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International AS and A-level

Physics (9630)
PH04 Energy and energy resources
Report on the examination

June 2024

REPORT ON EXAMINATION: INTERNATIONAL A-LEVEL PHYSICS (9630) PH04 JUNE 2024

QUESTION 01

01.1 This question was very accessible with most students able to apply the gravitational potential energy formulae. Most students were also able to use the efficiency; however, some mixed up the input and output powers, multiplying rather than dividing by 0.86.

01.2 This proved more challenging. While most students were able to apply one of the power equations, the most straightforward being $\boldsymbol{P = IV}$**,** there were a significant number of students who struggled to correctly apply the concepts of rms and peak voltages and currents. Students needed to realise that only the rms voltage and current should be used with the power equation. An attempt to calculate the peak voltage and then apply this to the mean power was incorrect, although it was awarded one mark. The correct approach was to use $\boldsymbol{P = IV}$ to determine the rms current and then multiply this by $\sqrt{\mathbf{2}}$.

01.3 This question proved challenging. Many answers compared HEP stations to fossil-fuel power stations, quoting advantages like not emitting greenhouse gases, instead of comparing the two types of HEP stations. In order to score here students needed to state an environmental benefit of the HEP station shown in **Figure 1** compared to a HEP station with a reservoir and dam. Students either needed to link the destruction of habitat to flooding or the area used by the reservoir, or discuss how the flow of the river was unaffected by the HEP station used in **Figure 1**.

01.4 Many students also struggled to express their ideas clearly enough here. To describe a base-power station, the idea of a constant supply of energy at all times was required; answers which expressed this in terms of base power, a large amount of power, or slow start-up or shut-down times were not accepted.

Answers could state that either type could or could not be a base power station provided this was justified. To justify the **Figure 1** HEP station, the answer had to state that the river could supply a constant power if the river was reliable enough; just stating that the flow of the river was constant was not considered enough. Alternatively, they could refer to the river's variable flow meaning it was unable to provide a constant power. For the HEP station with a dam, answers could refer to a need to pump water to fill the reservoir (and therefore its unsuitability) or express the idea that water from the reservoir could be used to maintain a stable output power when the water flow was low. Very few managed to argue that the reservoir could be used to provide stable power with sufficient detail to score here.

QUESTION 02

02.1 Many students were able to answer this question which required the use of the equation for the rate of energy transfer by conduction. A minority of students tried to use a different equation such as the equation for specific heat capacity and were unlikely to score.

The first mark was awarded for calculating the area of the glass; most students managed this. Examiners accepted values for the radius that treated the quoted diameter as either the inner or outer diameter of the glass. Only a very small number of students confused the radius and diameter. A slightly larger minority used an incorrect formula for the area: instead of using the surface area of a sphere, they used the area of a circle or the volume of sphere.

02.2 While this question was accessible, a significant number of students made some mistakes with the calculations. While the vast majority of students could apply the equation for specific heat capacity, there were issues with trying to calculate the volume (and hence) mass of the glass.

There were a number of different approaches which were credited: subtracting the volume of the spheres with the inner and outer radii of the glass was the most popular. Some students realised that they could approximate the glass as a prism and multiplied the surface area by the thickness which was also accepted. A significant minority of students worked out the volume of the bulb as if it was filled with glass; this was allowed partial credit, as it could be used as a step towards the correct volume.

QUESTION 03

03.1 This question proved challenging for some students. However, most students were able to score at least one mark. Most students realised that the change in kinetic energy was transferred to potential energy but only some appreciated that neither nuclei were stationary at the distance of closest approach, either treating the final $\boldsymbol{E_k}$ as zero or missing the point that both nuclei had $\mathbf{4.0 \times 10^{-15}}$ J of kinetic energy.

03.2 This question allowed three-quarters of students to score some marks but only the best students were able to score full marks. The question did not specify the directions of the nuclei, so students who realised this and mentioned at least one or more of the possible effects of direction were generally able to score well. The majority of students assumed that the particles were headed directly towards each other and were also able to access three marks. While students were able to appreciate that there was a greater kinetic energy and therefore the distance of closest approach was going to be smaller, most did not discuss the change in kinetic energy being the important point. The change could be indicated by directly referring to the change in kinetic energy or by referring to the amount of energy transferred to potential energy, but a reference to the initial kinetic energy was not enough. Students who realised that, unlike in 03.1, the nuclei were at rest at the distance of closest approach, were also rewarded. Those who realised that the distance of closest approach was inversely proportional to the change in kinetic energy were rewarded. Most students who went down this route wrote about the energy being doubled and gained some marks; however, only a very small minority realised that the total change in kinetic energy was increased by a factor of four, as the nuclei were now transferring all their kinetic energy to potential energy.

03.3 This question proved very challenging with only a minority of students appreciating that, as the mean value was quoted, some nuclei would have a larger kinetic energy than the mean and therefore be able to fuse.

03.4 This question also proved challenging for students to answer well. It was hoped that answers would reflect the assumptions about an ideal gas and why they were not true in a plasma. As nearly all answers lacked this level of detail, answers which correctly pointed out (i) what the assumptions were and (ii) that they did not apply to a plasma, were rewarded in most cases. However, in the case of the motion not being random some justification was required as there were many misconceptions about why this might be the case. Also, statements that the collisions were inelastic had to be supported by stating that fusion was the reason for inelastic collisions, since the collisions which do not result in fusion are still elastic.

03.5 This question proved very accessible with most students scoring full marks.

QUESTION 04

04.1 This question proved very accessible. However, as a 'show that' question, for both marks, full working and an answer to at least one more significant figure than the approximate value given in the question must be provided. It was expected that the students would use the number given in the question to show that the energy was 934 MeV. Those using the value of 931.5 MeV from the formulae and data booklet did not gain full marks. For full marks students were expected to justify the power of ten, either by using $\mathbf{1.6 \times 10^{-13}}$ or showing the answer as $\mathbf{934 \times 10^{6}}$ eV or equivalent, before converting to MeV.

04.2 This was also accessible, with most students able to score two marks. The common mistakes were students forgetting to double the mass of the helium-3 and the mass of the proton.

04.3 Most students found this question straightforward. However, many were caught out by the requirement to justify the doubling of the energy, in terms of either two reactions or two helium nuclei required in the next stage.

04.4 This proved surprisingly challenging for a recall question. While most students knew that two protons were required to make a deuterium nucleus, a significant minority added extra protons and neutrons to either side of the equation and so lost the first mark. There was also some confusion about the positron and neutrino, with a significant number of students not gaining the second mark because they did not provide the numbers for the positron or suggesting an anti-neutrino was emitted.

04.5 This was an accessible four mark question, with many students achieving full marks and three-quarters of students scoring at least one mark. Most students were able to use the mass of hydrogen and the molar mass to determine the number of hydrogen nuclei. They were then able to convert this to the amount of energy released and use the power to calculate the amount of time this would require. However, a significant number of students did not determine accurately the number of fusions that would take place. While some realised that two hydrogen nuclei were required or that each cycle needed to happen twice, they did not realise that this meant four hydrogen nuclei were required per cycle. A small number thought that six hydrogen nuclei were required.

04.6 This also proved challenging for students to express in the level of detail required. Most students could link the quantities of kinetic energy to temperature, although some only referred to energy and were not able to gain this mark. However, the reason for the increase in kinetic energy proved harder to establish. Some were confused about what was important, thinking that the speed was constant and therefore an increased mass required an increased kinetic energy. Others were not precise enough in their language, writing about more protons rather than noting it was the increase in charge which led to increases in either repulsive force or electric potential energy.

QUESTION 05

05.1 While this question was accessible to most students, some tried to work this out from first principles rather than using the 'maximum power available from a turbine' formula in the formulae and data booklet. Very few students who attempted this route were able to complete the algebra sufficiently well to score more than one mark. A small minority forgot to convert their answer to MW as asked for in the question and so did not gain the final mark. A few students squared $\boldsymbol{v}$ instead of cubing it; some wrote $\boldsymbol{v}^{\mathbf{3}}$ and were able to get the first marking point. Those who wrote $\boldsymbol{v}^{\mathbf{2}}$ were unable to score. Those students who mixed up radius and diameter were able to score one mark.

05.2 This question proved challenging for many students, with only a tiny minority able to score two marks. The most common mark awarded was for students who recognised that the air had to keep some kinetic energy to move through the turbine, with some students referring to the Betz limit. However, the other reason for this, where only some of the air actually comes into contact with the blades, was only rarely referred to.

The question asked about the kinetic energy being available to the turbine, rather than the amount of electricity that was generated. Thus, the question was about the transfer of energy to the turbine from the wind and not the inefficiencies of the turbine or the conversion to electrical energy. Therefore references to work done by friction were ignored. As the question stated that '*not all of the … energy was available*', simply stating that the process was not 100% efficient was insufficient to gain a mark.

05.3 The question proved to be accessible with most students gaining this mark.

05.4 Some students used the wrong torque for this question and a small minority gave the answer in J rather than MJ. However, most students were able to score two marks.

05.5 Most students choose the wrong torque for this question and thus scored 1. Only a minority realised that the resultant torque was the driving torque (which was equal to the maximum resistive torque) minus the resistive torque at $\boldsymbol{t = 0}$.

05.6 Nearly all students were able to complete this successfully, although some students did not notice that the angular speed was given in the question and attempted to calculate it. Most of these answers scored one mark.

05.7 Most answers did not provide enough for three marks, although around half scored at least one. Some students introduced air resistance rather than referring to the resistive torques provided by the question. Good answers realised that the resultant torque decreased when the resistive torque provided by the generator increased, decreasing the angular acceleration. To get full marks for this approach students had to reference $\boldsymbol{T = I\alpha}$ which many failed to do. A few confused the torques and thought that as the resistive torque increases so did the acceleration.

QUESTION 06

06.1 Most students correctly identified that the work done was the area under the graph. A significant minority were not able to determine this within range, although the techniques used were valid and scored two marks. When determining the area under a curve by approximating straight lines or triangles, often the lengths of the segments were too large.

Some students attempted to calculate the area, sometimes via integration. The majority of students who tried this approach assumed that Boyle's law applied; however the temperature of the gas was not constant and therefore this approach did not give the correct answer. Students should be taught to apply the methods given in the specification. Some students did know the correct equation for the work done by an adiabatic expansion of air, although this is beyond the specification, and were able to score marks.

06.2 Many students were able to use ratios to calculate the new temperature. However, some students assumed that the volume remained constant, despite the graph showing this not to be the case and scored no marks. An approach that was used was to determine the equation of state directly, in a two-stage process; this was also rewarded. Only a small minority forgot to change the temperature to kelvin.

06.3 In order to make progress students had to determine the number of moles of air in the pump. They could then divide the number of moles required by this number to obtain the answer. As this was just greater than 26 strokes of the pump, students who stated that one more strike was required and quoted 27 also received credit. Those who tried to calculate the increase in pressure or volume from one pump were unable to make much progress and did not gain any marks.

06.4 This question was accessible to many students, with most scoring some marks. The first mark was for recognising that work was done on the gas; simply stating that W was positive was insufficient unless W was explicitly identified as the work done on the gas. To gain the second mark, students had to link the rapid time for the process to the lack of heat transfer; this was the most commonly missed mark. The last mark was for referring to the first law of thermodynamics, which most students managed, and for linking the internal energy to the temperature. Some responses thought that Q referred to the change in heat of the gas, rather than the heat transferred into or out of the system, and so were unable to access the last mark.

SECTION B: MULTIPLE-CHOICE QUESTIONS 07-21

The multiple-choice questions covered parts of the specification not covered in Section A. The distractors in these questions were written with common errors and misconceptions in mind. These questions are therefore an extremely useful resource when preparing students.

The multiple-choice questions were generally accessible. A number of questions were found to be very straightforward by students. These included B7, B8, B10, B12 and B15 which were all answered correctly by at least 75% of students.

The questions found to be the most difficult were B16 and B19 – answered correctly by fewer than 40% of students.