrated competence in all of the Common Practical Assessment Criteria (CPAC) routinely and consistently, even if they haven't completed the usual minimum requirement of practical activities. As centres move back to normal working it is expected that this relaxation of Practical Endorsement will be removed.

Although the last few years have been difficult times for centres, we have still seen centres maintain a good practical programme as part of their delivery of the specification. There are several key features which characterise centres which successfully implement practical endorsement:

- Good planning of practical work. A suitable plan identifies not only when specified practicals will be conducted but also states the specific CPAC that will be assessed. The plan may be part of the Scheme of Work or a separate document.
- Planning allows for the development as well as the assessment of skills within Practical Endorsement.
- Both Teacher and Candidate Records are maintained and updated regularly.
- Practical books are used in 'real time' at the bench by candidates when completing a practical. We do not expect to see practical books in immaculate condition! Candidates should not write on scraps of paper and later copy the work up neatly into practical books.
- Candidate work is annotated showing where the candidate achieves or fails to achieve a CPAC, (e.g. with *CPAC 4* ✓ or *CPAC5(b)* ✗*)*. If they do not succeed the candidate is given brief feedback so they have a better chance of getting it next time.
- Centres are willing to mark candidate work 'not achieved', where necessary. We do not expect to see every candidate getting every criterion each time they are assessed! Indeed, when this happens there will be legitimate concerns about whether the work has been appropriately assessed. There should be a progression. The key question is, 'Is the candidate competent at the end of the course?'

Comments on individual questions/sections

Centres are reminded that in order to award a pass for Practical Endorsement, a candidate needs to ‘consistently and routinely meet the criteria’. This means there needs to be evidence of multiple occasions where a candidate evidences a pass for each CPAC statement. It is important that suitable opportunities have been built into the assessment plan which allow candidates to generate this evidence.

It should also be noted that candidates can work in groups when assessed. However, each candidate must generate suitable evidence that he or she independently meets the criteria. Centres therefore need to give careful consideration to how group work is conducted so that individual candidates can be assessed on their own performance.

CPAC 1
The assessment of this CPAC requires the candidate to correctly follow written instructions to carry out an experimental technique or procedure. If a teacher feels it is necessary to intervene and correct a candidate’s technique etc. then the candidate should not be awarded the CPAC.

This is a difficult CPAC for a monitor to comment upon remotely. In the vast majority of cases the monitor accepted the teacher’s judgement unless there was strong evidence to suggest the CPAC was incorrectly awarded.

CPAC 2
This is the most difficult CPAC for candidates to evidence since it involves higher level skills. Please make sure that you know where and when you are going to assess this CPAC. It is also important that sufficient time is given to candidates to develop the necessary skills before assessment occurs. Generally, we do not expect to see this CPAC assessed in the first two terms of an A level course. However, we do expect to see evidence of some assessment of this criterion by the end of the first year of the A level course. This skill may be evidenced by a candidate planning to carry out a procedure and then adapting their approach as necessary.

It is not necessary to assess every element of CPAC 2 each time this CPAC is assessed. However, it is a requirement that each element of CPAC 2 is met during the course. If you are monitored, the monitor will look at the coverage of each element.

CPAC 3
There is no need to assess this skill every time a practical is completed; choose practicals where there are some more significant hazards (e.g. experiments involving heating / lasers or the use of radioactive sources etc.).

CPAC 3(a) requires candidates to identify hazards and assess the risks associated with the hazards. A simple written risk assessment is the easiest and best way of evidencing this aspect of the skill.

CPAC 3(b) should be assessed by observation of candidates conduct during a practical session.

CPAC 4
We noticed that occasionally a candidate was awarded a pass in an experiment where the evidence in the candidate work showed that they were not working to the required standard. Please check candidate data carefully.

Observations should be made directly into candidate practical books. They should not be written on to scraps of paper and copied up later. Please **avoid** using templates for tables that direct candidates how to record data. Templates may be useful to teach candidates a good approach to recording data early in the course but when it comes to assessment candidates **must** devise their own tables. If you give the candidate a table, then CPAC 4 cannot be awarded. The tables which candidates construct **must** have appropriate headings with quantities and units. The units must be written in the table column head and not in the body of the table. If units are missing, do not award criteria. It is also good practice to get candidates to put uncertainties in the header to ensure they write down the correct number of significant figures.

Please carefully check candidates' data. Is it recorded to appropriate precision? All raw data should be recorded to the resolution of the instrument used. If data readings are not consistently recorded correctly by candidates in a particular experiment, then do not award the criteria. Is there sufficient data? Is the data what you expect? Please set suitable standards at the beginning of the course. It does not matter if a candidate did not always achieve the criterion.

CPAC 5
This important higher-level skill should be assessed from early in the course. There is no shortage of suitable assessment opportunities in Physics.

CPAC 5 has two elements:
(a) Uses appropriate software and / or tools to process data, carry out research and report findings.
(b) Sources of information are cited demonstrating that research has taken place, supporting planning and conclusions.

CPAC 5(a) This element of the CPAC is generally very well assessed in Physics. There should be evidence of candidates processing data using graphs and calculations. Centres should require candidates to use software (e.g. Excel) to draw graphs on a number of occasions. Candidates will need to be shown how to use Excel correctly.

Make sure graphs are constructed correctly, i.e. there is a title, each axis is correctly labelled, points plotted correctly, an appropriate scale used, suitable trend lines and error bars added as appropriate etc.

Processing data also involves carrying out calculations. There is no shortage of opportunities to assess this in physics. Please keep an eye on the number of significant figures in any processed data.

CPAC 5(a) also includes 'carry out research and report findings'. The report may simply be the conclusion they draw from their data. This may include determining the values of constants, considering whether experimental data supports a given hypothesis, and making predictions etc.

CPAC 5(b) Candidates must show evidence of referencing sources of information. This aspect of CPAC is still not getting enough attention from some centres. Just a few centres are to be commended for having candidates demonstrating referencing on multiple occasions. There is no need to use the Harvard System in referencing; however, a reference must have sufficient information to be traceable. If URLs are quoted, the date accessed should also be recorded.

Opportunities for assessing referencing **must** be built in from early in the course. The information referenced may be, for data or a quote; the information may come from a textbook, journal, website Eduqas data sheet. For example, if the candidate quotes a value such as g or h, where did they get the value? It should be referenced; if they used the Eduqas web sheet this can be cited.

Summary of key points

Practical Endorsement should be a servant to the subject. If Practical Endorsement is done well then it should assist in making better physicists. Use it to this end. Do not let it become an end in itself.

Successful delivery of Practical Endorsement needs careful thought and planning. Make sure that there are ample opportunities for candidates to evidence all aspects of each CPAC statement. We do not expect candidates to achieve CPAC statements every time practical work is assessed. Where CPAC is met every time by all candidates then that is an indicator that a centre may not be appropriately assessing.

Ensure that candidates are engaged with Practical Endorsement. PE and its assessment should be explained at the beginning of the course. In addition, candidates must be clearly informed which CPAC is being assessed in a particular practical session.

Where a team of teachers deliver physics, there must be evidence that candidate records are monitored to support standardisation across all subject teachers. This is a requirement that is noted in the monitor's report and must be implemented for a centre to pass the monitoring visit.

Please also remember that candidates must be informed whether they have achieved Practical Endorsement before the centre submits outcomes to Eduqas in accordance with JCQ requirements. Eduqas will not change centre gradings if a centre has passed the monitoring visit.

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