Year 13 Physics

Mock Test

Time Allowed: 2 Hours

Total Marks: 100

16 April 2023

Calculator Allowed

Full Name of Student: …………………………………………………………

NB Tutors Ltd, Unit 79, Capital Business Centre, 22 Carlton Road, South Croydon, CR2 0BS

1.

(a) Explain what is meant by the *internal energy* of a gas.

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....[2]

(b) A bicycle tyre has a volume of $2.1 \times 10^{-3}\,m^3$. On a day when the temperature is 15 °C the pressure of the air in the tyre is 280 kPa. Assume that air behaves as an ideal gas.

(i) Calculate the number of moles *n* of air in the tyre.

n = ……………. mol [3]

(ii) The bicycle is ridden vigorously so that the tyres warm up. The pressure in the tyre rises to 290 kPa. Calculate the new temperature of the air in the tyre. Assume that no air has leaked from the tyre and that the volume is constant.

temperature = ………….. °C [3]

(iii) Calculate, for the air in the tyre, the ratio

$$\frac{\text{internal energy at the higher temperature}}{\text{internal energy at 15°C}} .$$

ratio = …………..

Justify your reasoning.

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....[2]

[Total for Question 1 = 10 marks]

Question 2 is on the next page.

2.

Fig. 3.1 shows apparatus used to investigate circular motion. The bung is attached by a continuous nylon thread to a weight carrier supporting a number of slotted masses which may be varied. The thread passes through a vertical glass tube. The bung can be made to move in a nearly horizontal circle at a steady high speed by a suitable movement of the hand holding the glass tube. A constant radius *r* of rotation can be maintained by the use of a reference mark on the thread.

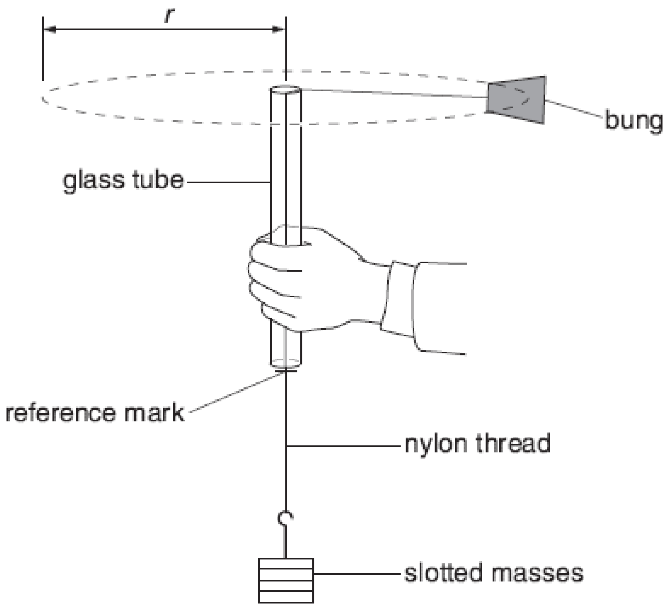

Fig. 3.1

(a) **(i)** Draw an arrow labelled **F** on Fig. 3.1 to indicate the direction of the resultant force on the bung.

[1]

(ii) Explain how the speed of the bung remains constant even though there is a resultant force *F* acting on it.

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.... **[2]**

(b) **(i)** Two students carry out an experiment using the apparatus in Fig. 3.1 to investigate the relationship between the force F acting on the bung and its speed v for a constant radius. Describe how they obtain the values of F and v.

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.... **[5]**

(ii) **1** Sketch, on Fig. 3.2, the expected graph of F against v^2.

[1]

Fig. 3.2

2 Explain how the graph can be used to determine the mass m of the bung.

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.... **[2]**

[Total for Question 2 = 11 marks]

3.

(a) An object is oscillating with simple harmonic motion. Place a tick (✓) in the box against each true statement that applies to the acceleration of the object.

The acceleration …

… is in the opposite direction to the displacement.	☐
… is directly proportional to the amplitude squared.	☐
… increases as the displacement decreases.	☐
… increases as the speed of the object decreases.	☐

[2]

(b) The graph in Fig. 3.1 shows the variation of the velocity *v* of the object with time *t*.

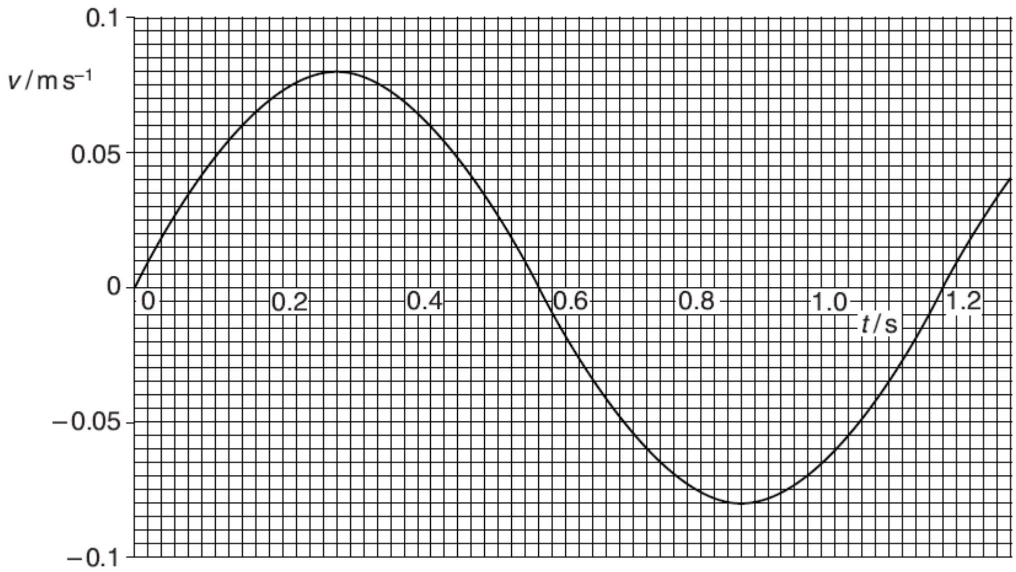

Fig. 3.1

Using the graph, determine

(i) the frequency of the motion

frequency = ... Hz **[1]**

(ii) the amplitude of the motion

amplitude = ... m **[2]**

(iii) the maximum acceleration of the object.

acceleration = ... $m\,s^{-2}$ **[2]**

(c) (i) With the help of a suitably labelled graph, explain what is meant by *resonance* of a mechanical system.

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.... **[4]**

(ii) State and explain an everyday example of resonance.

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.... **[2]**

[Total for Question 3 = 13 marks]

4.

(a) Define the *farad*.

.... **[1]**

(b) Fig. 2.1 shows a capacitor **C** of capacitance 5.4 nF connected to a battery. The switch $\mathbf{S_1}$ is closed and the capacitor is charged to a p.d. of 12 V.

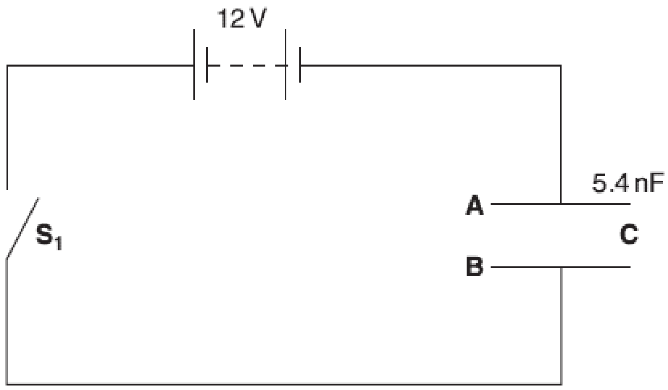

Fig. 2.1

The plates of the capacitor are labelled **A** and **B**.

(i) Explain how the plates of the capacitor become charged in terms of the movement of charged particles in the circuit.

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.... **[2]**

(ii) Calculate

1 the charge stored by the capacitor

charge = ... C **[1]**

2 the energy transferred to the capacitor.

energy = ... J **[1]**

(c) Fig. 2.2 shows the capacitor **C** connected to a resistor **R**.

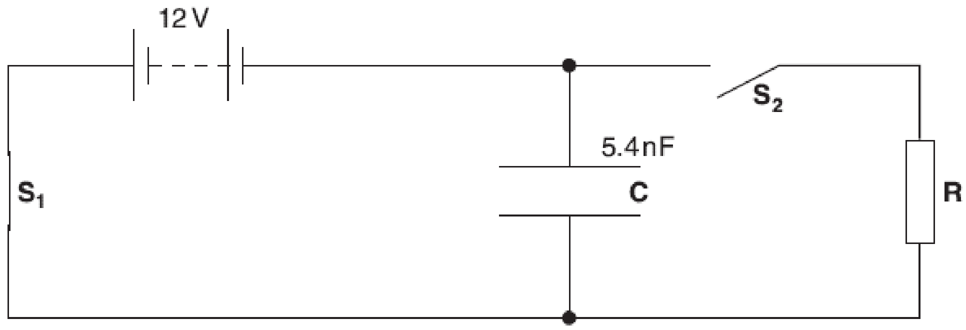

Fig. 2.2

The switch $\mathbf{S_1}$ is now opened and switch $\mathbf{S_2}$ is closed. The current in the resistor **R** is monitored. The initial current through **R** is 3.24 μA.

(i) Show that the resistance of the resistor **R** is 3.7 MΩ.

[1]

(ii) Calculate the current through **R** after a time t = 0.080 s.

current = ... μA **[2]**

(d) Explain the effect on the initial rate of discharge of the capacitor when a second resistor of resistance 3.7 MΩ is connected in parallel with the resistor **R**.

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.... **[2]**

[Total for Question 4 = 10 marks]

5.

(a) State, in words, Newton's law of gravitation.

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.... **[1]**

(b) Fig. 3.1 shows the circular orbits of two of Jupiter's moons: Adrastea, **A**, and Megaclite, **M**.

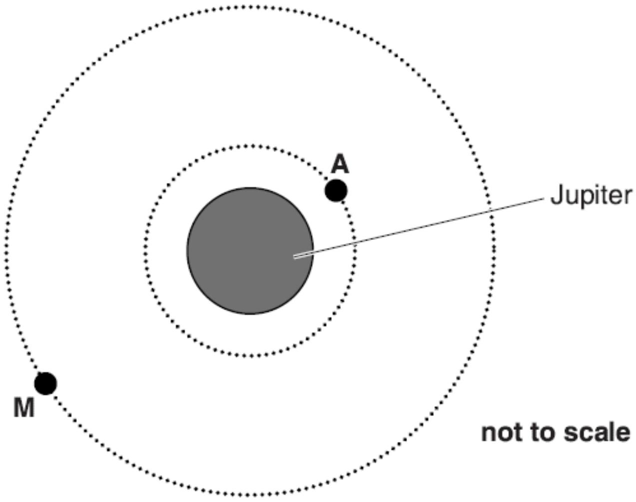

Fig. 3.1

Use the following data in the calculations below.

orbital radius of **A** = 1.3×10^{8} m
orbital period of **A** = 7.2 hours
gravitational field strength at orbit of **A** = 7.5 N kg^{-1}
orbital radius of **M** = 2.4×10^{10} m

Calculate

(i) the mass of Jupiter

mass = ... kg **[3]**

(ii) the gravitational field strength at the orbit of **M**

gravitational field strength = ... $N\,kg^{-1}$ **[2]**

(iii) the orbital period of **M**.

orbital period = ... hours **[3]**

[Total for Question 5 = 9 marks]

6.

Molten lead at its melting temperature of 327°C is poured into an iron mould where it solidifies. The temperature of the iron mould rises from 27°C to 84°C, at which the mould is in thermal equilibrium with the now solid lead.

mass of lead = 1.20 kg
specific latent heat of fusion of lead = $2.5 \times 10^4 \text{ J kg}^{-1}$
mass of iron mould = 3.00 kg
specific heat capacity of iron = $440 \text{ J kg}^{-1} \text{ K}^{-1}$

(a) Calculate the heat energy absorbed by the iron mould.

answer = ... J
(2 marks)

(b) Calculate the heat energy given out by the lead while it is changing state.

answer = ... J
(1 mark)

(c) Calculate the specific heat capacity of lead.

answer = ... $\text{J kg}^{-1} \text{ K}^{-1}$
(3 marks)

(d) State **one** reason why the answer to part 1 **(c)** is only an approximation.

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(1 mark)

[Total for Question 6 = 7 marks]

Question 7 is on the next page.

7.

This question is about electric fields.

(a) Fig. 2.1 shows the electric field pattern drawn by a student for two oppositely charged plates.

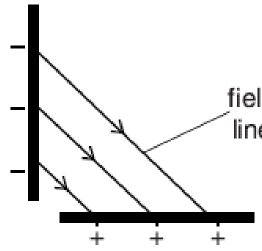

Fig. 2.1

State **two** errors made by the student in this drawing of the field pattern.

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.... **[2]**

(b) At a distance r from the centre of a radioactive nucleus the electric field strength is E.

Fig. 2.2 shows the graph of the electric field strength E against $\frac{1}{r^2}$.

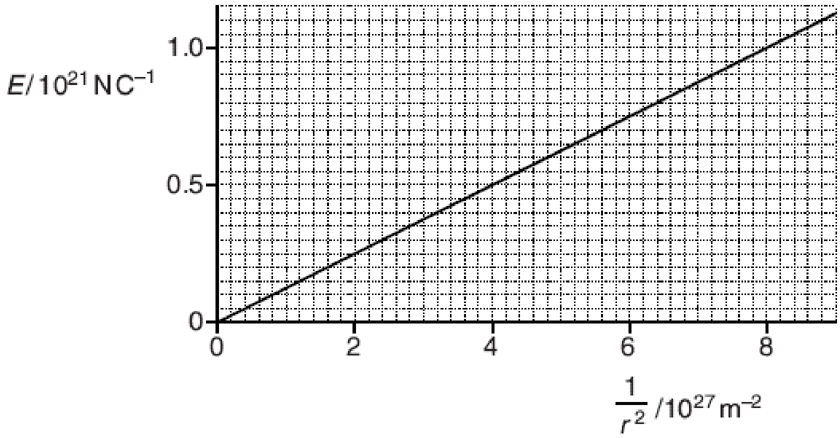

Fig. 2.2

(i) The electric field strength is given by the equation $E = \dfrac{Q}{4\pi\varepsilon_0 r^2}$.

Determine the gradient of the line and hence calculate the charge on the nucleus.

charge = ... C **[2]**

(ii) The radioactive nucleus emits an alpha particle.
State the change, if any, to the graph shown in Fig. 2.2 for the resultant (daughter) nucleus. Explain your answer.

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.... **[2]**

(c) A negatively charged droplet of oil is held **stationary** between two horizontal plates. The potential difference between the plates is 1.50 kV. Fig. 2.3 shows the two forces acting on this charged droplet.

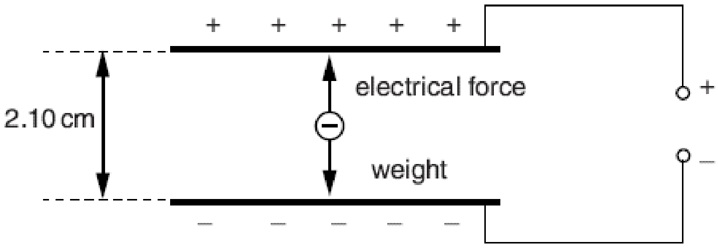


Fig. 2.3

The droplet is spherical and has a radius of 1.27×10^{-6} m. The density of oil is $950\,kg\,m^{-3}$. The separation between the plates is 2.10 cm.

(i) Show that the magnitude of the charge on the droplet is about 1.1×10^{-18} C.

[3]

(ii) Calculate the number of electrons causing the charge on the droplet.

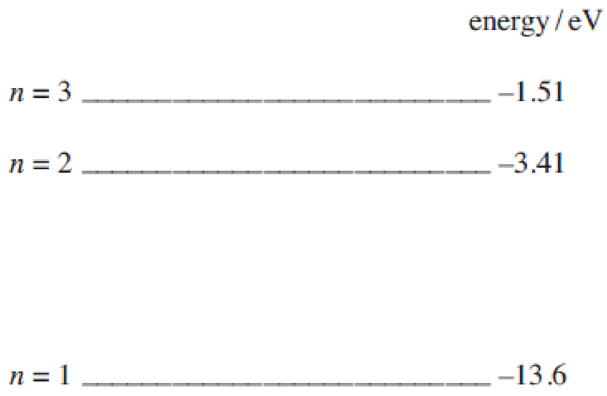
number of electrons = ... **[1]**

[Total for Question 7 = 10 marks]

8.

Figure 1 shows the lowest three energy levels of a hydrogen atom.

Figure 1



(a) An electron is incident on a hydrogen atom. As a result an electron in the ground state of the hydrogen atom is excited to the $n = 2$ energy level. The atom then emits a photon of a characteristic frequency.

(a) (i) Explain why the electron in the ground state becomes excited to the $n = 2$ energy level.

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(2 marks)

(a) (ii) Calculate the frequency of the photon.

frequency = ... Hz

(3 marks)

(a) (iii) The initial kinetic energy of the incident electron is 1.70×10^{-18} J.

Calculate its kinetic energy after the collision.

kinetic energy = ... J

(2 marks)

(a) (iv) Show that the incident electron cannot excite the electron in the ground state to the $n = 3$ energy level.

(2 marks)

(b) When electrons in the ground state of hydrogen atoms are excited to the $n = 3$ energy level, photons of more than one frequency are subsequently released.

(b) (i) Explain why different frequencies are possible.

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(1 mark)

(b) (ii) State and explain how many possible frequencies could be produced.

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(2 marks)

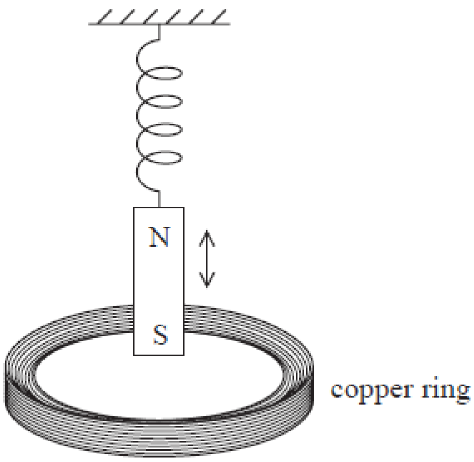
[Total for Question 8 = 12 marks]

9.

(a) State Faraday's law of electromagnetic induction.

(2)

(b) A magnet is attached to the end of a spring as shown in the diagram.



The magnet is displaced vertically and released so that it oscillates.
Explain why this produces an alternating current in the copper ring.

(4)

(c) The average vertical component of the magnetic flux density through the coil varies at a maximum rate of 0.035 T s^{-1}.
Calculate the maximum current in the copper ring.

radius of copper ring = 5.0 cm
resistance of copper ring = 6.7×10^{-5} Ω

(4)

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Maximum current = ...

[Total for Question 9 = 10 marks]

Question 10 is on the next page.

10.

The fissile isotope of uranium, ${}^{233}_{92}U$, has been used in some nuclear reactors.
It is normally produced by neutron irradiation of thorium-232.
An irradiated thorium nucleus emits a β^- particle to become an isotope of protactinium.

This isotope of protactinium may undergo β^- decay to become ${}^{233}_{92}U$.

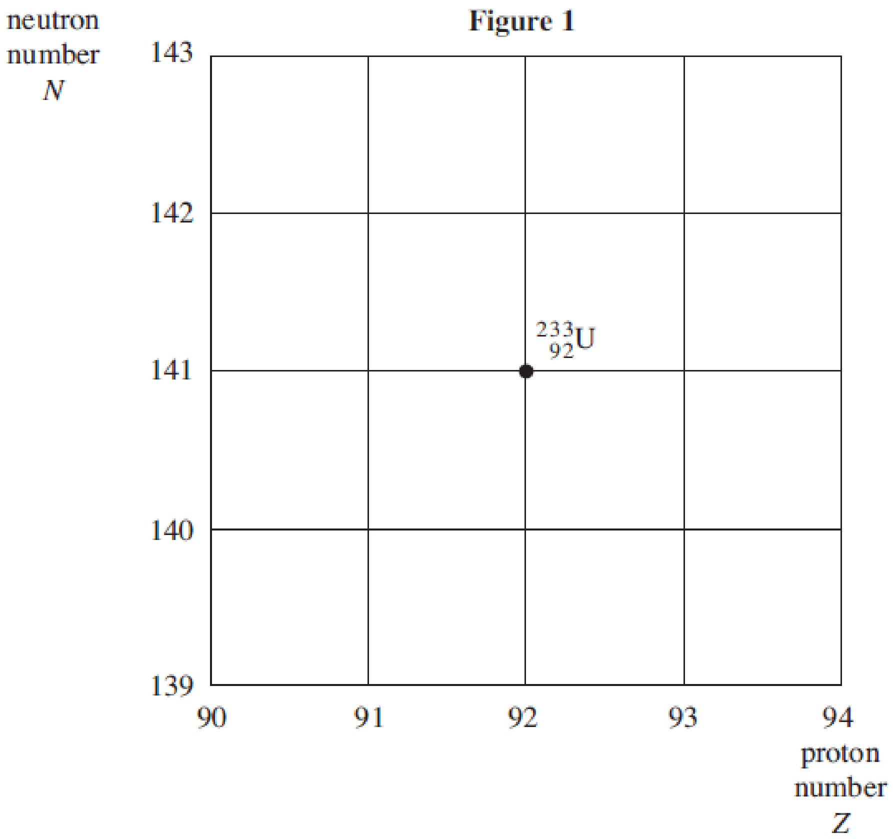
(a) Complete the following equation to show the β^- decay of protactinium.

$$^{\cdots\cdots}_{\cdots\cdots}Pa \rightarrow {}^{233}_{92}U + \beta^- + \ldots\ldots\ldots$$

(2 marks)

(b) Two other nuclei, **P** and **Q**, can also decay into ${}^{233}_{92}U$.
P decays by β^+ decay to produce ${}^{233}_{92}U$.
Q decays by α emission to produce ${}^{233}_{92}U$.
Figure 1 shows a grid of neutron number against proton number with the position of the ${}^{233}_{92}U$ isotope shown.
On the grid label the positions of the nuclei **P** and **Q**.

Figure 1



(2 marks)

(c) A typical fission reaction in the reactor is represented by

$$^{233}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{91}_{36}\text{Kr} + ^{139}_{56}\text{Ba} + x \text{ neutrons}$$

(c) (i) Calculate the number of neutrons, x.

answer = ...neutrons
(1 mark)

(c) (ii) Calculate the energy released, in MeV, in the fission reaction above.

mass of neutron = 1.00867 u

mass of $^{233}_{92}$U nucleus = 232.98915 u

mass of $^{91}_{36}$Kr nucleus = 90.90368 u

mass of $^{139}_{56}$Ba nucleus = 138.87810 u

answer = ...MeV
(3 marks)

[Total for Question 10 = 8 marks]

- End of Test -
