Questions matter

A-level

Physics

7408/3BC Paper 3 Section B Engineering Physics

Report on the Examination

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General Comments

Many students were well-prepared for the examination, with a good knowledge and understanding of the specification topics and concepts. They also showed their ability to tackle questions set in unfamiliar contexts, particularly in questions 2 and 3.

In contrast, there were students who seemed to have little knowledge of basic concepts, and who therefore struggled to apply them. Examples of this are angular momentum, the first law of thermodynamics and basic heat-engine theory.

It was pleasing to see that the majority of answers showed students had read the questions carefully, with relatively few going completely off track.

The questions that proved most difficult were those designed to test assessment objective 3 (AO3). These questions require students to analyse, interpret or evaluate information, and often to go on and make a judgement. The mainly AO3 questions were **02.2**, **02.3**, **03.3**, and **04.2**. Parts of **01.2** and **03.1** were also AO3, but students seemed to manage these better, even though the context of **03.1** was likely to be very unfamiliar.

As in previous years, many students do themselves no favours by offering handwriting that is very difficult to read combined with poorly organised answers. On the other hand many students write clear and well-explained answers with all steps shown in calculations.

There was little indication that students ran out of time.

Question 01.1

Nearly 70% of students were able to score one or more marks. There were some good answers which showed a sound understanding of how the law of conservation of angular momentum applied to the propeller and turntable. Many answers went further than the expected mark scheme by giving reasons for the different moments of inertia of the turntable and propeller.

Most of those who scored two marks missed the idea that the turntable must rotate in the opposite direction to the propeller for angular momentum to be conserved. Those who simply wrote that the turntable rotates anticlockwise '*due to'* conservation of angular momentum did not get the mark for this. A statement about the equal and opposite momentums was required.

Some students filled the answer space with an explanation that failed to mention angular momentum, despite the instruction in the question. Some wrote that the angular momentum of the propeller and/or turntable *'must be constant*' instead of *'must be conserved*'.

Common misconceptions were:

- the turntable must have greater angular momentum than the propeller because its moment of inertia is greater
- the turntable and propeller both rotate clockwise to conserve angular momentum.

As in previous years, some students were sloppy with terminology, referring to '*inertia*' instead of *'moment of inertia'*, and *'momentum'* instead of *'angular momentum'*.

Question 01.2

This was the levels of response question, with a mark allocation of six marks. On the whole it was a well-answered question. About one-quarter of students gave a level three (5 or 6 marks) answer. Three-quarters of students scored two marks or more.

It was pleasing to see many thorough answers which showed a good understanding of both the practical and theoretical aspects of the question.

Examiners were looking for answers to cover three areas:

1. measuring the angular speeds
2. the other measurements needed
3. how the moment of inertia of the turntable would be determined.

The most common answer for area 1 was to use a fiducial mark and timer or stop clock, although some failed to include both. Any indication of making a mark or marks to enable rotations to be counted would do. Cameras, light gates and various sensors were also suggested. For these other means, further practical details for finding angular speed were often missing.

This area could not be considered to be fully covered if students suggested that one rotation only should be timed or filmed, or if they thought the number of rotations should be counted in a given time (ignoring the necessity to measure part rotations).

Most students explained how rev s^{-1} should be converted to rad s^{-1}.

In area 2 it was not uncommon for answers mistakenly to include a measurement of the radius (or diameter) and mass of the turntable. They would go on to state the moment of inertia of the turntable could be calculated using $I = mr^2$ or $0.5\ mr^2$, thereby negating the whole point of the experiment.

One problem for examiners was the interpretation of students' use of the word *'radius'* in relation to the steel mass. It had to be clear that the measurement needed was the distance, or radius, of the steel mass to the *axis of rotation (*or *centre of turntable). 'The radius of the steel mass'* was insufficient, especially when a micrometer was suggested for its measurement. The use of a ruler was expected for this.

In area 3 the application of conservation of angular momentum to the situation was covered confidently by many. A small minority thought the application of conservation of energy (including the initial gravitational potential energy of the steel mass) was needed.

Question 02.1

Nearly 60% of students scored full marks, but nearly one-fifth scored no marks at all. The specification asks for an understanding of 'representation of graphical methods of uniform and non-uniform angular acceleration'.

Many answers showed that students were able to find the area of the angular velocity against time graph in terms of ω_{max}. This was usually done by splitting the graph in Figure 4 into two triangles and a trapezium or three triangles and a rectangle. Some tried more complicated methods.

Many students missed the final mark because they had misread a time interval from the graph. This was treated as an arithmetic error.

Question 02.2

Students had to realise that they needed to calculate the torques for the three peaks shown in Figure 5. To do this they needed the angular accelerations for the three stages shown in Figure 4.

About 20% of students scored the one mark for calculating the torque at 2.1 s, probably because the question directed them to this time. They did not go on to consider that they needed to show that the torque was lower at the other peaks in order to deduce that torque was a maximum at 2.1 s.

Those who calculated the torque for two peaks scored two marks. A few students discounted the peak at 5.0 s because they saw from Figure 4 that the acceleration was negative. If they *mentioned* this as the reason for discounting the torque there, they could get three marks provided they also calculated the torques at the first two peaks. This was condoned because the torque would be a braking torque with friction assisting the platform in decelerating.

Where comparisons were made, the mark scheme condoned the dropping of the factor ($\times\ 10^3$) in values of moment of inertia, and hence torque.

The question proved difficult, with about half the students scoring no marks at all and nearly 4% not even attempting it. It tested AO2 and AO3.

Question 02.3

This question was aimed to test assessment objective AO3. It required students to make a judgement about where the maximum power was likely to be. Only around one third of students scored at least one of the marks. A measure of the perceived difficulty of the question is reflected in the roughly 10% of students who did not attempt it.

It could be tackled in one of two ways, by a written explanation or by calculation. Those who chose the calculation route were generally more successful.

The answer required an analysis of Figures 4 and 5 and reference to $P = I\alpha\omega$, whilst appreciating that after 2.1 s:

- the moment of inertia decreased slightly
- the angular acceleration remained the same
- the angular speed increased.

The conclusion could then be made that the power is greater at a time closer to 2.7 s.

Those who successfully used the calculation route found the angular speed at 2.1 s and multiplied it by their torque from **02.2**. This gave one mark. They then found the power near or at 2.7 s by multiplying the moment of inertia at 2.7 s (or just before) by the angular acceleration and by $\omega_{\max}$.

Question 03.1

Question 3 required students to analyse an unfamiliar indicator diagram from an early type of internal-combustion engine. The specification (Section 3.11.2.4) states "Questions may be set on other cycles, but they will be interpretative and all essential information will be given."

There was a significant amount of reading time. Students needed to follow how the engine worked and match the indicator diagram to the series of events. The analysis was complicated by the fact that the engine is double acting.

Despite all this, **03.1** proved to be very accessible. Although only around 10% of students scored five marks, 60% scored three or more marks, and only about 6% scored zero.

The mark scheme rewarded *process* rather than accuracy when determining the area of the p-V loop and hence the indicated power. So even a rough and ready attempt at the area could still gain four marks if they went on to use two from:

- correct scaling factor,
- subtracting pumping loop,
- correct cycles /second.

and with their numbers, use (area of p - V loop) × (number of cycles per second) to get a value for indicated power.
This enabled more students to score marks.

Commonly seen methods of finding the area(s) were

- counting small squares
- counting 'large' squares
- using a mixture of large and small squares
- approximating the loops to triangles.

The more able students could correctly deduce the number of cycles per second, but fewer realised the pumping loop needed to be subtracted. Weaker students found they could make a fair stab at finding an area in squares and converting to joules and then use their values to calculate power.

The majority of students showed the conversion to joules, but some just put the number of squares in the formula for indicated power. Just mentioning something like 'one small square = 1 J' was enough.

For five marks a correct answer only was required. This had to be based on accurately finding the areas of the main and pumping loops, subtracting the pumping loop, using a correct scaling factor and using 4 cycles per second.

Question 03.2

A very straightforward question requiring substitution of given data into the formulae for input and output power. Both formulae are in the data and formulae booklet.

About 60 % calculated both powers correctly, with one third calculating one of the two powers. Common errors were:

- incorrect powers of ten in input power
- using output power = 39 × 120
- using output power = torque × rev s^{-1} = 39 × 2

Question 03.3

This question was further evidence for students struggling with questions designed to test AO3. They were asked to give two reasons for the Lenoir engine having a much lower output power than a four-stroke petrol engine. The mark scheme had seven reasons listed, some of which might seem fairly obvious, but students were not able to make the comparison between the Lenoir engine and a petrol engine.

About one third of students were able to give one appropriate reason, but only around 6% gave two. The most obvious and common correct answer was the very low speed of the Lenoir engine.

Far too many students tried to use their knowledge of the differences between ideal and real internal-combustion engines, or between diesel and petrol engines rather than use the information in the question.

Some of the answers considered unsatisfactory were:

- high friction of the Lenoir engine (with no reference to lubrication or combustion on both sides of the piston)
- greater numbers of valves in the Lenoir engine and more cylinders in a petrol engine
- differences in output torque
- the Lenoir engine is an old design.

Answers which referred simply to low efficiency or the smaller area of the p-V loop for the Lenoir engine were not awarded a mark. The examiners were looking for the *reasons* for low efficiency or the smaller area, and these are the points listed in the mark scheme.

Question 03.4

Approximately two-thirds of the students scored the one mark here for identifying the correct statement about different powers and efficiencies.

Question 04.1

Students were asked to define Q, ΔU and W in the equation for the first law of thermodynamics.

The mark scheme used the definitions that are given in the specification, and because of this marking was strict. When they had only one correct out of the three, they scored zero.

The definition of Q was required in Q 03.1 on the 2023 paper. This year students made the same mistakes as outlined in last year's Examiner Report. We wanted three elements: energy transfer/ to /the system. We did not accept 'heat' or 'to or from'.

It was fairly common to see very brief answers such as 'heat transferred' for Q, 'internal energy' for ΔU and 'work done' for W.

Only about 9 % of students scored two marks here.

Question 04.2

In previous papers questions on the first law have usually been calculations and students generally cope well with them. The specification (section 3.11.2.1) states 'Applications of first law of thermodynamics' and this includes both qualitative and quantitative applications.

This year students were asked to apply the first law to a room containing a working refrigerator, but it is clear that the majority were not prepared for a descriptive explanation. Answers showed little understanding of how Q, ΔU and W fitted the scenario. For example, many thought $W = 0$ because the volume of the room did not change.

Many did not make any reference to the first law, and some referred to the second law. Few treated the room as a system, concentrating instead on the working of a refrigerator. Too many answers made reference to hot and cold air, to heat sources and sinks, and to changes in temperature rather than internal energy.

Nearly 80% of students failed to score any marks at all.

Question 04.3

For one mark, examiners were looking for a downwards *arrowed line* to a labelled *low-temperature* (or *cold*) *sink*. Various words were accepted as an alternative to '*sink*', but not '*source'*.
About half of all answers scored the mark.

Question 04.4

This was a straightforward 'bookwork' question testing AO1. The equation for maximum thermal efficiency is in the formulae and data booklet, and the mark scheme expected this to be referenced. Many answers went straight to the second mark point about the impossibility of having a sink at absolute zero.

It was decided to give a maximum of one mark to those who used the idea of Q_C going to the sink, so W could not equal Q_H. For this mark, the answer had to include a definition of efficiency.

Mark Ranges and Award of Grades

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