Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 2

Wednesday 28 October 2020 (afternoon)

Candidate session number

1 hour 15 minutes

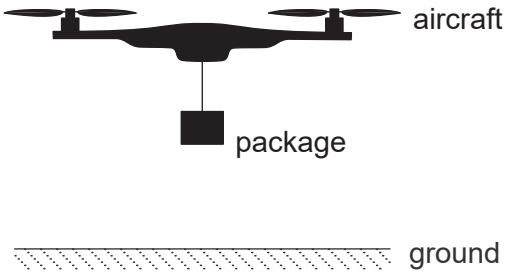
Instructions to candidates

- 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]**.

8820 – 6505

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

1. A company delivers packages to customers using a small unmanned aircraft. Rotating horizontal blades exert a force on the surrounding air. The air above the aircraft is initially stationary.



The air is propelled vertically downwards with speed *v*. The aircraft hovers motionless above the ground. A package is suspended from the aircraft on a string. The mass of the aircraft is 0.95 kg and the combined mass of the package and string is 0.45 kg. The mass of air pushed downwards by the blades in one second is 1.7 kg.

(a) (i) State the value of the resultant force on the aircraft when hovering. [1]

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(ii) Outline, by reference to Newton's third law, how the upward lift force on the aircraft is achieved. [2]

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(iii) Determine *v*. State your answer to an appropriate number of significant figures. [3]

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(Question 1 continued)

(b) The package and string are now released and fall to the ground. The lift force on the aircraft remains unchanged. Calculate the initial acceleration of the aircraft. [2]

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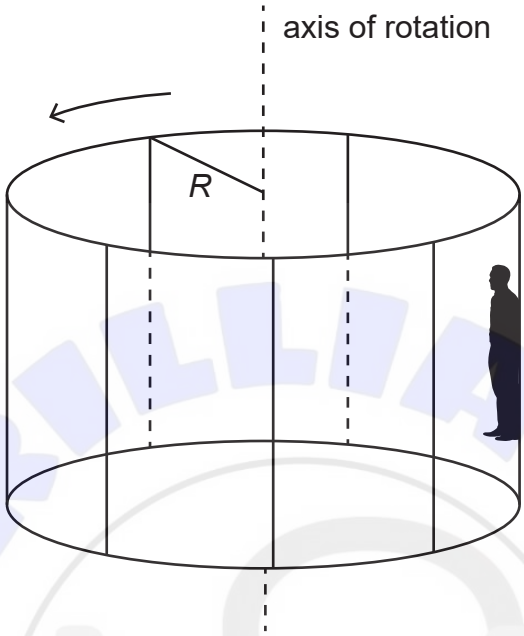
2. The Rotor is an amusement park ride that can be modelled as a vertical cylinder of inner radius *R* rotating about its axis. When the cylinder rotates sufficiently fast, the floor drops out and the passengers stay motionless against the inner surface of the cylinder. The diagram shows a person taking the Rotor ride. The floor of the Rotor has been lowered away from the person.



(a) Draw and label the free-body diagram for the person. [2]

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(Question 2 continued)

(b) The person must not slide down the wall. Show that the minimum angular velocity ω of the cylinder for this situation is

$$\omega = \sqrt{\frac{g}{\mu R}}$$

where μ is the coefficient of static friction between the person and the cylinder. [2]

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(c) The coefficient of static friction between the person and the cylinder is 0.40. The radius of the cylinder is 3.5 m. The cylinder makes 28 revolutions per minute. Deduce whether the person will slide down the inner surface of the cylinder. [3]

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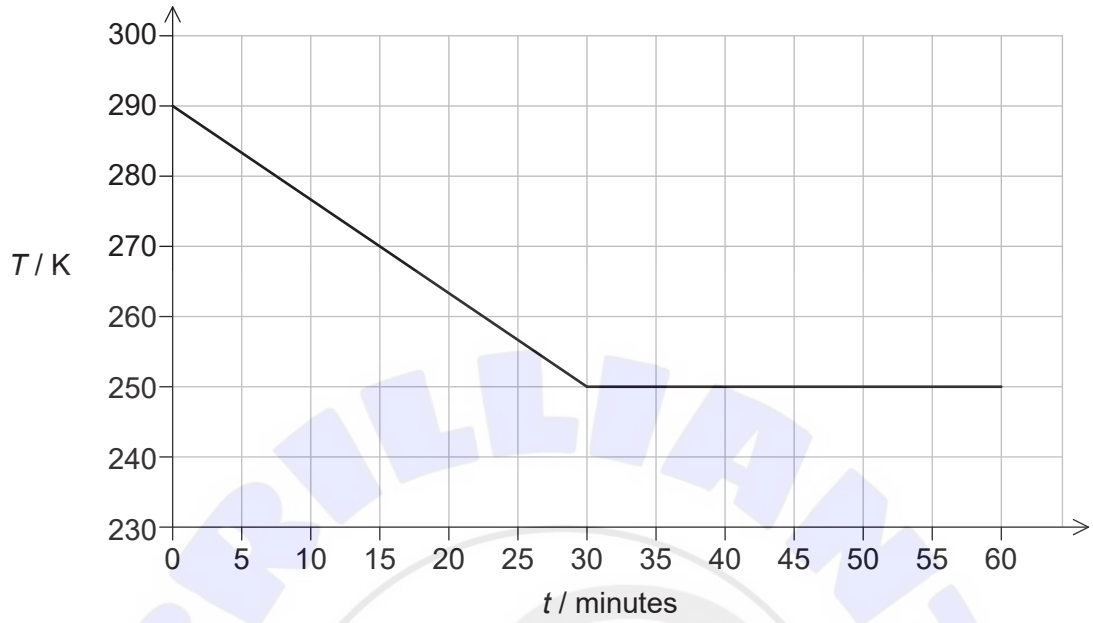
3. A sample of vegetable oil, initially in the liquid state, is placed in a freezer that transfers thermal energy from the sample at a constant rate. The graph shows how temperature T of the sample varies with time t.



The following data are available.

Mass of the sample = 0.32 kg
Specific latent heat of fusion of the oil = 130 kJ kg^{-1}
Rate of thermal energy transfer = 15 W

(a) (i) Calculate the thermal energy transferred from the sample during the first 30 minutes. [1]

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(ii) Estimate the specific heat capacity of the oil in its liquid phase. State an appropriate unit for your answer. [2]

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(Question 3 continued)

(b) The sample begins to freeze during the thermal energy transfer. Explain, in terms of the molecular model of matter, why the temperature of the sample remains constant during freezing. [3]

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(c) Calculate the mass of the oil that remains unfrozen after 60 minutes. [2]

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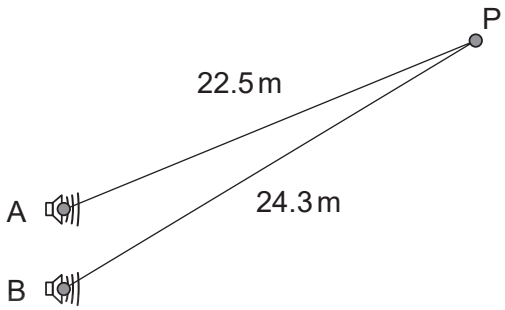
4. Two loudspeakers, A and B, are driven in phase and with the same amplitude at a frequency of 850 Hz. Point P is located 22.5 m from A and 24.3 m from B. The speed of sound is 340 m s^{-1}.



(a) Deduce that a minimum intensity of sound is heard at P. [4]

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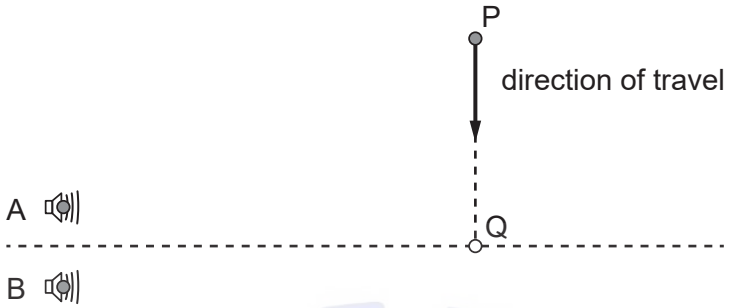
(Question 4 continued)

(b) A microphone moves along the line from P to Q. PQ is normal to the line midway between the loudspeakers.



The intensity of sound is detected by the microphone. Predict the variation of detected intensity as the microphone moves from P to Q. [2]

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(c) When both loudspeakers are operating, the intensity of sound recorded at Q is I_0. Loudspeaker B is now disconnected. Loudspeaker A continues to emit sound with unchanged amplitude and frequency. The intensity of sound recorded at Q changes to I_A.

Estimate $\frac{I_A}{I_0}$. [2]

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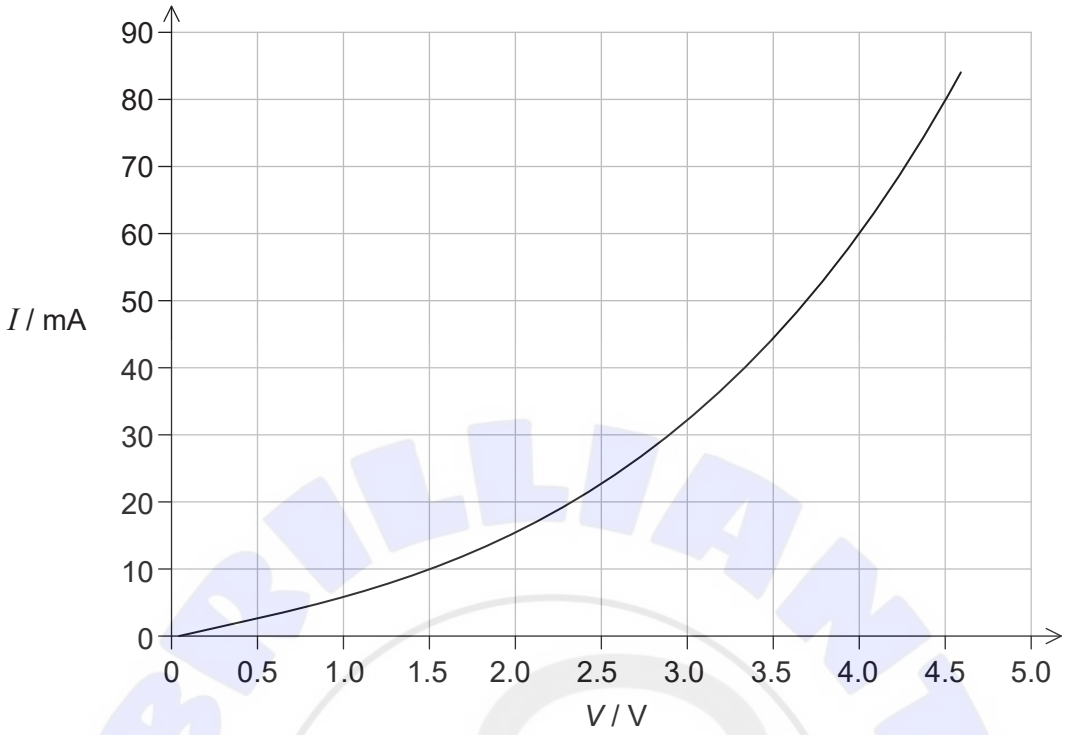
5. The graph shows how current I varies with potential difference V across a component X.



(a) Outline why component X is considered non-ohmic. [1]

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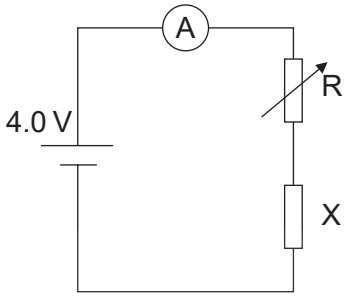
(Question 5 continued)

(b) Component X and a cell of negligible internal resistance are placed in a circuit.
A variable resistor R is connected in series with component X. The ammeter reads 20 mA.



(i) Determine the resistance of the variable resistor. [3]

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(ii) Calculate the power dissipated in the circuit. [1]

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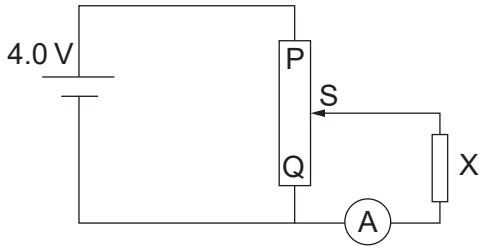
(Question 5 continued)

(c) Component X and the cell are now placed in a potential divider circuit.



(i) State the range of current that the ammeter can measure as the slider S of the potential divider is moved from Q to P. [1]

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(ii) Describe, by reference to your answer for (c)(i), the advantage of the potential divider arrangement over the arrangement in (b). [2]

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6. (a) One possible fission reaction of uranium-235 (U-235) is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2^{1}_{0}n$$

The following data are available.

Mass of one atom of U-235 = 235 u
Binding energy per nucleon for U-235 = 7.59 MeV
Binding energy per nucleon for Xe-140 = 8.29 MeV
Binding energy per nucleon for Sr-94 = 8.59 MeV

(i) State what is meant by binding energy of a nucleus. [1]

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(ii) Outline why quantities such as atomic mass and nuclear binding energy are often expressed in non-SI units. [1]

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(iii) Show that the energy released in the reaction is about 180 MeV. [1]

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(b) A nuclear power station uses U-235 as fuel. Assume that every fission reaction of U-235 gives rise to 180 MeV of energy.

(i) Estimate, in $J\,kg^{-1}$, the specific energy of U-235. [2]

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(Question 6 continued)

(ii) The power station has a useful power output of 1.2 GW and an efficiency of 36 %. Determine the mass of U-235 that undergoes fission in one day. [2]

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(c) A sample of waste produced by the reactor contains 1.0 kg of strontium-94 (Sr-94). Sr-94 is radioactive and undergoes beta-minus (β^-) decay into a daughter nuclide X. The reaction for this decay is

$$^{94}_{38}\text{Sr} \rightarrow \text{X} + \bar{\nu}_e + e.$$

(i) Write down the proton number of nuclide X. [1]

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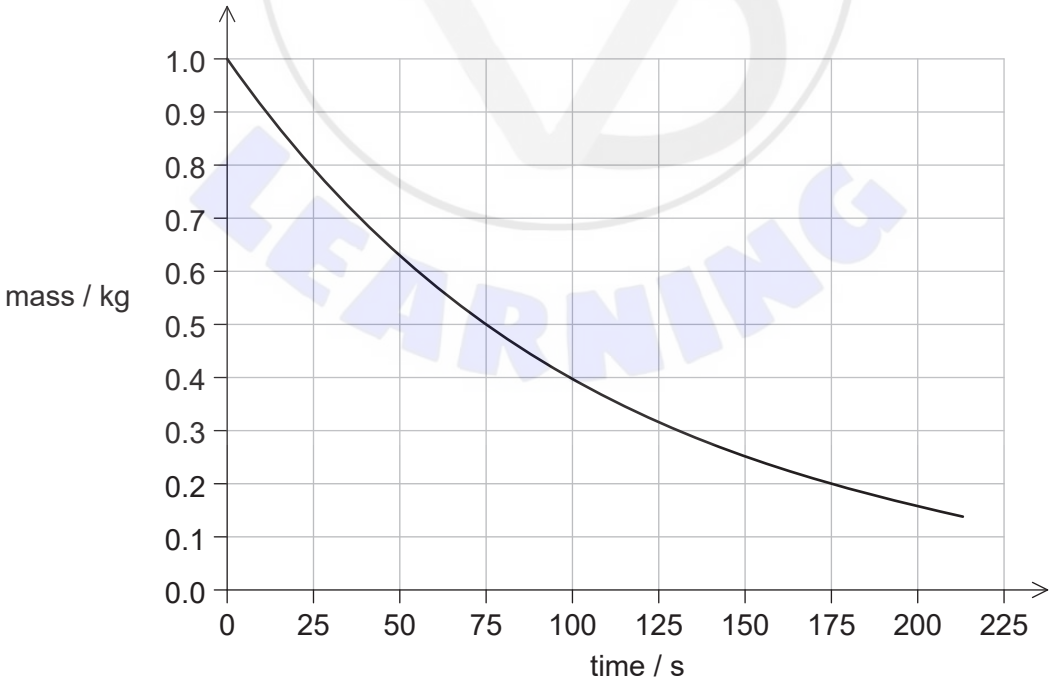
The graph shows the variation with time of the mass of Sr-94 remaining in the sample.



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(Question 6 continued)

(ii) State the half-life of Sr-94. [1]

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(iii) Calculate the mass of Sr-94 remaining in the sample after 10 minutes. [2]

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Answers written on this page
will not be marked.