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Physics
Standard level
Paper 2

30 April 2025

Zone A morning | **Zone B** morning | **Zone C** morning

Candidate session number

1 hour 30 minutes

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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]**.



Please **do not** write on this page.

Answers written on this page
will not be marked.



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

1. A box of mass 1.2 kg is lying at rest on a surface. The coefficient of static friction between the box and the surface is 0.36 and the coefficient of dynamic friction between the box and the surface is 0.28.

(a) Outline why the coefficients of friction have no units. [1]

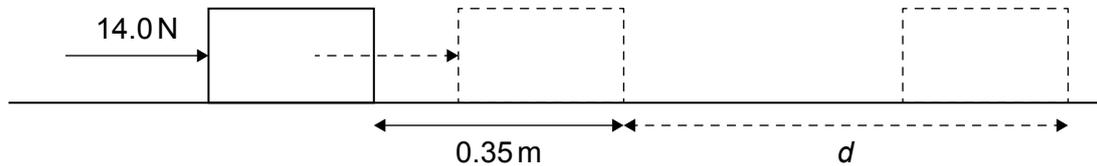
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(b) Show that the minimum force needed to accelerate the box is about 4 N. [2]

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A force of 14.0 N acts on the box for 0.35 m as shown. The force is then removed and the box continues to move. The box comes to rest after a further displacement d .

diagram not to scale



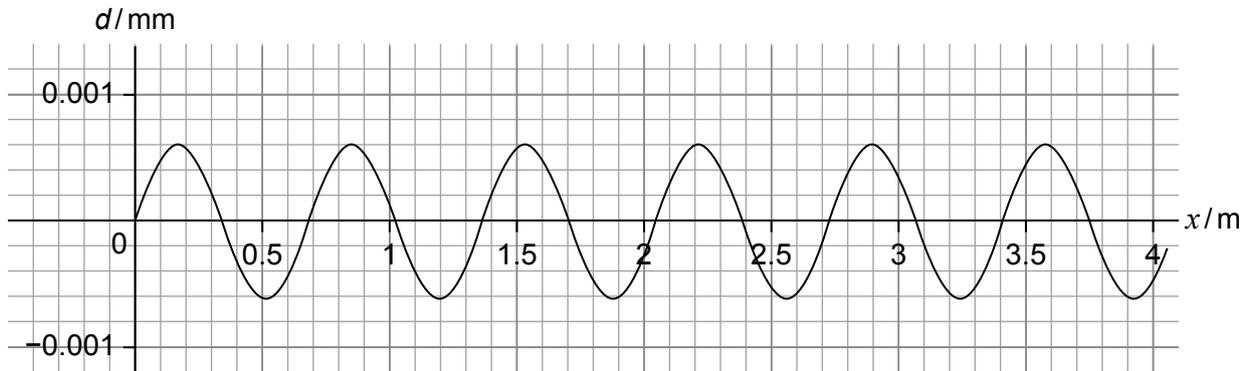
(c) Determine d . [3]

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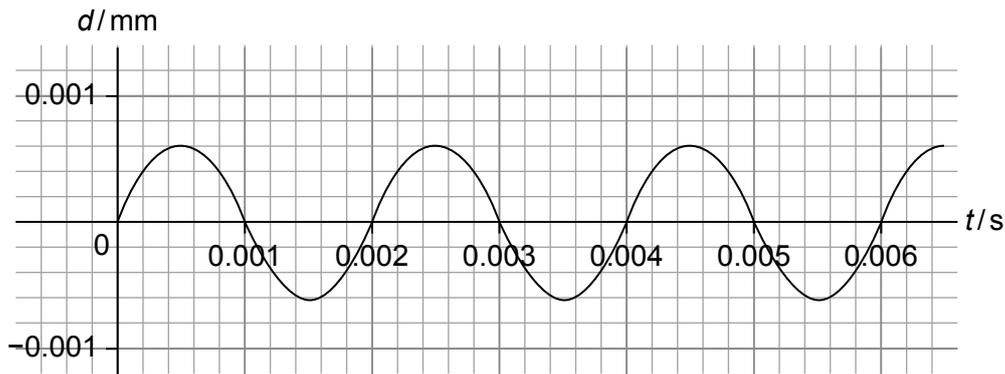
2. **Graph 1** shows the variation of particle displacement d with position x for a travelling sound wave.

Graph 1



Graph 2 shows the variation of particle displacement d with time t for the same travelling sound wave.

Graph 2



(a) (i) State the wavelength and the period of the sound wave. [2]

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(ii) Calculate the speed of the sound wave. [1]

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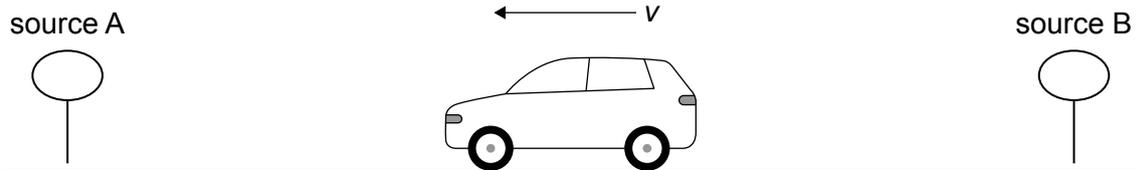


(Question 2 continued)

The Doppler effect applies to both sound and light waves.

A car is moving at constant velocity v between two sources of sound as shown in the diagram. The sources emit sound at 440 Hz and at 540 Hz. The driver hears both sounds at the same frequency.

diagram not to scale



- (b) (i) Explain which frequency is emitted by source A. [1]

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- (ii) The spectrum of light received from a galaxy shows a peak at a wavelength of 659.0 nm. The peak corresponds to an atomic transition in the hydrogen atom that emits a wavelength of 656.1 nm when observed in a laboratory on Earth.

Calculate the velocity of the galaxy with respect to Earth. [2]

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3. (a) A stationary isotope of ${}_{88}\text{Ra}$ (Radium) decays into Rn (Radon) and an alpha particle.

(i) Identify the proton number of Rn. [1]

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The following data are available:

Atomic mass of Ra = 226.02540 u

Atomic mass of Rn = 222.01757 u

Mass of α = 4.00260 u

(ii) Show that the energy released in this decay is about 5 MeV. [2]

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(iii) Show that about 98% of the energy released is carried by the alpha particle. [2]

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(Question 3 continued)

(b) In an experiment performed by Geiger, Marsden and Rutherford to investigate the atomic structure, alpha particles were directed into a thin metal foil.

(i) Describe two observations of this experiment. [2]

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(ii) Outline how the experiment was interpreted. [2]

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4. Earth orbits the Sun at an average distance of 1.50×10^8 km.

The mass of the Sun is 2.0×10^{30} kg.

(a) Calculate the gravitational field strength of the Sun at a distance of 1.50×10^8 km from its centre. [2]

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The orbital speed of Earth around the Sun is not constant.

(b) (i) State Kepler's first law of orbital motion. [1]

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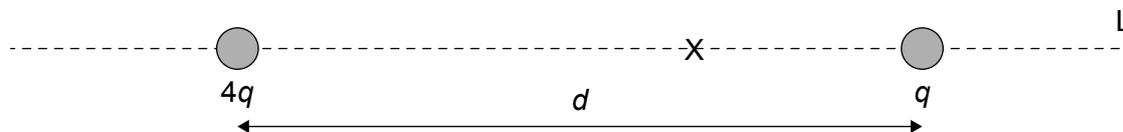
(ii) Explain why the kinetic energy of Earth changes as it orbits the Sun. [2]

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5. Two positive electric charges of magnitudes q and $4q$ are a distance d apart, along a line L.

diagram not to scale



(a) X is a point along L where the electric field E due to the charges is zero.

Show that X is at a distance $\frac{2}{3}d$ from the largest charge.

[2]

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A negative charge N is placed stationary at X.

(b) (i) N is just displaced along L, closer to q , and released.

Explain the subsequent motion of N.

[1]

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(ii) N is just displaced upwards, perpendicularly to L, and released.

Explain the subsequent motion of N.

[1]

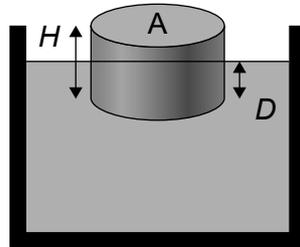
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6. A cylindrical cork of height H and cross-sectional area A is floating stationary in water. Its depth below the water surface is D .

diagram not to scale



- (a) (i) Draw and label the forces acting on the cork. [1]
(ii) Show that

$$\frac{D}{H} = \frac{\rho_c}{\rho_w}$$

where ρ_c is the density of the cork and ρ_w is the density of water. [2]

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(Question 6 continued)

The cork is displaced downward by a force. It is then released and it oscillates.

- (b) Outline why the cork undergoes simple harmonic motion. [2]

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(Question 6 continued)

- (c) (i) Explain why the density of most substances in a solid state is larger than its density in a liquid state. [2]

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Water shows an anomaly with respect to what is stated in (c)(i).

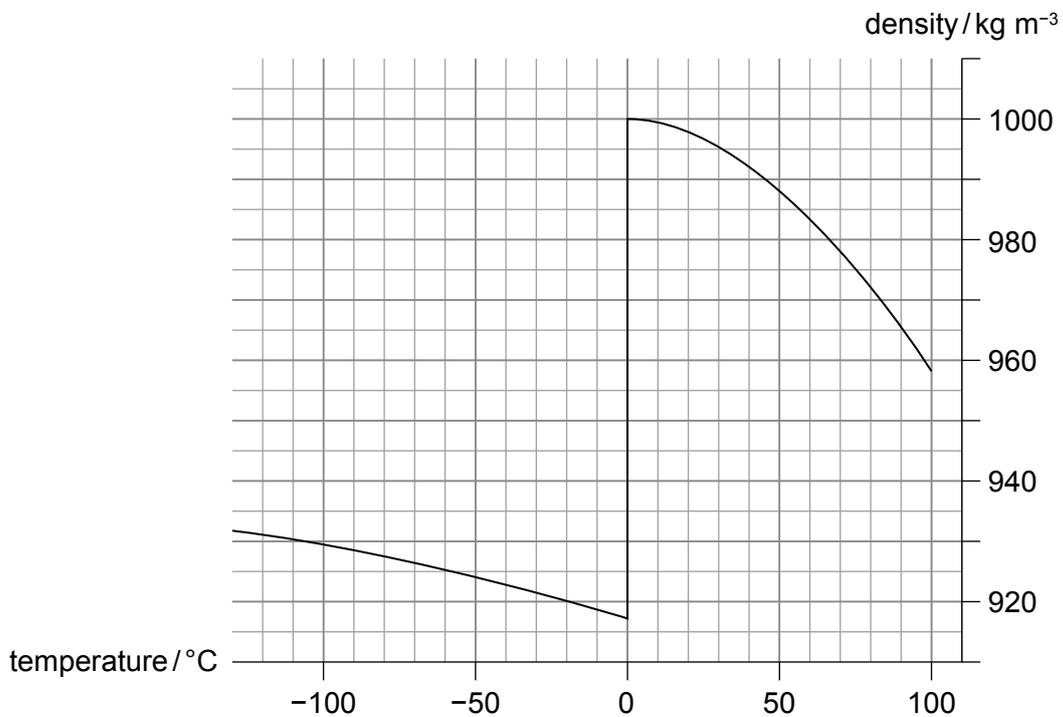
Graph 1 shows the variation with temperature of the density of water between -100°C and 100°C . **Graph 2** shows the same graph enlarged for the range 0 to 10°C .

- (ii) Identify the temperature at which water has its maximum density. [1]

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Graph 1

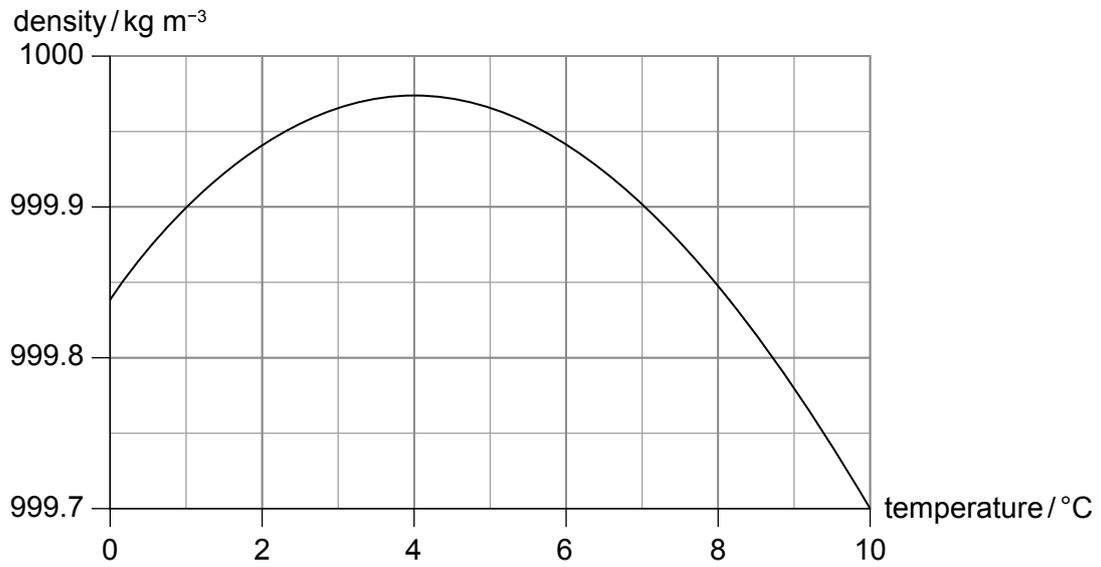


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(Question 6 continued)

Graph 2



(This question continues on the following page)



16EP13

Turn over

(Question 6 continued)

- (d) An icebreaking ship is designed to withstand a collision with an iceberg, a large partially submerged body of ice freely floating in water. The designers model the shape of the iceberg as a cylinder with an approximate cross-sectional area of 4200 m^2 and height above sea level of 32 m.

The following data are available:

$$\begin{aligned} \rho_{\text{ice}} &= 920 \text{ kg m}^{-3} \\ \rho_{\text{seawater}} &= 1030 \text{ kg m}^{-3} \end{aligned}$$

- (i) Show that the mass of the iceberg is about $1.2 \times 10^9 \text{ kg}$. [2]

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The designers assume that the mass of the ship is about $\frac{1}{40}$ the mass of the iceberg and is moving at 12 ms^{-1} when it collides with the iceberg. They stick together after the collision.

- (ii) Calculate the speed of the ship after the collision. [2]

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(Question 6 continued)

Ice in a still lake will usually form in a single layer on the surface.

(e) On a winter day, the surface of a lake is frozen. The temperature of the air above the lake is -6.0°C . The layer of ice frozen on the surface of the lake has a thickness of 1.9 cm.

(i) The thermal conductivity of ice is $2.3\text{W m}^{-1}\text{K}^{-1}$. Calculate the rate per unit area at which thermal energy leaves the lake by conduction through the ice layer. [2]

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(ii) The depth of water below the ice is 22 m and its average initial temperature is 2.0°C . Estimate the minimum thermal energy per unit area that must be removed to freeze all the water in the lake. [3]

The following data are available:

$$\text{Specific heat capacity of water} = 4.2 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$$

$$\text{Latent heat of fusion of water} = 3.3 \times 10^5 \text{ J kg}^{-1}$$

$$\rho_{\text{water}} = 1000 \text{ kg m}^{-3}$$

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(Question 6 continued)

Layers of ice on lakes do not grow thicker than a small percentage of the lake's depth even when the exterior temperature remains constant below the freezing point for some time.

(iii) Explain how the rate calculated in (e)(i) changes as the layer of ice grows thicker. [1]

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(iv) Discuss why the anomaly in the value of the density of water supports life in water on Earth. [2]

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