Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 2

26 October 2023

Zone A afternoon | **Zone B** afternoon | **Zone C** afternoon

Candidate session number

1 hour 15 minutes

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[50 marks].**

8823–6511

Answer **all** questions. Answers must be written within the answer boxes provided.

1. A space probe of mass 95 kg is designed to land on the surface of an asteroid. The gravitational field strength g of the asteroid at its surface is $2.7 \times 10^{-3}\,\text{m s}^{-2}$.

(a) The radius r of the asteroid is 230 km. Calculate the mass of the asteroid. [2]

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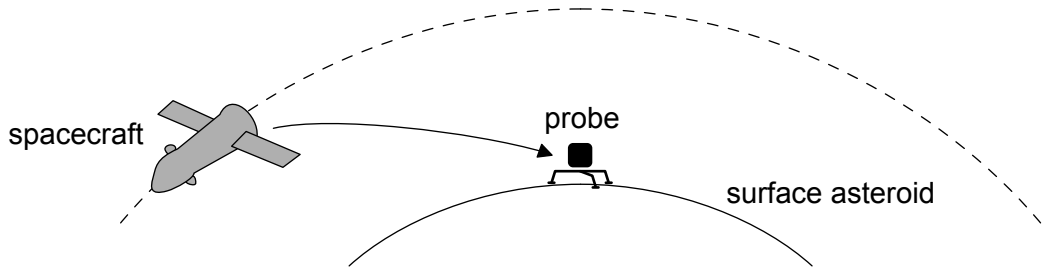
(b) The probe is carried to the asteroid on board a spacecraft.



Calculate the weight of the probe when close to the surface of the asteroid. [1]

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(Question 1 continued)

(c) (i) As the probe approaches the surface of the asteroid, a rocket engine is fired to slow its descent. Explain how the engine changes the speed of the probe. [3]

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(ii) A constant force of 12.0 N is exerted by the rocket engine. Determine the time for which the rocket must fire to reduce the speed of the probe from 0.64 $m\,s^{-1}$ to zero. State your answer to an appropriate number of significant figures. [4]

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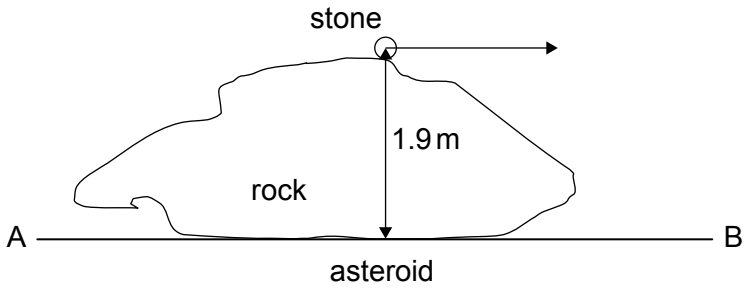
will not be marked.

(Question 1 continued)

(d) As the probe lands, a small stone resting on a rock on the asteroid's surface is projected horizontally from the top of the rock. The horizontal speed of the stone is $34\,m\,s^{-1}$ from a height of 1.9 m above the surface of the asteroid.

diagram not to scale



Estimate the horizontal distance from the stone's point of projection along the line AB at which the stone lands. Ignore the curvature of the asteroid. [2]

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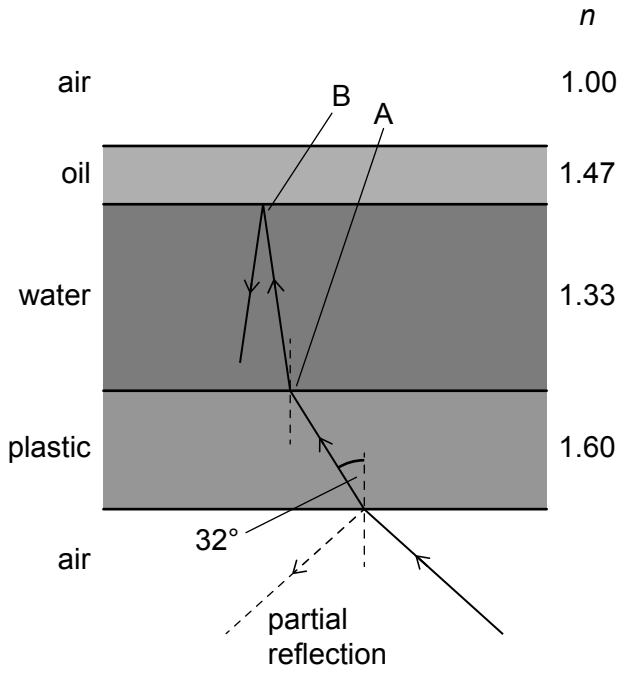
2. Monochromatic light enters the base of a plastic beaker that contains water with an oil layer floating on it. A student draws a diagram to show the directions the light takes as it passes through the layers. The student's diagram has one **error** at position A and one **error** at position B. The refractive indices of the materials are shown on the diagram.

diagram not to scale



The light is refracted at an angle of 32° when it enters the plastic layer as shown.

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(Question 2 continued)

(a) Identify, with a reason, the **error** in the student's diagram for

(i) light crossing the plastic–water interface (position A). [2]

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(ii) light at the water–oil interface (position B). [2]

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(b) Calculate the angle of incidence at the air–plastic interface. [2]

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(Question 2 continued)

(c) Calculate the critical angle for the plastic–water interface. [2]

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(d) The student hypothesizes that the partially-reflected ray of light from the bottom surface of the plastic is polarized.

(i) Outline what is meant by polarization. [1]

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(ii) Explain how the hypothesis can be tested experimentally. [2]

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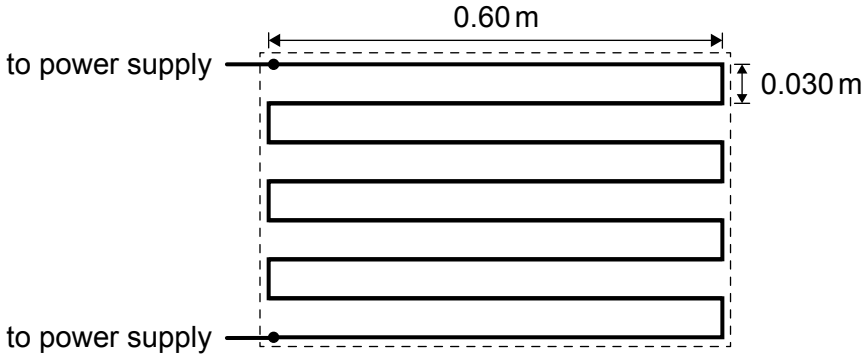
3. An engineer designs an electric heater to melt ice from the rear window of a car. The heater consists of a single thin metal wire made from a high-resistance alloy. The horizontal parts of the wire are 0.60 m long and are separated by a vertical distance of 0.030 m. The heater is designed for a 12 V supply and for an output power of 150 W.

diagram not to scale



(a) (i) Calculate the resistance of the heater when it is at its working temperature. [1]

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(ii) The total length of the metal wire is 5.0 m. Calculate the radius of the wire. [3]

Resistivity of the high-resistance alloy $= 1.5 \times 10^{-6}\,\Omega\,\text{m}$

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(Question 3 continued)

(b) The heater is used to clear a layer of ice from the window over an area indicated by the dotted line on the diagram. The water that has melted immediately flows away from the heater. Determine the minimum time required to melt the ice. [3]

Thickness of ice layer	$= 0.50\,\text{mm}$
Initial temperature of ice	$= 0\,^{\circ}\text{C}$
Density of ice	$= 900\,\text{kg}\,\text{m}^{-3}$
Specific latent heat of fusion of ice	$= 0.336\,\text{MJ}\,\text{kg}^{-1}$

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(c) The battery of the car was almost discharged before turning on the heater. Discuss how this is likely to affect your answer to (b). [2]

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(d) Outline **two** reasons why it is important for scientists to research effective solutions for energy storage using battery technology. [2]

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4. The table shows some of the energy levels for a hydrogen atom.

	Level	Energy / eV
Excited states	$n = 3$	−1.51
	$n = 2$	−3.40
Ground state	$n = 1$	−13.6

(a) Explain how electromagnetic radiation is emitted from a hydrogen atom in an excited state. [2]

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(b) When radiation of wavelength 6.6×10^{-7} m is incident on cold hydrogen gas some of it is absorbed by the gas. Determine the initial and final states of the hydrogen atom that are involved in this absorption. [3]

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5. Ceres is a dwarf planet in the asteroid belt. The following data are available.

Mean distance of Ceres from the Sun $= 4.4 \times 10^{11}$ m

Mean power output of the Sun $= 3.8 \times 10^{26}$ W

(a) (i) Determine the mean temperature of Ceres assuming that it acts as a black-body radiator. [3]

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(ii) Ceres has a solid rocky core covered with solid ice. The mean temperature is higher than your answer in (a)(i) because radioactive nuclei in the centre of Ceres are decaying. Outline how the energy from the radioactive decay reaches the surface. [2]

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(Question 5 continued)

(b) At the mean temperature of Ceres water undergoes a phase change directly from solid to gas.

(i) Compare the molecular conditions of the solid phase and the gas phase at the same temperature. [3]

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(ii) About 160 mol of water are released from the surface of Ceres every second. The maximum surface temperature of Ceres is −38 °C. The pressure of the gas immediately after release is 8.9 Pa. Determine the volume of water vapour released every second from the surface of Ceres. Assume that the conditions are maintained when the gas is released. [3]

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