Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Standard level
Paper 2

Monday 3 May 2021 (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]**.

2221 – 6511

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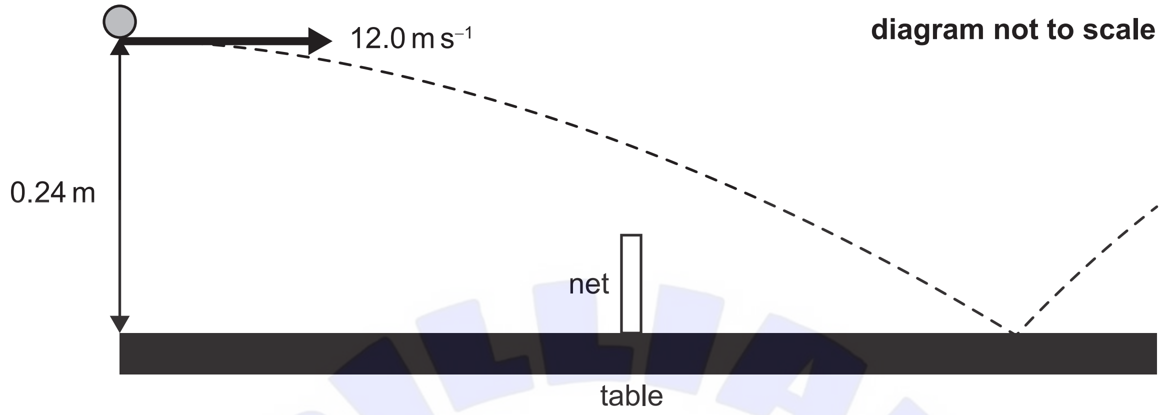
Answer **all** questions. Answers must be written within the answer boxes provided.

1. Two players are playing table tennis. Player A hits the ball at a height of 0.24 m above the edge of the table, measured from the top of the table to the bottom of the ball. The initial speed of the ball is 12.0 m s^{-1} horizontally. Assume that air resistance is negligible.



(a) Show that the time taken for the ball to reach the surface of the table is about 0.2 s. [1]

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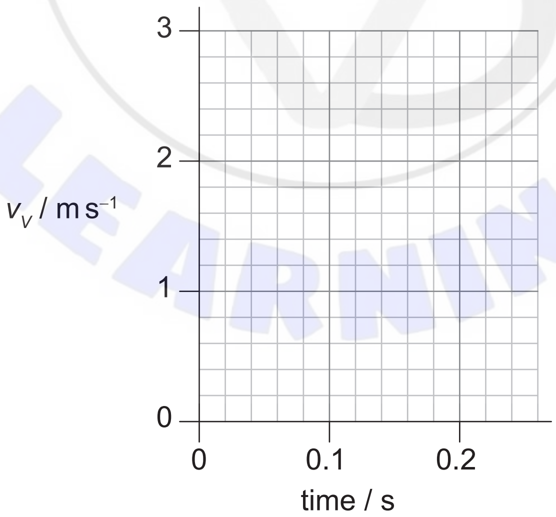
(b) Sketch, on the axes, a graph showing the variation with time of the vertical component of velocity v_v of the ball until it reaches the table surface. Take g to be +10 m s^{-2}. [2]



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(Question 1 continued)

(c) The net is stretched across the middle of the table. The table has a length of 2.74 m and the net has a height of 15.0 cm.

Show that the ball will go over the net. [3]

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(d) The ball bounces and then reaches a peak height of 0.18 m above the table with a horizontal speed of 10.5 m s^{-1}. The mass of the ball is 2.7 g.

(i) Determine the kinetic energy of the ball immediately after the bounce. [2]

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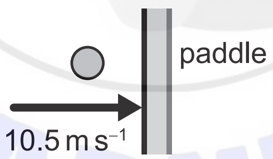
(ii) Player B intercepts the ball when it is at its peak height. Player B holds a paddle (racket) stationary and vertical. The ball is in contact with the paddle for 0.010 s. Assume the collision is elastic.



Calculate the average force exerted by the ball on the paddle. State your answer to an appropriate number of significant figures. [3]

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will not be marked.

2. A planet is in a circular orbit around a star. The speed of the planet is constant.

(a) (i) Explain why a centripetal force is needed for the planet to be in a circular orbit. [2]

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(ii) State the nature of this centripetal force. [1]

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(b) Determine the gravitational field of the planet.

The following data are given:

Mass of planet = 8.0×10^{24} kg
Radius of the planet = 9.1×10^{6} m. [2]

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3. A mass of 1.0 kg of water is brought to its boiling point of 100 °C using an electric heater of power 1.6 kW.

(a) (i) The molar mass of water is 18 g mol^{-1}. Estimate the average speed of the water molecules in the vapor produced. Assume the vapor behaves as an ideal gas. [2]

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(ii) State **one** assumption of the kinetic model of an ideal gas. [1]

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(b) A mass of 0.86 kg of water remains after it has boiled for 200 s.

(i) Estimate the specific latent heat of vaporization of water. State an appropriate unit for your answer. [2]

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(ii) Explain why the temperature of water remains at 100 °C during this time. [1]

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(Question 3 continued)

(c) The heater is removed and a mass of 0.30 kg of pasta at –10 °C is added to the boiling water.

Determine the equilibrium temperature of the pasta and water after the pasta is added. Other heat transfers are negligible.

Specific heat capacity of pasta = 1.8 $kJ\,kg^{-1}\,K^{-1}$
Specific heat capacity of water = 4.2 $kJ\,kg^{-1}\,K^{-1}$ [3]

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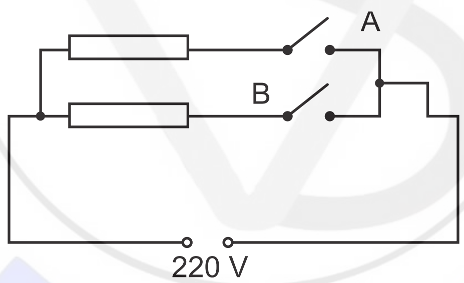
(d) The electric heater has two identical resistors connected in parallel.



The circuit transfers 1.6 kW when switch A only is closed. The external voltage is 220 V.

(i) Show that each resistor has a resistance of about 30 Ω. [1]

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Turn over

(Question 3 continued)

(ii) Calculate the power transferred by the heater when both switches are closed. [2]

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4. A planet orbits at a distance *d* from a star. The power emitted by the star is *P*. The total surface area of the planet is *A*.

(a) (i) Explain why the power incident on the planet is

$$\frac{P}{4\pi d^2} \times \frac{A}{4}.$$

[2]

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(ii) The albedo of the planet is α_p. The equilibrium surface temperature of the planet is *T*. Derive the expression

$$T = \sqrt[4]{\frac{P(1-\alpha_p)}{16\pi d^2 e\sigma}}$$

where *e* is the emissivity of the planet. [2]

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(b) On average, the Moon is the same distance from the Sun as the Earth. The Moon can be assumed to have an emissivity $e = 1$ and an albedo $\alpha_M = 0.13$. The solar constant is $1.36 \times 10^3\,\text{W m}^{-2}$. Calculate the surface temperature of the Moon. [2]

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5. Radioactive uranium-238 $\left({}^{238}_{92}\text{U}\right)$ produces a series of decays ending with a stable nuclide of lead. The nuclides in the series decay by either alpha (α) or beta-minus (β^-) processes.

(a) Uranium-238 decays into a nuclide of thorium-234 (Th).

Write down the complete equation for this radioactive decay. [1]

$${}^{238}_{92}\text{U} \rightarrow$$

(b) Thallium-206 $\left({}^{206}_{81}\text{Tl}\right)$ decays into lead-206 $\left({}^{206}_{82}\text{Pb}\right)$.

Identify the quark changes for this decay. [1]

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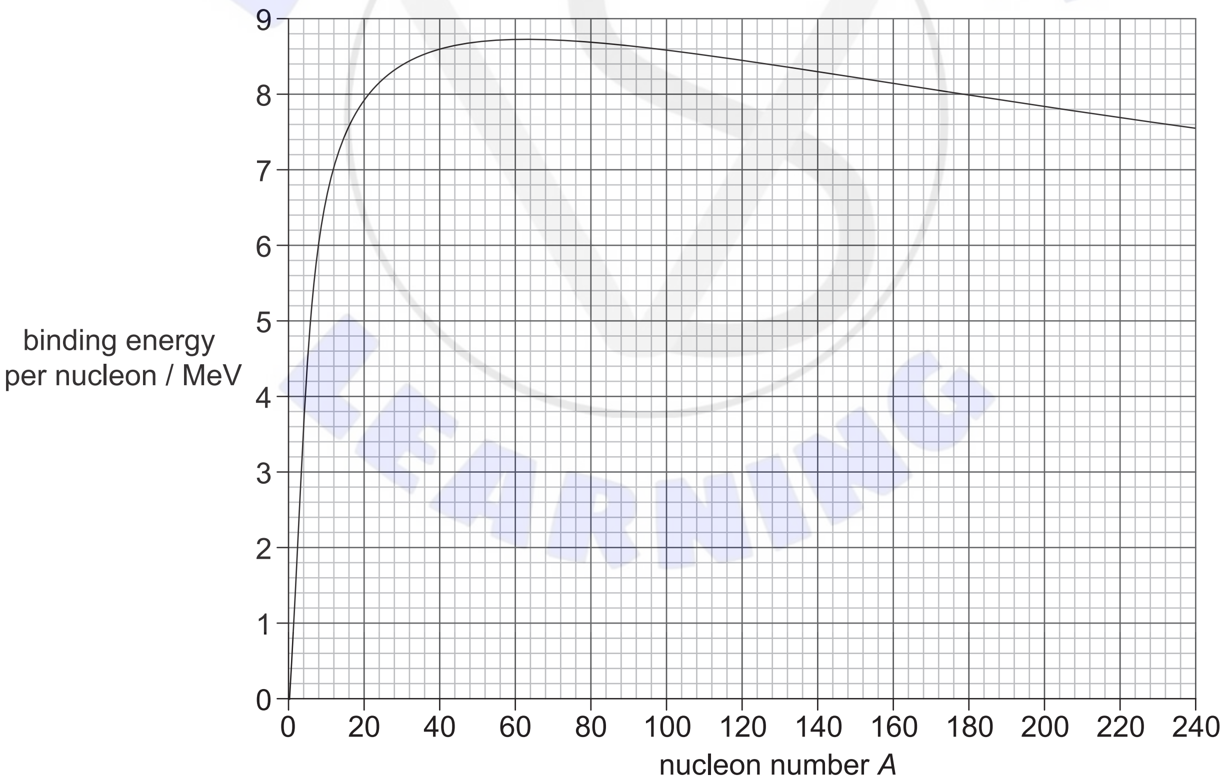
(c) The graph shows the variation with the nucleon number *A* of the binding energy per nucleon.



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(Question 5 continued)

(i) Outline why high temperatures are required for fusion to occur. [2]

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(ii) Outline, with reference to the graph, why energy is released both in fusion and in fission. [1]

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(iii) Uranium-235 $\left({}^{235}_{92}U\right)$ is used as a nuclear fuel. The fission of uranium-235 can produce krypton-89 and barium-144.

Determine, in MeV and using the graph, the energy released by this fission. [2]

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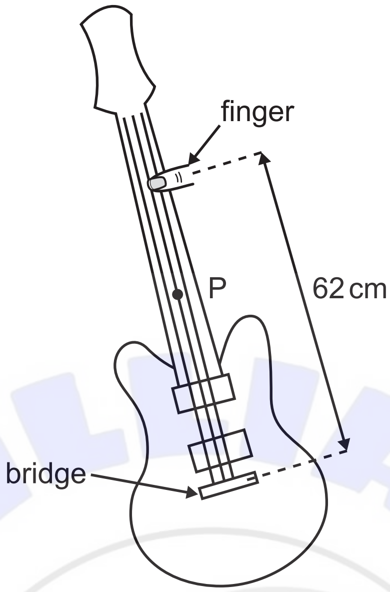
6. On a guitar, the strings played vibrate between two fixed points. The frequency of vibration is modified by changing the string length using a finger. The different strings have different wave speeds. When a string is plucked, a standing wave forms between the bridge and the finger.



(a) Outline how a standing wave is produced on the string. [2]

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(b) The string is displaced 0.4 cm at point P to sound the guitar. Point P on the string vibrates with simple harmonic motion (shm) in its first harmonic with a frequency of 195 Hz. The sounding length of the string is 62 cm.

(i) Show that the speed of the wave on the string is about 240 m s^{-1}. [2]

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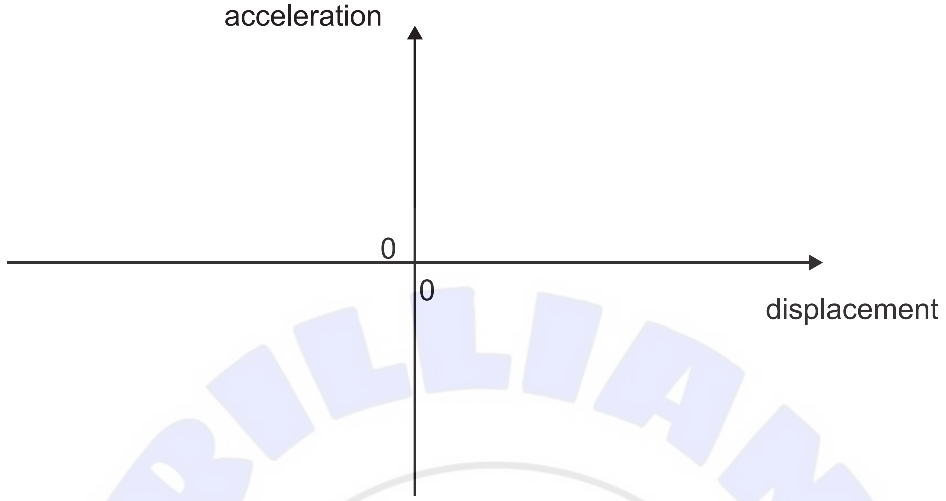
(Question 6 continued)

(ii) Sketch a graph to show how the acceleration of point P varies with its displacement from the rest position. [1]



7. Conservation of energy and conservation of momentum are two examples of conservation laws.

(a) Outline the significance of conservation laws for physics. [1]

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(b) When a pi meson $\pi-$ ($d\bar{u}$) and a proton (uud) collide, a possible outcome is a sigma baryon Σ^0 (uds) and a kaon meson K^0 ($d\bar{s}$).

Apply **three** conservation laws to show that this interaction is possible. [3]

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References:

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