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Physics A PHYA5/2C

(Specification 2450)

Unit 5/2C: Applied Physics

Report on the Examination

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GCE Physics, Specification A, PHYA5/2C, Section A, Nuclear and Thermal Physics

General Comments

The exam had good discrimination and the complete range of marks from zero to full marks were seen. Students showed some general areas of weakness in tackling this paper. The first was a lack of clarity when answering standard questions that should have been extremely straightforward. So the typical mark for explaining what is meant by the term ‘binding energy’ was one mark out of two. The same mark was also a typical score in question 4(b). The second area of weakness across a range of abilities was question parts 3(b) and (c) in which many students could not deal effectively with solid angles, detection efficiency and the inverse square relationship between range and intensity of gamma rays. However, other topics were done well resulting in a paper that was of very comparable difficulty to previous papers.

Question 1

In part (a) almost all students knew the correct equation to use and only the less able students made errors. The first of these was to use the mass of water in the heating chamber rather than the rate of flow of water. The second error, which was less common, was to try to convert between Kelvin and Celsius by adding 273 to the answer. Again in part (b) it was only the less able students who had any difficulty. The problem was that they could not cope with being given the rate of supply of energy. Overall the question was done well.

Question 2

Even though part (a) needed a little thought almost all students obtained the correct answer. By contrast part (b)(i) was simply a factual recall question, which was answered poorly by a significant minority. The main error was for students not to state the energy needs to be given out or is required, when a nucleus was formed or broken up. It was common to see written, ‘The energy to keep the nucleus together’. In part (b)(ii) a majority of students simply read the value from the graph and gave an answer near 7.88 MeV without appreciating the ‘per nucleon’ on the y-axis of the graph. Part (c)(i) was done well by most students. Some students missed marks due to a lack of care in choosing specific coordinates for the graphs to pass through. Most students made a good attempt at part (c)(ii). Part (c)(iii) was more difficult and only the better student could correctly combine the two equations required to answer the question. A common mistake made by a few students who looked as if they were going to get the correct answer was for them to confuse the time units they were using. These students obtained the correct answer but then multiplied it by $60\times60\times24\times365$.

Question 3

A majority of students could not give two clear specific sources of background radiation. The answers given in response to question part (a) were all too often of a general nature and too vague to be worthy of a mark. For example, ‘power stations’ or ‘the air’. The answers needed to be clearer statements like, ‘radioactive material leaked from a power station, or radon gas in the atmosphere. As only one mark was being awarded only one detailed source gained the mark provided the second point was in some way appropriate even if poorly stated. Part (b)(i) was a very good discriminator. More able students realised that a comparison of areas was required to answer the question. Part (b)(ii) was also a good discriminator. Only the top 20% of students used the detection efficiency factor as well as the fraction of gamma rays hitting the detector to obtain the correct answer. Most used only the 1/400 detection efficiency. Students were more successful in choosing the correct unit. Part (c) was interesting in that students either attempted the question successfully or they left this section blank.

Question 4

Part (a)(i) was an easy introductory question, which most students got correct. Part (a)(ii) was also successfully attempted in a majority of scripts. Use of the ideal gas equation again was more popular than using pressure is proportional to temperature. A small percentage of papers gave answers to only 2 significant figures rather than the 3 required. A majority of students only scored one mark out of two for part (b). They correctly referred to the random motion but failed to refer to a mean when giving some quantity, such as kinetic energy, that increases with temperature.

Question 5

Only the less able students tried to draw graphs of completely the wrong shape by showing peaks etc. in part (a). A significant minority however failed to get the mark because they drew the graph with a horizontal asymptote. Part (b)(i) also scored well. Only the bottom 25% had difficulty over the use of the density equation or the volume of a sphere. Not many students got caught out by powers of 10 in the calculation but this could have been because of the ‘show that’ nature of the question. Part (b)(i) proved to be much more difficult and only the top third of the students scored the 2 marks. Some unsuccessful attempts showed the equation for the radius in terms of the atomic mass number but they did not know where to obtain r_o from the information supplied. Part (c) was a good discriminator and the mean mark was between 3 and 4 out of 6. Two thirds of the students supplied information about alpha particles being scattered electrostatically. Many hinted at the idea that the least distance of approach is connected to a measure of the radius of the nucleus. This group of students also referred to electrons behaving as waves to explain diffraction. The bottom third of students scored poorly because they did not add much information to what they would have covered at GCSE. It was common to see an explanation of the scattering distribution of alpha particles and give nothing else. In this way they almost completely ignored the wording of the question. Students had obviously been taught this section of the specification in a vast number of different ways. To give students the greatest benefit, no individual marking point was required for any particular score. Any of the selection of points listed in the marking scheme were noted and taken into consideration along with the quality of communication. As a consequence, for example, some students scored full marks even though they did not refer to any equations. Most students lost marks by not including enough of the points listed. They did not include many statements that were wrong apart from one notable exception. A majority of students who gave the equation to find the least distance of approach for an alpha particle related the initial kinetic energy of the alpha particle with the Coulomb force expression rather than the potential energy expression.

GCE Physics, Specification A, PHYA5/2C, Section B, Applied Physics

General Comments

The vast majority of students were able to attempt all the questions and there was no indication that they were short of time. As is usual on this option students seemed more at home with the numerical questions than the qualitative questions. The very nature of this option means that questions will be set in contexts that they will not have seen before (e.g. the pop gun and the circular saw) but this did not appear to put them off. The majority, however, were not prepared for Question 3 on the use of a flywheel for smoothing the motion of a reciprocating engine, and this is probably because a question on this particular aspect of flywheels has not been set on this option in recent years. This question also tested quality of written communication (QWC) and was worth up to 6 marks. The remaining questions all had some parts that echoed topics that have been tested before, and where practice with past questions will have given some degree of confidence.
Answers to 3 (a), 4 (b) and 4 (c) were often far too brief, with students no doubt expecting to be given credit for single word answers or just a few words (e.g "area under graph", "friction", "exhaust").

It is recommended that all teachers of this option use the support booklet on Applied Physics. It can be downloaded here.

Question 1

This question was on the compression of air in a child's pop gun, and parts (a)(i) and (ii) were generally answered well, though some lost the mark for not giving the answer to two significant figures in (a)(ii). Part (b) was similar to Question 3 (a)(ii) in the 2011 examination, yet only about half the students scored the full two marks. Most students were able to score the first mark, for stating that in an adiabatic compression $Q = 0$, but many of these then went on to give *minus* 1.4 J for the change in internal energy, not using the fact that work done *on* the air is negative, so that compressing the air would give an *increase* in internal energy. This was surprising as they had shown in (a)(ii) that the temperature (and hence internal energy) had gone up. As in previous papers, a significant number of students quoted the first law equation correctly (it's in the Data and Formulae booklet) but showed they did not really understand the terms Q and ΔU.
Only the most able students were able to achieve full marks in part (c). There were some very good answers supported by well-drawn sketches of adiabatic and isothermal curves on a $p – V$ graph starting from the same point and curving upwards to the left. The best many could do was to state that a slow compression would be isothermal or nearly so, and for this they scored one mark.

Question 2

It was pleasing to see that many students are confident in dealing with torque, power and energy in rotational dynamics. Part (a)(i) was nearly always correctly answered, but in (a) (ii) the friction torque was often ignored altogether or *subtracted* from the 'cutting' torque, instead of being *added* to it. It was surprising to see that many students could not change rev min^{-1} to rad s^{-1}, but if they carried their wrong value to parts (b) and (c), a generous use of 'carried error' in the marking meant that they could still pick up full marks for those parts, provided the rest of their working was correct. In Question 2 part (b) many used $I = T/\alpha$ but failed to realise that only the friction torque was acting. The unit was generally well known. In part (c) the easiest route was to use power dissipated = $\frac{1}{2} I \omega^2/t$ but some made hard work of it and found braking deceleration, braking torque and then used *power* = $T \times \omega$ but often not knowing that the speed to use here is the average angular speed.

Question 3

Part (a) asked students to *state* and *explain* how to use a graph of torque against angular velocity to find work done in one revolution. Many students failed to gain a mark here, mainly because they wrote only "find the area under the graph" without giving any explanation. All that was wanted in the way of explanation was to link the area to $W = T\theta$, or to show that they knew the area required was the area under either graph between 0 and 2π rad.
Although there were some well-written answers to part (b), covering several of the points in the mark scheme, these were very few and far between. It was clear that the majority of students were totally unprepared for this. The question highlighted three areas for discussion, and it was expected that

students would be able to show some understanding, perhaps not of all three but certainly of one or two. The specification asks for an understanding of the use of flywheels in machines, and an important use of a flywheel is in smoothing out the otherwise irregular motion in reciprocating machinery.
All too often answers just described in words the T against ω graph of Figure 4 or said that because the acceleration varies, and $T = I\,\alpha$, the torque varies, without mentioning forces or moments. Many tried to use conservation of energy and/or angular momentum, not taking into account the fact that the engine drove the flywheel so external torques and work input were involved. Many wrote that the larger the moment of inertia the smaller would be the engine speed and vice versa. A significant number drew on the previous year's QWC question on the design of a flywheel for maximum energy storage, and a lot of what they wrote was not relevant here.

Question 4

A large majority of students scored at least two marks on part (a)(i), showing they knew that they needed to first find the area of the indicator diagram loop, and they knew how to do it. Common errors in (a)(i) were

- getting the scaling factor wrong (usually by not reading the volume axis carefully enough)
- missing out the need to convert squares to joules altogether,
- over- or under- estimating the area,
- missing the half factor when finding cycles per second
- not multiplying by 4 for the four cylinders.

Question 4 part (a) (ii) required a knowledge that *overall efficiency = brake power/input power*. This formula is not in the Data and Formulae booklet, and many were floored by this, so tried to contrive to fit the data into one of the equations for efficiency that does appear in the booklet, often to no avail. A common mistake was to include indicated power somewhere in their working. Many, however, were credited for being able to calculate the input power provided they used the 100 seconds correctly.

In part (b), students were asked to account for the difference between indicated power and brake power, and because the formula *friction power = indicated power – brake power* appears in the formula booklet, the mark scheme was fairly severe. Only those students who were able to give an example of where friction occurs (e.g in bearings, between piston and cylinder, in driving the water or oil pumps) gained the mark. Friction between (or "of" or "in") moving parts was not considered enough here.

Again, in part (c) what was required was a statement that line AB represents both induction **and** exhaust strokes. It is clear that this was not understood by the majority of students, even though the specification requires an *"…understanding of a four stroke petrol cycle and a Diesel engine cycle and of the corresponding indicator diagrams*."
In a real indicator diagram such as Figure 5, the difference in pressure between induction and exhaust is so small that both strokes show as a single line. Too many students mentioned neither induction or exhaust strokes and stated the obvious (e.g that it represents atmospheric pressure). A common misconception was that the line represents the intake of fuel, forgetting that in a Diesel engine fuel is injected at the end of the compression stroke, and not drawn in during induction.

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