AQA

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PHYSICS

7408/3BC Engineering Physics
Report on the Examination

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General Comments

The majority of students were able to attempt all of the questions and they appeared to have allowed themselves enough time on this section to answer the paper in full. The examiners saw many confident and high-scoring answers from students who were well prepared for the exam.

Questions 01.4, 03.2 and, to some extent, question 4 asked the students to analyse, interpret and evaluate data and come to a conclusion or make a judgement or decision. These questions tested Assessment Objective 3 (AO3) of the specification. The majority of students made clear concluding statements following their calculations, but a small minority let themselves down by writing a one-word answer such as "yes".

The levels-of-response question (question 4) was set in an unusual context, but most students were able to pick up marks by analysing the problem and making sensible points. This question was set not only to test specification content, but also to cover some of the wider aims - for example, students are expected to "consider applications and implications of science and evaluate their associated benefits and risks". (See pages 68 and 69 of the specification booklet.)

Questions 01.1 and 03.3 required students to recall basic definitions. More students than expected were not prepared for this. For an option specialising in rotational dynamics and thermodynamics, students should give definitions that use correct terminology.

Answers showed that students were more confident with rotational dynamics than with thermodynamics. The mean mark as a percentage of the maximum mark was between 72 and 74% in 01.3, 01.4, 02.1 and 02.2. In the calculations, students usually took care to show the stages in their working, but a minority wrote down numbers without giving any evidence of where they came from. They might have held intermediate stages in their heads or their calculators until a final step. Examiners will try to give credit where they can, but a number or answer seemingly plucked out of thin air may not get a mark. Students cannot expect the examiners to make a link or fill a gap.

A minority of students were let down by poor handwriting. Examiners try to interpret *words* that are difficult to read by using the gist of a sentence, but it is impossible to do this with poorly-written *numbers*. Students should be advised to write and display calculations clearly.

Question 1

01.1 Only 41.4% of students scored the one mark for this question. Nearly all answers referred to angular momentum remaining constant, but many failed to include the proviso that there must be no external torque acting. Many wrote 'force' for 'torque' and so failed to gain the mark. Examiners accepted momentum 'before' and 'after', even though students did not say what the before or after referred to. A significant number of students did not take the hint suggested by 01.1 that the whole of question 1 might be about conservation of angular momentum, and went on to answer 01.3 and 01.4 in terms of conservation of rotational kinetic energy.

01.2 Students were well-prepared for this; 95.1% scored the full two marks. The 2.6% who scored one mark are likely to have missed out '239' and gone straight from the calculation to the 'show that' answer of 240 (kg m^2).

01.3 There were some excellent answers (47.1% of students gained all three marks), but although nearly all students knew that the moment of inertia would decrease, a number did not get the second mark for *explaining* the decrease. It was not enough to simply state that the radius was decreasing. Examiners were looking for reference to the change in distribution of the mass of the pods, not just the arms. (Students were told the mass of the arms was negligible.) It was possible to score the third mark by reference to conservation of angular momentum, without scoring the second. A small number of students explained the change in angular speed as being a consequence of conservation of kinetic energy, and so failed to gain the last mark.

01.4 The calculations here were usually done well, and most came to a sensible written conclusion. Those who used the conservation of kinetic energy could score no marks for this question (just over one fifth of the students).

Question 2

02.1 The question asked for one function of a flywheel. Only a brief answer was required and 73.5% of students were able to score the mark. Storing energy was the most common answer, followed by the smoothing out of torque. Answers which only gave an *application* of a flywheel (for example, kinetic energy recovery systems or a potter's wheel) were not credited.

02.2 In this question, students were asked to work out the frictional torque acting on a flywheel by first finding the loss in potential energy of a magnet attached to the rim. Despite the heavy hints given in the question, 36.9% of students scored no marks. Students who knew how to start usually ended up with three or two marks. It was expected that students would use $r \sin 8^{\circ}$ to calculate the vertical distance of position B below the horizontal. Because the angle was small, the first mark was also awarded to those who used $r \tan 8^{\circ}$ or the arc length for an angle of 8°. The next step was to calculate the loss in gravitational potential energy corresponding to this distance; about 56% of students were able to do this. In the use of $T = mgh/\theta$ for the last step, it was not uncommon to find students converting $172\ ^{\circ}$ to radians, despite 3.00 rad being given in the stem of the question.

02.3 Students usually cope well with the angular versions of the equations of motion and this question was no exception. Common errors were not squaring ω_1 in $\omega_2^{\,2} = \omega_1^{\,2} - 2\alpha\theta$ or not converting 573 rev to radian correctly (or not even attempting to). Students were allowed an error carried forward in their calculation of the moment of inertia for the last mark. Pleasingly, 57.2% of students gained maximum marks here.

Question 3

03.1 The mark was scored by 47.1% of the students.

03.2 This question concerned the work done and efficiency of a modified ideal diesel engine cycle. Students were asked to make judgements about the two claims given in the question. Estimating the extra work done for Claim A caused few problems for most students. Counting squares was the most common method but, as an alternative, full credit for the calculation could be gained by approximating the area 1→4→5→1 to a triangle. Of those who knew what they were doing in Claim B, many failed to gain a mark by underestimating the area of the loop 1→2→3→4→1. This did not, however, prevent them from scoring subsequent marks. The examiners accept that there was some ambiguity in the question. An alternative mark scheme was prepared to account for those who attempted to calculate separate efficiencies for both cycles, and then found the increase. The question should have given either the efficiency of the first cycle, or its input energy. Only a minority of students tried this approach, and examiners took pains to ensure no students were disadvantaged. 30.5% of students scored four or five marks; 51.2% scored one, two or three marks. Teachers of this option might like to know that this question was about an Atkinson cycle, a variation of which is used in some modern car engines to improve fuel consumption.

03.3 There were many disappointing answers to this question. All too often, Q was defined as "heat", "heat flow" or "heat transfer", with no mention of the word 'energy'. It is to be expected that students taking an option specialising in thermodynamics would have a strong understanding of the first law of thermodynamics, and not be sloppy in their definitions. Some wrote "total energy", probably because it was the sum of two entities, ΔU and W. About 39% scored one mark out of the two, mainly because their understanding of the meaning of ΔU was much better. 18.4% of the students scored no marks at all. There were instances where the terms internal energy, heat and temperature were used as if they meant the same thing.

03.4 Answers here reinforced the examiners' view (from 03.3) that the first law is not fully understood. 21.5% of students scored both marks, but another 35.8% could only score the one mark for calculating the work done in process 5→1 (with or without the minus sign). This is work done **on** the air, so must be **negative** in $Q = \Delta U + W$. The calculations "$-374\ \text{J} + 150\ \text{J} = -224\ \text{J}$", or "$374\ \text{J} - 150\ \text{J} = 224\ \text{J}$", were commonly seen.

03.5 The majority of students who judged correctly that the highest temperature in the cycle was at point 3 were able to score full marks (45.8% of students), but some failed to gain the last mark by not reading accurately enough the pressure and volume at point 3 on Figure 4. The first mark was an 'easy' mark for *attempting* to use $pV = nRT$, for example by using any point in the cycle. Despite this, nearly 10% of the students scored zero, and 8.2% did not attempt the question. Many students had no idea which point in the cycle corresponded to maximum temperature, so were unable to access the second and third marks.

Question 4

This question was answered well by those students who had a good understanding of the meaning of efficiency and who had previously come across the idea of combined heat and power (CHP). These students were able to explain the upper limit of efficiency of a heat engine, often quoting $(T_H - T_C)/T_H$ and sometimes mentioning the second law of thermodynamics. They then went on to address the paper mill CHP scheme using the data given. The most common points made using the data were that:

- when all the energy required by the mill came from the National Grid, the corresponding input energy would be 495 MW;
- the input energy to the generator is 158 MW or 167 MW (depending on whether they used a generator output of 57 or 60 MW);
- the energy in the exhaust gases (101 or 107 MW) is not enough to provide all 141 MW for process heating;

- the generator can provide the 57 MW load for all the electrical equipment and offices.

It was pleasing to see answers from students who were able to think around the problem and who came up with arguments concerning the economics of the scheme (capital, installation, maintenance and staffing costs) and reliability. The marking was generous at the lower end. Students could score a mark for practically any sensible reason for low efficiency of a heat engine, even though the question related to maximum theoretical efficiency. Some wrote half a page on reasons for low efficiency of 4 stroke engines, which were not relevant here. The concept of efficiency is in the main part of the specification (Section 3.4.1.7) and in the option, but a significant number of students showed a lack of understanding. For example, the output power of the generator was given in the question as 60 MW, but this did not stop students calculating the output as 60×0.36 or 21.6 MW. A common recommendation was to use the National Grid because it could easily supply all the power needed, completely missing the idea of making use of energy that would otherwise be wasted. Just over three-quarters of the students were awarded at least two out of the six marks available; however, only 4% gained full credit.

Mark Ranges and Award of Grades

Grade boundaries and cumulative percentage grades are available on the Results Statistics page of the AQA Website.