A-LEVEL
PHYSICS

7408/3BC Engineering Physics
Report on the Examination

7408/3BC
June 2023

Version: 1.0

Further copies of this Report are available from aqa.org.uk

General Comments

It was pleasing to see answers from students who were well-prepared for the examination. These students often gave all the steps shown in calculations and wrote well-argued answers to the qualitative questions.

On the other hand, there were students who could only gain marks here and there. Their answers showed an incomplete grasp of even basic aspects of rotational dynamics and thermodynamics. Some had an idea of what the answer should be, but either expressed themselves poorly, or failed to include the correct terminology expected from an in-depth study of the option topics.

As usual in this option, questions were set in contexts that were probably new to the students. This particularly applies to the punching machine of Q1, the grinding wheel of Q2 , the air bubble of Q3 and the double-engine of Q5. Many students were able to apply their knowledge comfortably to parts of these questions, but others struggled to do so. These questions had parts that tested the higher level Assessment Objective AO3, requiring students to analyse or evaluate information or ideas and make judgements.

Many students' handwriting was very hard to read. Examiners did their best, but even so some marks may have been lost as a result of an examiner's inability to decipher particular words.

Question 01.1

Nearly 70% of students were able to write the analogous equation correctly. Marks were not awarded for writing

- 'inertia' for 'moment of inertia'
- 'rotational acceleration' or just 'acceleration' for 'angular acceleration'
- 'force' for 'torque'

We condoned the use of 'proportional to' for 'equals' or '='
A few answers were well off the mark, and included angular momentum, energy, or mass.

Question 01.2

An 'easy' first mark was given for $I = \Sigma mr^2$. It was common to see $I = mr^2$ instead, and no credit was given for this. For the second mark, examiners were looking for an understanding that the moment of inertia depends on how the mass is distributed around the axis of rotation. Too many answers referred simply to 'r' being greater for plate **A** than for plate **B**, without defining 'r', and often not referring to mass. Answers also referred to the distances of 'centres of mass' of the plates from the axis of rotation, not realising that the centre of mass of plate **B** is on the axis. Only about one quarter of students scored 2 marks.

Question 01.3

Students were asked to sketch how the ω - t graph would change for the punching machine when fitted with a flywheel with a greater moment of inertia. About 60% of students scored at least 1 mark. The mark scheme required two features:

- a smaller fall in angular speed from **A** to **B**
- a smaller initial gradient after **B**.

Other features, eg the slope of **A** to **B** or the position of **C**, were ignored. There was not enough information in the question to predict the changes. It helped if the sketches were carefully drawn.

In many it was difficult to see any difference between the initial gradient from their **B** to **C** and the original gradient, so a mark was not awarded. It was common to see the new ω_B as lower than the original.

Question 01.4

This question was allocated 1 mark for explaining a difference between their graph and the original graph. Many simply stated a difference without giving a reason. Only about one quarter of the students scored the mark.

Sometimes the difference described did not match their sketch graph. There were many clear and concise answers that referred to how the increased moment of inertia for the same energy led to a smaller drop in angular velocity. Those who described the lower initial gradient after **B** using $T = I\,\alpha$ also usually expressed themselves well.

Question 02.1

It is unlikely that students will have ever used a treadle-operated machine such as that shown in Figure 3. This did not seem to pose a problem for most students as answers showed they understood the mechanism. About half scored at least 1 mark.

The first mark was for $T = F \times r$ in words or symbols, with some explanation of what they understood r to be in the context of the crank and connecting link mechanism. The best answers referred to some, but not necessarily all, of the following:

- the line of action of the force and its distance from the axle
- the fact that the connecting link was always nearly vertical
- meaning that the force transmitted would be at an angle to the crank
- torque would be zero when the crank was at the dead centre and a maximum when parallel to the ground (and to the left)
- the operator's inability to maintain a constant force

Answers which did not score marks were those couched in terms of kinetic energy, conservation of angular momentum or of varying angular acceleration causing the torque to vary. Many mixed up the terminology, eg by confusing the crank with the axle, or treating them as the same thing.

Question 02.2

Over one third of students could not score marks on this, despite the question referring to angular impulse and the equation being in the data and formulae booklet.

The 2 marks were awarded if students used both elements of angular impulse ($T\Delta t$ and $\Delta(I\omega)$ or, in this case $I\Delta\omega$). Some students referred only to either $T\Delta t$ or $\Delta(I\omega)$ without linking them. We expected answers to refer to Δt being small , rather than "it happens quickly" or "suddenly", leading to a large torque. 30% of students scored 2 marks.

Question 02.3

This was a straightforward calculation using $\alpha = \Delta\omega/t$ and $T=I\,\alpha$. There was an alternative route using $\frac{1}{2}I\omega^2 = T\theta$, with θ found from an equation of motion. This question was answered well, with nearly 90% scoring both marks.

Question 02.4

Students had to contend with three torques in this question: friction torque at the bearing, 'sharpening' torque at the tool, and driving torque. Those who missed out friction torque altogether scored no marks.

It was pleasing to see that the majority of students knew to subtract friction torque from driving torque to get sharpening torque, and went on to score two marks. Those who added friction torque to the driving torque were awarded a generous ECF (error carried forward) for the second mark point: they had at least tried to take the friction torque into account.

Around 60% scored two marks, and about 20% scored 1 mark.

Question 02.5

This was an unusual question, designed to test AO3. Students were asked to deduce which of three electric motors was chosen to drive the grinding wheel, given their T - ω characteristics.

The second sentence of the data given below Figure 5 states: "The maximum power of each motor is developed at about $0.5\omega_0$." A problem not predicted by the setters of the question was that students would skim over this and read it as: "The maximum power of each motor is about $0.5\omega_0$."

For example, these students would give the power output of motor **E** as 0.5×240 or 120 W. As a result many students went on to score only 1 or 0 marks out of 3.

Another common error was to think that the maximum power is equal to the area under the graph.

On the other hand, there were some excellent, well-argued answers. Nearly 40% of students scored 3/3. Some put their information clearly in a table, eg with headings of ω_0, $0.5\omega_0$, T, Pmax, ⅔ Pmax.

Examiners were not expecting students to spend much time reading the graphs to 0.01 N m or 0.02 N m, hence the "about" in the criteria. Some leeway was given.

Question 03.1

Just over a third of students were able to recall/define Q in the first law for 1 mark for this question. Three elements were required: <u>energy</u> transfer / <u>to</u> / the <u>system</u>. We did not accept 'heat' or 'to or from'. The definition is clearly stated in the specification for the option.

Question 03.2

Nearly two-thirds of students were successfully able to apply the first law of thermodynamics to the adiabatic compression of the air bubble.

Question 03.3

Students are well-practised with calculations on $pV^{\gamma} = c$ and $PV/T = c$, with 56% scoring 3 marks and 26% scoring 2 marks. Many correctly calculated the pressure, but not the temperature. A fairly common answer was 293 K, ie they treated the compression as isothermal.

ECF was given for using an incorrectly calculated p_2 to calculate T_2. Despite the powers of ten, and a power of 1.4, there were relatively few numerical errors.

Question 03.4

This was another AO3 question. Students were asked to make a judgement about the work done when the air bubble is compressed slowly rather than quickly.

Common misconceptions were:

- the same brake force is applied for longer so the work done must be greater
- the volume change is the same so, from $W = p\Delta V$, the work done will be the same
- for an isothermal compression the p-V curve is less steep so the area under it is greater
- there is heat transfer in a slow compression, so more work has to be done to transfer the heat.

Many students tried to use the first law of thermodynamics, and showed a misunderstanding of the symbols or how they could apply in the situation. Many thought the work done would remain the same and gave ingenious arguments in support.

Nearly half of the students scored the first mark for associating a slow compression with an isothermal compression. About 17% scored the full 2 marks. Full answers linked work done to some or all of:

- the steepness of adiabatic and isothermal curves on a p-V diagram
- the area under the adiabatic and isothermal curves on a p-V diagram
- the lower pressures attained in an isothermal compression.

It was pleasing to see some answers accompanied by a sketch of the adiabatic and isothermal compressions on a p-V graph.

Question 04

This levels-of-response question had a mark allocation of 6 marks. It was a straightforward question on engines, requiring mainly recall or bookwork.

The question tested assessment objective AO1 – knowledge and understanding of ideas and processes. Careful revision should have helped students to be able to cover several of the mark points. Despite this, many students were only able to achieve 0 or 1, sometimes from over a page of writing.

The specification clearly requires an understanding of a diesel engine indicator diagram and comparison with the theoretical diesel engine cycle.

For marking, the mark points in the additional comments column of the mark scheme were grouped into 3 'areas'. These were:

- regions A and B
- region C
- efficiency.

For 5 or 6 marks all three areas had to be covered, with the answer giving some, but not all, of the mark points.

About 10% of students scored 5 or 6, showing a good knowledge of the differences between the theoretical and real diesel engine cycles. They were able to give at least three reasons for the lower efficiency of the real engine.

Many students were able to cover one or two areas well, but their answers on the other area(s) may only have covered one mark point per area.

It was common to see differences described but no reasons, or incorrect reasons, given. A wide variety of dubious reasons were given for the heating not being at constant pressure in Figure 8. All that was required was that heating at constant pressure is very difficult to control (given the conditions under which combustion occurs).

The need for region **C** in the real engine and not the theoretical, was generally well understood.

Common errors were that:

- in region A the rounded corners were due to valves opening and closing (whereas of course in this region all valves remain closed)
- all processes in the theoretical cycle are instantaneous
- induction and exhaust strokes take place in the theoretical cycle but at atmospheric pressure so need not be shown
- the induction stroke introduces fuel, or air-fuel mixture, into the engine
- the smaller area of the indicator diagram cycle is due to friction in the engine (Friction was, of course, accepted as a reason for the lower efficiency of a real engine.)
- the theoretical cycle is 100% efficient
- the efficiency of the real engine is lower because there is heat transfer to the surroundings
- diesel engines require a spark.

Nearly 20% of students scored no marks at all. They may have shown some knowledge of thermodynamics or engines but they did not answer the question set.

Question 05.1

This was answered well. Either the temperatures or the powers could be used. 86% of students scored the mark. Most incorrect answers calculated the efficiency as $6.4/16.0 = 0.40$.

Question 05.2

Mathematically, the analysis of ideal engines should not pose too many problems. Many answers showed a lack of conceptual understanding of the two ideal engines.

About 30% of answers had the efficiencies and output powers of each of the two engines correctly calculated (for 2 marks).

In two-thirds of these answers they were not able to go on and score the third mark because they calculated the overall efficiency as $(0.30 + 0.43)$ or $(0.30 \text{ x } 0.43)$. Or they wrote a conclusion that compared only the overall output powers **or** the overall efficiencies, and not both.

It was good to see work from students who had followed the advice to annotate Figure 10. They clearly wrote on Figure 10 the input and output powers and the powers to the cold spaces.

A fairly common error was to confuse the output power with the power rejected to the cold space.

Mark Ranges and Award of Grades

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