

Physics

Advanced

Paper 3: General and Practical Principles in Physics

Friday 5 June 2020 – Afternoon

Time: 2 hours 30 minutes plus your additional time allowance

In the boxes below, write your name, centre number and candidate number.

Surname					
Other names					
Centre Number					
Candidate Number					

YOU MUST HAVE

Ruler

YOU WILL BE GIVEN

Diagram Booklet, Data, formulae and relationships Booklet

INSTRUCTIONS

Answer ALL questions.

Answer the questions in the spaces provided – there may be more space than you need.

INFORMATION

The total mark for this paper is 120.

The marks for EACH question are shown in brackets – use this as a guide as to how much time to spend on each question.

In questions marked with an ASTERISK (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.

You may use a scientific calculator.

ADVICE

Read each question carefully before you start to answer it.

Try to answer every question.

Check your answers if you have time at the end.

You are advised to show your working in calculations including units where appropriate.

Answer ALL questions in the spaces provided.

- 1 A teacher is explaining the differences between accuracy and precision to her students. Look at the diagram for Question 1 in the Diagram Booklet. It shows different degrees of accuracy and precision. The circles represent targets A, B, C and D and the dots represent arrows hitting the targets.**

Explain how targets A, B, C and D represent differing degrees of accuracy and precision. (4 marks)

(continued on the next page)

Turn over

1 continued.

(TOTAL FOR QUESTION 1 = 4 MARKS)

2 A student released a ping pong ball in front of a metre rule and used a phone camera to record the motion of the ball as it fell. The phone camera captures 60 images per second, which may be played back one image at a time.

(a) The ball was dropped from a height such that it reached its terminal velocity as it passed the metre rule.

(i) Explain how the terminal velocity of the ball could be determined using the phone camera recording. (4 marks)

(continued on the next page)

Turn over

2 continued.

- (ii) Explain how a systematic error could affect the value obtained for the terminal velocity. (2 marks)**

(continued on the next page)

2 continued.

- (b) This experiment could have been attempted using a stopwatch to measure the time as the ping pong ball fell.**

Explain an advantage of using a phone camera rather than a stopwatch. (2 marks)

(TOTAL FOR QUESTION 2 = 8 MARKS)

- 3 A student carried out an experiment with a pendulum hung from a fixed support. Look at the diagram for Question 3 in the Diagram Booklet. The fixed support was a distance h above floor level.**

As the student was unable to measure the length of the pendulum directly, she measured the distance d from the bob to the floor.

(continued on the next page)

3 continued.

(a) To determine the period T of the pendulum, the student used the following method:

- **release the bob from its highest position and start a stopwatch**
- **stop the stopwatch when the bob reaches the same position again.**

Criticise the student's method for measuring the period. (2 marks)

(continued on the next page)

Turn over

3 continued.

- (b) Look at the graph for Question 3(b) in the Diagram Booklet. The student used her data to plot a graph of T^2 against d .**

Determine a value for the acceleration due to gravity g . (5 marks)

(continued on the next page)

Turn over

3 continued.

g = _____

(TOTAL FOR QUESTION 3 = 7 MARKS)

- *4 Radium is a radioactive element. The most common isotope of radium has a half-life of almost two thousand years. A sample of radium can remain at a higher temperature than its surroundings for a long period of time.**

Explain how a sample of radium is able to release significant amounts of energy over a long period of time. (6 marks)

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(TOTAL FOR QUESTION 4 = 6 MARKS)

5 Look at the image for Question 5 in the Diagram Booklet. It shows a statue of Buddha in Sri Lanka, which is protected by a lightning conductor.

- (a)** During a storm, a potential difference of 2.7 MV was generated between a cloud and the top of the lightning conductor on the statue. A flash of lightning passed between the cloud and the lightning conductor, producing a current of 25 kA for a time of 7.5 ms .

Calculate the energy transferred by the lightning strike. (3 marks)

Energy transferred = _____

(continued on the next page)

5 continued.

- (b) The lightning conductor is a length of copper wire with a diameter of $1.2 \times 10^{-2} \text{ m}$ and a resistance of $4.3 \times 10^{-3} \Omega$. It runs along the back of the statue from the base to a height of 1.5 m above the top of the statue.

A guidebook claims that the statue is over 30 m high.

Assess the validity of this claim. (4 marks)

resistivity of copper = $1.7 \times 10^{-8} \Omega \text{ m}$

(continued on the next page)

Turn over

5 continued.

(c) Give a reason why the lightning conductor should be taller than the statue. (1 mark)

(TOTAL FOR QUESTION 5 = 8 MARKS)

- 6 A student determined the latent heat of vaporisation of a liquid using an electrical heater to boil the liquid in a Pyrex beaker.**

Look at the apparatus used for Question 6 in the Diagram Booklet.

- (a) She connected the heater into a circuit and took measurements of the potential difference V and the current I for the heater.**

Look at the diagram for Question 6(a) in the Diagram Booklet. Complete the circuit diagram to show a suitable circuit. (2 marks)

(continued on the next page)

6 continued.

- (b) The student monitored the mass of the beaker and the liquid m over the time t for which the liquid was boiling. Look at the graph for Question 6(b) in the Diagram Booklet. Her results are plotted.**

The student used her graph to determine a value for the latent heat of the liquid in the beaker. She concluded that the liquid was pure water. On page 11 in the Diagram Booklet is the table.

Comment on the validity of the student's conclusion. (7 marks)

$$V = 20.5V$$

$$I = 10.5A$$

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Turn over

6 continued.

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6 continued.

- (c) Explain how this method might be modified to improve the accuracy of the student's conclusion. (2 marks)**

(TOTAL FOR QUESTION 6 = 11 MARKS)

- 7 At the end of the 19th century, J.J. Thompson used electric and magnetic fields to deflect beams of charged particles. Look at the diagram of his apparatus for Question 7 in the Diagram Booklet.**

Electrons were accelerated through a potential difference to produce a beam of high-energy electrons. The beam was then deflected in perpendicular directions by the magnetic and electric fields. The final position of the beam on the screen was determined by the charge and mass of the electrons.

- (a) Explain how electrons from the source become a beam of high-energy electrons. (2 marks)**

(continued on the next page)

7 continued.

(b) Look at the diagram for Question 7(b) in the Diagram Booklet. An electron is travelling left to right and enters a region of uniform magnetic field. The direction of the magnetic field is perpendicular to the direction of travel of the electron.

(i) The magnetic field deflects the electron in the direction up the page.

Explain the direction of the magnetic field that would produce this deflection. (2 marks)

(continued on the next page)

7 continued.

- (ii) Explain why the electron would travel in a circular path if no other forces acted on it.
(2 marks)**

(continued on the next page)

7 continued.

(c) In a modern version of Thompson's experiment, a uniform electric field of electric field strength E is applied so that the electric and magnetic forces on the electrons are equal and in opposite directions.

(i) Show that for electrons to be undeflected their velocity must be given by

$$v = \frac{E}{B}$$

where B is the magnetic flux density of the magnetic field. (2 marks)

(continued on the next page)

7 continued.

- (ii) The beam is produced by accelerating electrons through a potential difference of 250 V. The electric field strength is $1.4 \times 10^4 \text{ V m}^{-1}$. The magnetic flux density is $1.5 \times 10^{-3} \text{ T}$.

Calculate the value of the specific charge e/m for the electron using this data. (3 marks)

$e/m =$ _____

7 continued.

- (d) In his original experiments, Thompson determined the specific charge of a range of particles. His results indicated that the specific charge of an electron is about 2000 times bigger than that for a hydrogen ion.**

Deduce what conclusion can be made from this information. (1 mark)

(TOTAL FOR QUESTION 7 = 12 MARKS)

- 8 A student investigated the rate at which a hot liquid transfers thermal energy to the surroundings. He placed hot water in a Pyrex beaker and measured the temperature of the water using a liquid-in-glass thermometer.

Look at the table for Question 8 in the Diagram Booklet. He obtained the data for the temperature θ of the water at times t . He measured t using a stopwatch.

temperature of surroundings = 23°C

Theory suggests that a liquid transfers internal energy to the surroundings at a rate proportional to the temperature difference $\Delta\theta$ between the liquid and the surroundings.

This leads to the expression

$$\Delta\theta = \Delta\theta_0 e^{-bt}$$

where b is a constant and $\Delta\theta_0$ is the initial temperature difference.

(continued on the next page)

8 continued.

(a) Explain why a graph of $\ln \Delta\theta$ against t should be a straight line. (2 marks)

(continued on the next page)

8 continued.

(b) (i) Look at the grid for Question 8(b)(i) in the Diagram Booklet. Plot a graph of $\ln \Delta\theta$ against t .

Use the columns provided in the table to show any processed data. (5 marks)

(ii) Determine the value of b . (3 marks)

$b =$ _____

(continued on the next page)

Turn over

8 continued.

- (c) The student suggested that the experiment would have been more accurate if a temperature sensor and data logger had been used to collect the data.**

**Assess the validity of the student's suggestion.
(4 marks)**

(continued on the next page)

Turn over

8 continued.

(TOTAL FOR QUESTION 8 = 14 MARKS)

- 9 A simple loudspeaker consists of a cone, a coil of wire and a magnet. The cone and coil are attached to each other and are free to move. An alternating current in the coil causes the cone to oscillate. The loudspeaker is mounted in a wooden box. Look at the diagram for Question 9 in the Diagram Booklet. It shows a cross-section through the loudspeaker.**

A student made the following observations:

- **when an alternating potential difference (p.d.) is applied to the coil, the cone oscillates**
- **the frequency of oscillation is the same as the frequency of the p.d.**
- **at particular frequencies, the box vibrates with a large amplitude.**

***(a) Explain these observations. (6 marks)**

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9 continued.

(b) The student connected a signal generator to the loudspeaker, and placed the loudspeaker near to one end of a long tube containing sand. Look at the diagram for Question 9(b) in the Diagram Booklet. The student adjusted the signal generator until the sand collected in small heaps.

**(i) Explain why the sand collects in heaps.
(4 marks)**

(continued on the next page)

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9 continued.

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9 continued.

- (ii) The student determined the distance d between the centres of adjacent heaps.**

Describe the procedure she should follow to determine an accurate value for d . (3 marks)

(continued on the next page)

9 continued.

- (iii) Assess whether the experimental data is consistent with a value for the speed of sound of 340 m s^{-1} . (3 marks)**

signal generator frequency = 3.25 kHz .

$d = 5.1 \text{ cm}$

(TOTAL FOR QUESTION 9 = 16 MARKS)

- 10 Look at the image for Question 10(a) in the Diagram Booklet. It shows a spring is made from loops of thick steel wire.**

There are two extra loops, one on each end of the spring.

- (a) A student determined the length of steel used to make the spring by using vernier calipers to measure the width w of the spring.**

The length of wire l on each loop is given by $l = \pi w$

Look at the table for Question 10(a) in the Diagram Booklet. The student obtained the values for w .

- (i) Calculate l . (3 marks)**

(continued on the next page)

Turn over

10 continued.

$l =$ _____

- (ii) Estimate the percentage uncertainty in your value for l . (2 marks)

% uncertainty in $l =$ _____

(continued on the next page)

Turn over

10 continued.

(iii) Calculate the total length L of wire used to make the spring. (2 marks)

$L =$ _____

(continued on the next page)

10 continued.

(b) The student measured the diameter d of the steel wire and obtained a value of 2.52 mm.

(i) Explain which instrument he used to measure the diameter. (2 marks)

(ii) Estimate the percentage uncertainty in the student's value for d . (1 mark)

% uncertainty in d = _____

(continued on the next page)

Turn over

10 continued.

(iii) The student used a balance to measure the mass m of the spring.

He obtained a value of $32.0 \pm 0.5 \text{ g}$.

Estimate the percentage uncertainty in the mass of the spring. (1 mark)

% uncertainty in m = _____

(continued on the next page)

10 continued.

- (iv) The student calculated the density ρ of the steel using the equation

$$\rho = \frac{m}{V}$$

Calculate the percentage uncertainty in his value for the density of steel. (1 mark)

% uncertainty in
value for density of steel = _____

- (v) Determine whether the data collected leads to a value for the density of steel in agreement with the standard value. (4 marks)

density of steel = $7\,800 \text{ kg m}^{-3}$

10 continued.

(TOTAL FOR QUESTION 10 = 16 MARKS)

11 Solar panels consisting of combinations of photovoltaic cells use energy in the radiation received from the Sun to generate electricity.

- (a) An advertisement for solar panels claims that the intensity of radiation from the Sun incident at the top of the Earth's atmosphere is more than 2 kW m^{-2} .**

Assess the validity of this claim. (4 marks)

radius of Sun = $6.96 \times 10^8 \text{ m}$

surface temperature of Sun = 5790 K

distance from Sun to Earth = $1.50 \times 10^{11} \text{ m}$

(continued on the next page)

Turn over

11 continued.

(continued on the next page)

11 continued.

(b) Look at the diagram for Question 11(b) in the Diagram Booklet. The average intensity of radiation from the Sun incident at the Earth's surface over a 24-hour period has been determined to be 164 W m^{-2} .

(i) The average intensity of radiation from the Sun at the Earth's surface is much less than the intensity incident at the top of the Earth's atmosphere.

Explain why. (4 marks)

(continued on the next page)

Turn over

11 continued.

(continued on the next page)

11 continued.

- (ii) It is claimed that the area of solar panels needed to generate 100 GW of power is about 0.5% of the surface area of the Earth.**

Assess the validity of this claim. (4 marks)

radius of Earth = 6.4×10^6 m

typical efficiency of solar panels = 25%

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Turn over

11 continued.

(continued on the next page)

11 continued.

(c) Scientists are developing a space station equipped with large solar panels. The space station would be located in a geostationary orbit. The space station would transfer energy to Earth as microwaves.

(i) A space station in a geostationary orbit is above the equator and has a period of 24 hours.

Explain one advantage of locating the space station in a geostationary orbit. (2 marks)

(continued on the next page)

Turn over

11 continued.

- (ii) Calculate the height h of the space station above the equator when it is in a geostationary orbit. (4 marks)

$$\text{mass of Earth} = 6.00 \times 10^{24} \text{ kg}$$

$$24 \text{ hours} = 8.64 \times 10^4 \text{ s}$$

(continued on the next page)

Turn over

11 continued.

$h =$ _____

(TOTAL FOR QUESTION 11 = 18 MARKS)

TOTAL FOR PAPER = 120 MARKS
END