A-LEVEL
PHYSICS

7408/3BC: Paper 3B Engineering Physics
Report on the Examination

7408
June 2019

Version: 1.0

General Comments

There were questions on which nearly all students were able to gain some credit, and, it is hoped, achieve some confidence. The high mean marks for questions 1.1, 1.3, 3.1 and 3.2 suggest that students generally seemed more comfortable with the calculations than the qualitative questions.

Questions 2 and 3 introduced ideas that students might not have been familiar with (turning moment diagrams and the use of an 'economiser'), but all necessary information was given for them to be able to apply their knowledge, and many were able to rise to the challenge.

In last year's report, it was noted that in the questions which test Assessment Objective 3, where a deduction or conclusion must be made, some students were writing one-word or very brief answers. It was pleasing to note that this was not so evident this year.

As in previous years, many students disadvantaged themselves with poor handwriting and/or badly-presented answers. On the other hand, many students wrote clear and well-explained answers with all steps shown in calculations. When they did make a slip or arithmetic error, it was easy to spot where they had gone wrong and an ‘error carried forward’ was given to award marks for subsequent work.

Question 1.1

Students were asked to calculate the moment of inertia of the rotating parts of a fly-press given the rotational speed and rotational kinetic energy. About 60% of students scored both marks, the majority of the remainder either making no attempt to convert rev s^{-1} to rad s^{-1}, or by dividing 8.9 rev s^{-1} by 2π or 60 or both.

Question 1.2

In order to explain why the moment of inertia of the screw, punch and arms was much smaller about the axis of rotation than that of the balls, students were expected to show they had some idea of the meaning of moment of inertia. For the first mark, students had to make some reference to how the masses are distributed. Too many simply stated that the radius of the balls (meaning the distance from the axis) was greater than the radius of the other rotating components, without mentioning mass at all, or they quoted $I = \sum mr^2$ (often without the $\sum$) without any clear explanation of how it applied in this situation. A minority did not read the question carefully and referred to the balls being heavier, hence a greater moment of inertia.
The second mark was more discriminating and students were credited for explaining the word *much* in the question. If they emphasised the fact that the distance (of the mass from the axis) is squared and that this greatly affected the moment of inertia, they scored the mark.
Around 37% of students scored no marks at all.

Question 1.3

This was answered well, with more than 70% scoring 3 marks and only around 4% scoring no marks at all. Students could gain full credit if they used the incorrect value of ω_1 that they used in 1.1 and carried it through. Most were adept in handling the equations of motion. Only a few made an error in the time, some reading 89 ms as 89 s.

Question 1.4

In this question, students had to decide which of two options would enable the fly-press to store more rotational kinetic energy. When they realised that the moment of inertia (and hence energy) increased by y^2 and by R^3 they were well on the way to a full answer. Approximately half of the students were not able to make any headway. About 22% of students scored the full 3 marks, with many answers clearly expressed, both in the calculations and the concluding statement. Of the others, too many thought that increasing the radius of the balls would hardly influence the moment of inertia and hence energy stored. The dimensions *y* and *R* were clearly explained in the question, but it was difficult to interpret some answers, as students used *r* or $y + R$ for the distance defined as *y*.

Question 1.5

Despite the equation for angular impulse being in the Data and Formulae Booklet, only just over half of the students scored the mark for correctly identifying the unit.

Question 2.1

Over 80% of students were able to state that the area under the torque–angle curve represented work done. Some students gave a choice such as work done/energy and received no credit. A very small minority failed to gain marks when elaborating their answer, for example by writing '*work done against friction*' which is clearly not what the area represents.

Question 2.2

This was the extended response question, worth 6 marks. Unusually, it cut across both the rotational dynamics and thermodynamics sections of the option. About 10% of students gave several sensible and appropriate statements covering the three bullet points in the question and scored 5 or 6 marks. The most effective answers showed a clear understanding of why a flywheel is required for the diesel engine, but not for the motor.

It was pleasing to see answers which matched the diesel engine or electric motor to the load (described as 'a machine' in the question). The majority of students neglected the load altogether. Marking was generous at the lower end; only three of the many answer points in the mark scheme were needed to score 2 marks. Even so, fewer than half of students managed to score 3 or more marks. Many described everything they knew about diesel engines in their answer, but not much was relevant.

Examiners expected to see answers in which the varying torque was explained in terms of the changing force or pressure on the piston, but only a small number of students approached the question in this way. All too often they thought the torque was a consequence of the work done, rather than the other way round. Some students confused torque, power and work, or used these words as if they had the same meaning.

Other misconceptions were:

- there is zero force on the piston when at the dead centres
- the greater the moment of inertia of the flywheel, the slower the engine will rotate
- when the piston is momentarily stationary (at a dead centre) the output shaft is not rotating.

Question 3

Students were asked to analyse a closed heat-engine cycle comprising two isothermal processes separated by two constant pressure processes. The cycle described is an Ericsson cycle, and, like the Stirling cycle, it has the maximum theoretical cycle efficiency, or Carnot efficiency.

Question 3.1

More than 90 per cent of students achieved the mark for a simple application of $pV = constant$ to the isothermal process A → B.

Question 3.2

This question was also answered well, with about 75% of students scoring 2 marks. The most common approach was to apply $\frac{pV}{T} = \text{constant}$ (or $\frac{V}{T} = \text{constant}$) to points B and C in the cycle. Some took a more laborious approach and worked out n or nR using $pV = nRT$ for point B and substituted into $pV = nRT$ for point C. Some students mistakenly applied $\frac{V}{T} = \text{constant}$ to points with two different pressures, eg points A and C.

Question 3.3

This proved to be difficult, with around half of the students failing to gain any marks. Just over one-fifth of the students scored the two marks. There were many answers where the magnitude of the work done in process D to A was correctly calculated, but students missed the minus sign to show work is done **on** the air. A careful reading of the question should have informed students that the energy transfer in process B → C is the same as the energy transfer in process D → A, but of opposite sign. Many missed this.

Question 3.4

Students were fairly confident in the application of the first law of thermodynamics, and about 75% of students scored 1 or 2 marks. The most common reason for not scoring 2 marks was confusing ΔU and U, with students giving the statements '*ΔU is constant*' or '*U equals zero*'. Students who wrote $Q = \Delta U + W$, and then showed a misunderstanding of what the symbols meant, failed to gain one or both marks.

Question 3.5

About one-third of students scored only 1 mark out of 3, and this is likely to have been for calculating the maximum possible efficiency of the cycle, but this was as far as they could get. To calculate the actual efficiency, they needed to add the figures in their *W* column of Table 1 to find the net work done and then divide by 10300 J. 'Error carried forward' was given for their *W* for

process D → A. An alternative route for finding the work done was to find the area of the loop in Figure 3, but few used this method. All the information required, including the energy provided by heat transfer from an external source, was in the stem of 03.3 and **Table 1**. Perhaps students did not realise the importance of going back over earlier parts of the question to locate the appropriate information. Provided they had correctly calculated the efficiencies, students then needed to come to a sensible conclusion for three marks; only around 11% of students scored 3 marks.
A surprising number of students wrote a conclusion without having done any calculations at all, or based only on the maximum theoretical efficiency. About 7% of students made no attempt to answer the question.

Question 3.6

The most effective answers were those that discussed the practical difficulties of achieving isothermal processes, or making an economiser that would store or transfer energy effectively. For 2 marks the answer had to relate to the working of a real engine based on the cycle described in the question. Most answers applied to **any** engine, with references to friction and/or heat loss to surroundings, or the rounding of the corners of the indicator diagram. No credit was given for such answers. Only about one-third of students scored one or both marks.

Question 4.1

Reversed heat engines are still not understood well by the majority of students. The first mark was awarded for knowing that a heat pump tumble dryer takes some of its energy from a cold space. About one-quarter of students scored this mark. Many students thought that the heat pump transferred **air** from the cold space to the hot space.
The second mark was for developing this to explain why the heat pump tumble dryer uses less electrical energy than a conventional tumble dryer, but only approximately 16% of students were able to give a clearly thought-out answer.

Question 4.2

Answers to this question were better than for 4.1, with about half the students scoring 2 or 3 marks.
Normally, we would not reward students for using ºC in the equation $\frac{T_H}{(T_H - T_C)}$. In this case, however, coefficient of performance was not mentioned in the question, and the equation in terms of temperature is not in the Data and Formulae booklet, although it is in the specification. Since the students had to realise that both the coefficient of performance and the use of the temperature equation were needed, it was decided to condone the use of ºC, thereby allowing a maximum mark of 2. A considerable number of students did not convert to Kelvin.
Those who were able to calculate the coefficients of performance (or correctly argue that the CoP for the kitchen was higher) usually went on to correctly deduce that placing the tumble dryer in the kitchen would give the lower running costs.
A significant number of students calculated the efficiency of the tumble dryer as if it was a heat engine using $\frac{(T_H - T_C)}{T_H}$. Some calculated CoPs, but referred to them as efficiencies.

Mark Ranges and Award of Grades

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