Please write clearly in block capitals.

Centre number 3 5 8 9 7 Candidate number 9 3 2 3

Surname Matheson

Forename(s) Lewis

Candidate signature

I declare this is my own work.

A-level
PHYSICS

Paper 2

ALevelPhysicsOnline.com

Time allowed: 2 hours

Materials

For this paper you must have:

- a pencil and a ruler
- a scientific calculator
- a Data and Formulae Booklet
- a protractor.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 85.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7–31	
TOTAL	

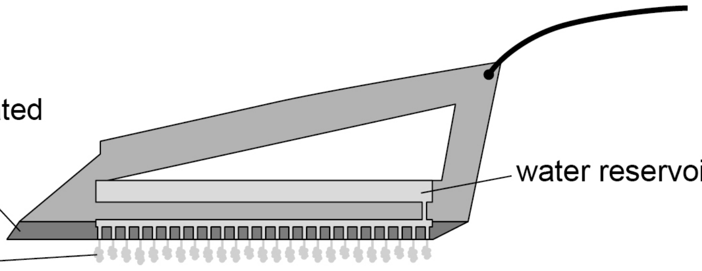
Do not write outside the box

Section A

Answer **all** questions in this section.

0 1 **Figure 1** shows an electric steam iron.

Figure 1



Water from a reservoir drips onto an electrically-heated metal plate. The water boils and steam escapes through holes in the metal plate.

The electrical power of the heater inside the iron is 2.1 kW.

Assume that all the energy from the heater is transferred to the metal plate.

0 1 . 1 The metal plate has a mass of 1.2 kg and is initially at a temperature of 20 °C. The heater is switched on. After a time t the metal plate reaches its working temperature of 125 °C.

Calculate t.

specific heat capacity of the metal = 450 J kg^{-1} K^{-1}

[2 marks]

$Q = Pt = mc\Delta\theta$

$t = \frac{mc\Delta\theta}{P} = \frac{1.2 \times 450 \times (125 - 120)}{2.1 \times 10^3}$ ✓

$t =$ 27 ✓ s

0 1 . 2 The metal plate is maintained at its working temperature.
Water at 20 °C drips continuously onto the metal plate.
Steam at 100 °C emerges continuously from the iron.

The maker claims that the iron can generate steam at a rate of $60\ \text{g min}^{-1}$.

Determine whether this claim is true.

specific latent heat of vaporisation of water = $2.3 \times 10^6\ \text{J kg}^{-1}$
specific heat capacity of water = $4200\ \text{J kg}^{-1}\ \text{K}^{-1}$

[3 marks]

$$mc\Delta\theta + mL = Pt$$

$$m(c\Delta\theta + L) = Pt$$

$$\frac{m}{t} = \frac{P}{c\Delta\theta + L} = \frac{2.1\times10^3}{4200\times(100-20)+2.3\times10^6}$$

$$= 7.97\times10^{-4}\ \text{kg s}^{-1}$$

$$= 0.797\ \text{g s}^{-1}$$

$$= 47.8\ \text{g min}^{-1}$$

$\therefore < 60\ \text{g min}^{-1}$

$\therefore$ Claim is false

5

Do not write outside the box

Turn over ►

0 2 . 1 In the kinetic theory model, it is assumed that there are many identical particles moving at random.

State **two** other assumptions made in deriving the equation $pV = \frac{1}{3}Nm(c_{rms})^2$.

[2 marks]

1 Collisions are perfectly elastic. ✓

2 Volume of particles are negligible compared to the volume of the container. ✓

0 2 . 2 Explain why molecules of a gas exert a force on the walls of a container.
Refer to Newton's laws of motion in your answer.

[3 marks]

The particles collide with the wall, changing direction ✓ and therefore velocity. As it is accelerating there must be a resultant force acting on it - this is Newton's 2nd law. ✓
Newton's 3rd law states that the force exerted by the particle on the wall is equal in size, opposite in direction and of the same type as the force of the wall exerted on the particle. ✓

0 2 . 3 A sealed flask of volume $0.35\ \text{m}^3$ contains an ideal gas at a pressure of $220\ \text{kPa}$. The mean kinetic energy of the gas molecules is $6.7 \times 10^{-21}\ \text{J}$.

Calculate the amount of gas in the container.

[3 marks]

$E_K = \frac{3}{2}kT$ $\quad T = \frac{2E_K}{3k}$

$T = \frac{2 \times 6.7 \times 10^{-21}}{3 \times 1.38 \times 10^{-23}} = 323.7\text{K}$ ✓

$pV = nRT \quad n = \frac{pV}{RT}$ ✓ $= \frac{220 \times 10^3 \times 0.35}{8.31 \times 323.7} = 28.6$

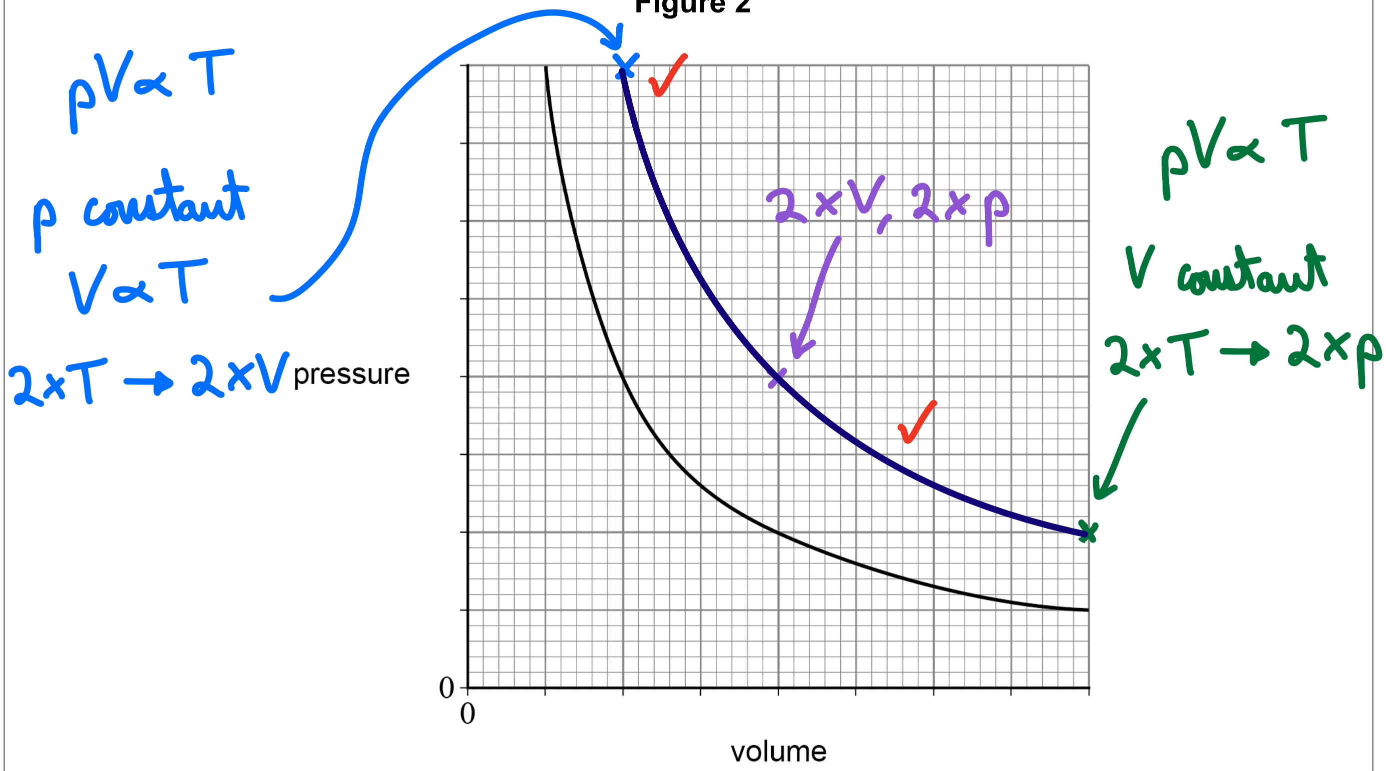
amount of gas = 29 ✓ mol

0 2 . 4 **Figure 2** shows the variation of pressure with volume for a fixed mass of an ideal gas at constant absolute temperature T.

Draw, on **Figure 2**, the graph for the same gas at temperature $2T$.

[2 marks]

Figure 2



10

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0 3 An isolated solid conducting sphere is initially uncharged.
Electrons are then transferred to the sphere.

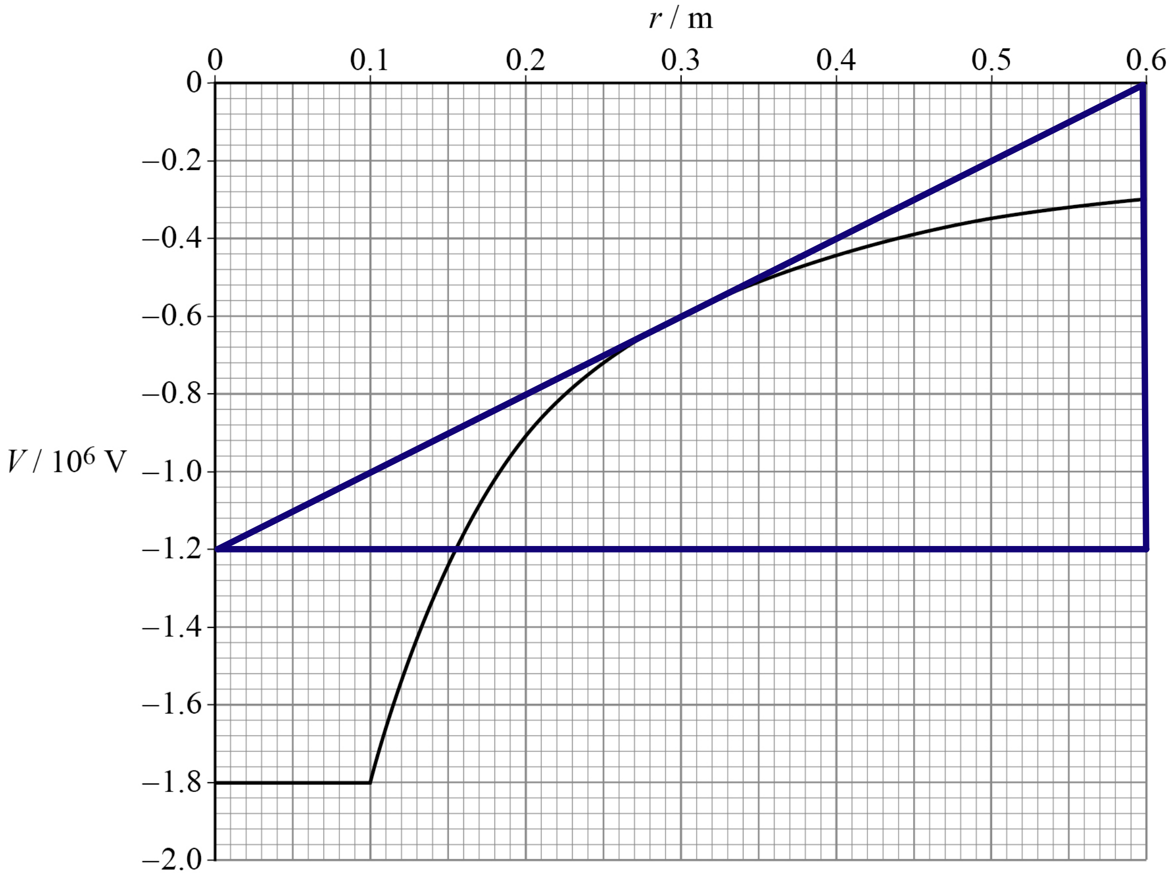
0 3 . 1 State and explain the location of the excess electrons.

[2 marks]

Electrons are on the surface ✓ of the sphere and equally spaced out ✓ due to the mutual repulsion of the charges.

Figure 3 shows how the electric potential V varies with distance r from the centre of the sphere.
The radius of the sphere is 0.10 m.

Figure 3



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0 3 . 2 The magnitude of the electric field strength E is related to V by $E = \frac{\Delta V}{\Delta r}$.

Determine, using this relationship, the magnitude of the electric field strength at a distance 0.30 m from the centre of the sphere.

State an appropriate SI unit for your answer.

[4 marks]

$E = \text{gradient} = \frac{\Delta V}{\Delta r} = \frac{0-(-)1.20\times10^{6}}{0.60-0}$ ✓ ✓

$= 2.0\times10^{6}$

or Vm^{-1}

electric field strength = 2.0×10^{6} ✓ unit NC^{-1} ✓

0 3 . 3 The sphere acts as a capacitor because it stores charge at an electric potential.

Show that the capacitance of the sphere is approximately 1×10^{-11} F.

[3 marks]

$V = \frac{Q}{4\pi\varepsilon_0 r}$ $\quad \frac{Q}{V} = 4\pi\varepsilon_0 r$ ✓

$C = \frac{Q}{V} = 4\pi\varepsilon_0 r = 4\times\pi\times 8.85\times10^{-12}\times 0.10$ ✓

$= 1.11\times10^{-11} \approx 1\times10^{-11}$ F ✓

Question 3 continues on the next page

Turn over ▶

Do not write outside the box

0 3 . 4 Electrons leak away from the sphere with time and the amount of energy stored by the sphere decreases. At one instant, the magnitude of the electric potential of the sphere has fallen to 1.0×10^6 V.

Calculate, for this instant, the change in the energy stored by the sphere.

[3 marks]

$$E = \frac{1}{2}CV^2$$

$$\Delta E = \frac{1}{2}C(V_0^2 - V_1^2)$$ ✓

$$\Delta E = \frac{1}{2} \times 1.11 \times 10^{-11}((1.8 \times 10^6)^2 - (1.0 \times 10^6)^2)$$ ✓

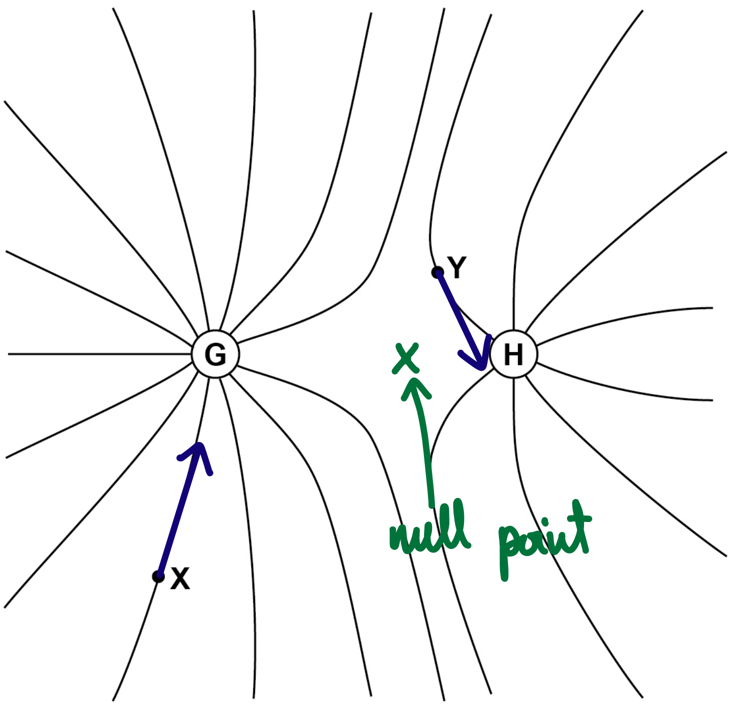
$$\Delta E = 12.45$$

change in energy = 12 ✓ J

12

0 4 The lines in **Figure 4** show the shape of the gravitational field around two stars **G** and **H**.

Figure 4



0 4 . 1 Compare, with reference to **Figure 4**, the masses of **G** and **H**.

[2 marks]

G has a greater mass ✓ because the null point is closer to H, this is where the field due to both stars is equal. ✓

0 4 . 2 **X** and **Y** are two points in the field.

Annotate **Figure 4** to show the field direction at **X** and the field direction at **Y**.

[1 mark]

See diagram for arrows at a tangent to field lines. ✓

Question 4 continues on the next page

Do not write outside the box

0 4 . 3 A spherical asteroid **P** has a mass of 2.0×10^{20} kg.

The gravitational field strength at its surface is $0.40\ \mathrm{N\,kg^{-1}}$.

Calculate the radius R of **P**.

[1 mark]

$$g = \frac{GM}{R^2} \qquad R = \sqrt{\frac{GM}{g}}$$

$$= \sqrt{\frac{6.67 \times 10^{-11} \times 2.0 \times 10^{20}}{0.40}}$$

$$= 1.83 \times 10^{5}$$

$R =$ 1.8×10^{5} ✓ m

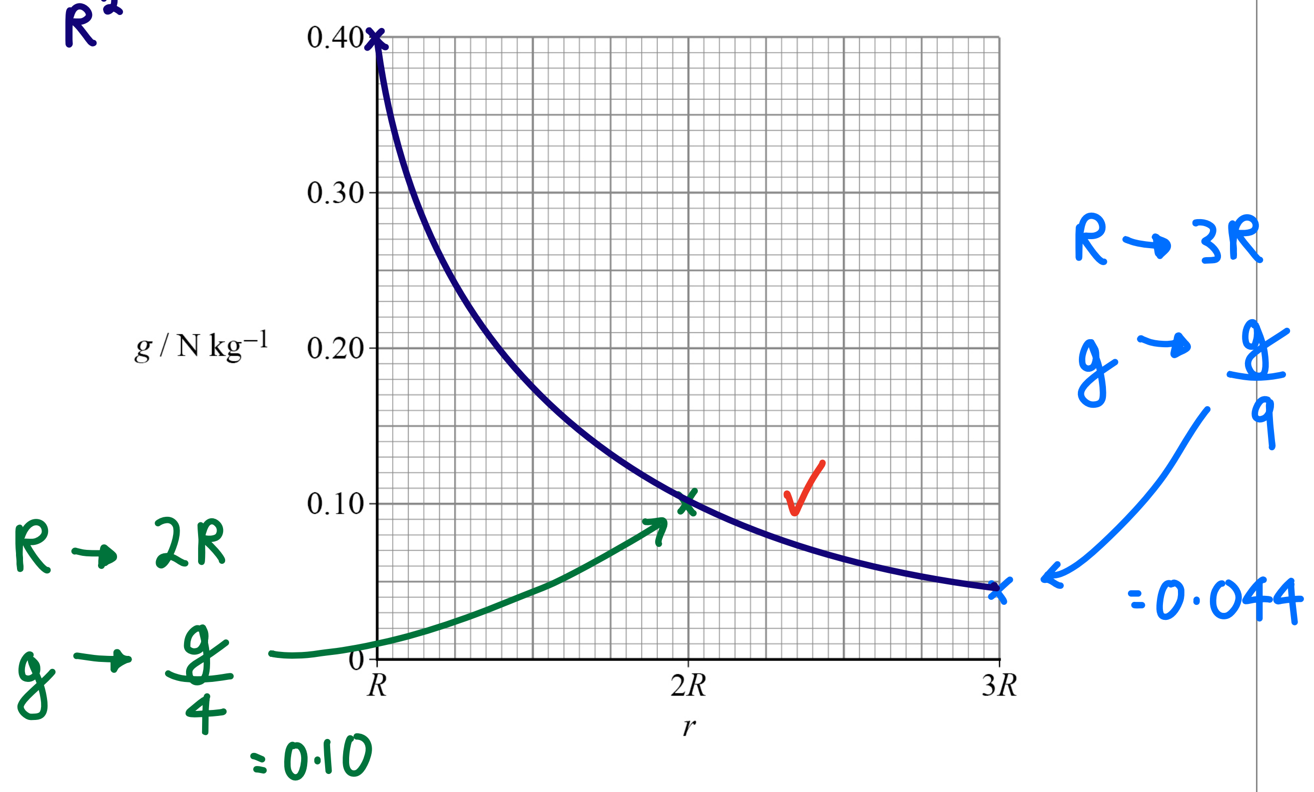
Do not write outside the box

0 4 . 4 Sketch, on **Figure 5**, the variation of the gravitational field strength g with distance r. The distance r is measured from the centre of **P**.

[1 mark]

$g \propto \frac{1}{R^2}$

Figure 5



0 4 . 5 Explain what is represented by the area under the graph between $r = R$ and $r = 2R$ on **Figure 5**.

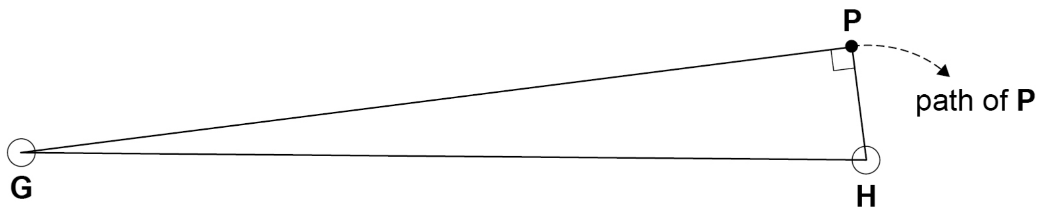
[2 marks]

This represents the increase in potential (work done per kilogram of mass) in moving an object from r = R to r = 2R.

Question 4 continues on the next page

Asteroid **P** approaches the two stars **G** and **H**.
Figure 6 shows one position of **P** close to **H**.

Figure 6

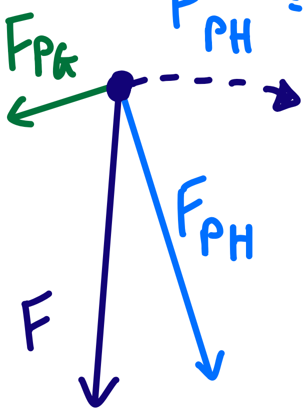


0 4 . 6 The gravitational force on **P** from **G** is 6.38×10^{12} N.
The mass of **H** is 3.00×10^{25} kg and the mass of **P** is 2.00×10^{20} kg.
The distance **HP** is 1.50×10^{11} m.

Calculate the magnitude of the acceleration of **P**.

[4 marks]

$F_{PG} = 6.38 \times 10^{12}$



$F_{PH} = \frac{G m_1 m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 3.00 \times 10^{25} \times 2.00 \times 10^{20}}{(1.50 \times 10^{11})^2}$

$= 1.78 \times 10^{13}$ N ✓

$F = \sqrt{F_{PG}^2 + F_{PH}^2}$ ✓

$= \sqrt{(6.38 \times 10^{12})^2 + (1.78 \times 10^{13})^2}$

$= 1.89 \times 10^{13}$ N ✓

$a = \frac{F}{m} = \frac{1.89 \times 10^{13}}{2.00 \times 10^{20}} = 9.448 \times 10^{-8}$

magnitude of acceleration = 9.45×10^{-8} ✓ m s^{-2}

Do not write outside the box

0 4 . 7 Explain why **P** cannot have a circular orbit around **H**.

[1 mark]

Resultant force does not act towards the centre of H. ✓

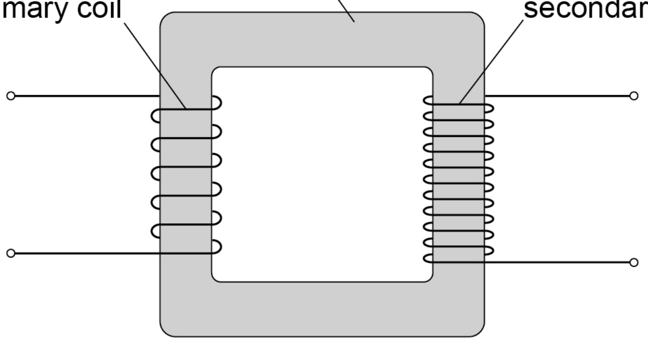
12

Turn over for the next question

Do not write outside the box

0 5 **Figure 7** shows a transformer.

Figure 7



0 5 . 1 Explain the functions of the core and the secondary coil.

[3 marks]

core Provides a greater flux linkage between the coils than air alone. ✓

secondary coil The alternating ✓ magnetic flux linking with it produces an induced emf ✓ that is determined by the ratio of turns in the primary and secondary coils.

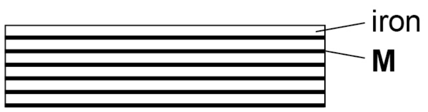
Do not write outside the box

0 5 . 2 **Figure 8** shows a cross-section through the transformer core. Thin iron sheets are separated by material **M**.

Explain how the efficiency of the transformer is increased by constructing the core in this way.

[3 marks]

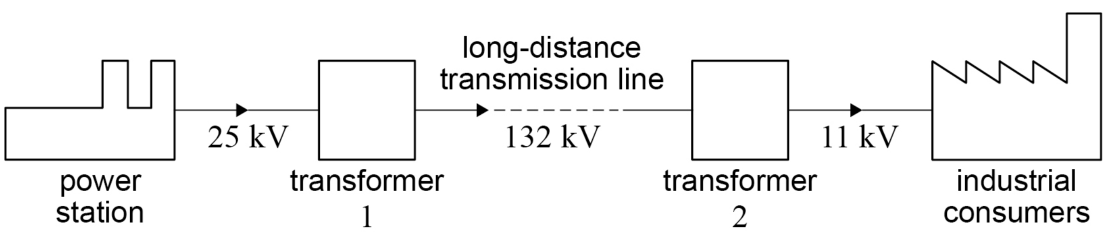
Figure 8



Material M is an insulator ✓ so it reduces eddy currents ✓ which increases efficiency. The thin sheets of iron mean that a smaller emf is induced in the core. ✓

Figure 9 shows a schematic diagram of a power transmission system.

Figure 9



0 5 . 3 Voltages between 33 kV and 400 kV are used for long-distance transmission.

Suggest why engineers have chosen 132 kV for this system.

[2 marks]

A higher voltage in the line means a lower current ∴ less power losses in the cable. ✓ But too high a voltage creates difficulties in insulating the wires. ✓

Question 5 continues on the next page

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0 5 . 4 The industrial consumers use 72 MW of power.
Transformers 1 and 2 each have an efficiency of 98% and the transmission line has an efficiency of 94%.

Calculate the current in the 25 kV line from the power station.

[3 marks]

$$\text{efficiency} = \frac{\text{useful output power}}{\text{total input power}}$$

$$\text{total input power} = \frac{\text{useful output power}}{\text{efficiency}}$$

efficiencies:

$T_1 = 0.98$
Line $= 0.94$
$T_2 = 0.98$

$$P = \frac{72 \times 10^6}{0.98 \times 0.94 \times 0.98}$$

$$P = 7.975 \times 10^7 \text{ W} \checkmark$$

$$P = VI \qquad I = \frac{P}{V} = \frac{7.975 \times 10^7}{25 \times 10^3} \checkmark = 3190$$

current = 3200 ✓ A

11

Do not write outside the box

0 6 Fission and fusion are two processes that can result in the transfer of binding energy from nuclei.

0 6 . 1 State what is meant by the binding energy of a nucleus.

[2 marks]

The energy required to separate ✓ the nucleus into its individual nucleons. ✓

0 6 . 2 Calculate, in MeV, the binding energy for a nucleus of iron $^{56}_{26}\mathrm{Fe}$.

mass of $^{56}_{26}\mathrm{Fe}$ nucleus $= 9.288 \times 10^{-26}$ kg

[3 marks]

mass defect $= 26m_p + 30m_n - m_{Fe}$ ✓

$\Delta m = (26 \times 1.673 \times 10^{-27}) + (30 \times 1.675 \times 10^{-27})$ ✓

$- 9.288 \times 10^{-26}$

$= 8.68 \times 10^{-28}$ kg

$E = mc^2 = 8.68 \times 10^{-28} \times (3.00 \times 10^8)^2 = 7.812 \times 10^{-11}$ J

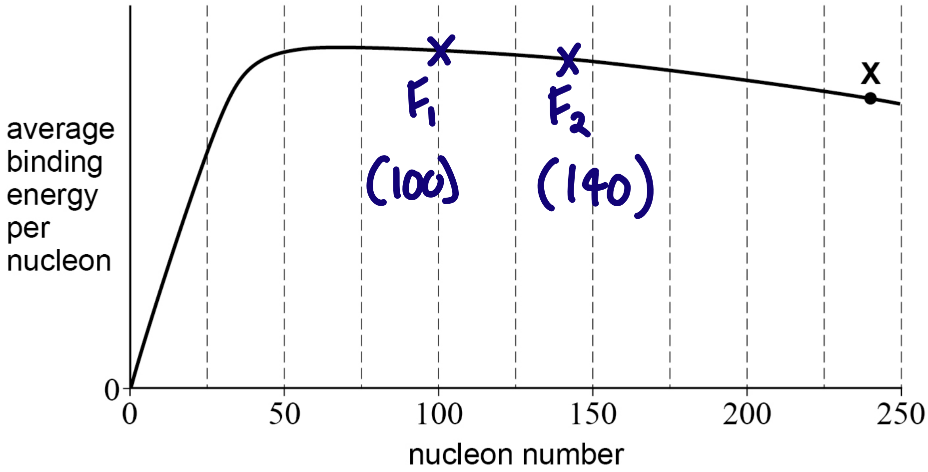
$E_J \rightarrow E_{eV}$ $\quad 7.812 \times 10^{-11} \div 1.6 \times 10^{-19} = 4.88 \times 10^8$ eV

binding energy = 488 ✓ MeV

Question 6 continues on the next page

Figure 10 shows a graph of average binding energy per nucleon against nucleon number for common nuclides.

Figure 10



0 6 . 3 The nuclide labelled **X** in **Figure 10** undergoes fission.

Annotate **Figure 10** with $\mathbf{F_1}$ and $\mathbf{F_2}$ to show **one** possible pair of nuclides resulting from the fission of **X**.

[2 marks]

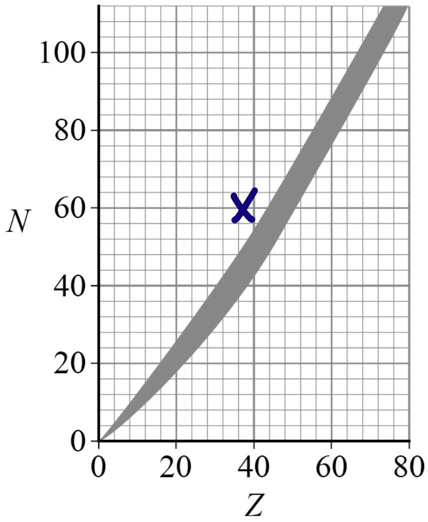
Nucleon number of X ≈ 240

$\therefore F_1 + F_2 \approx 240$ ✓✓

Do not write outside the box

0 6 . 4 **Figure 11** shows a graph of N against Z for stable nuclides.

Figure 11



Deduce the likely initial mode of decay of $\mathbf{F_1}$ and $\mathbf{F_2}$.
Refer to **Figure 11** in your answer.

[3 marks]

F_1 and F_2 will be above/left of the line where they have a high N:Z ratio ✓ Decay is beta minus ✓, moving down and right as a neutron decays into a proton ✓ as it becomes more stable.

10

END OF SECTION A

Turn over ►

Section B

Each of Questions **07** to **31** is followed by four responses, **A**, **B**, **C** and **D**.

For each question select the best response.

Only **one** answer per question is allowed.
For each question, completely fill in the circle alongside the appropriate answer.

CORRECT METHOD   WRONG METHODS

If you want to change your answer you must cross out your original answer as shown.

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sheets for this working.

0 7 An ideal gas, initially at 300 K, is compressed to half its original volume. It is then cooled at constant volume until the pressure is restored to its initial value.

What is the final temperature of the gas?

[1 mark]

A 150 K

B 200 K

C 300 K

D 600 K

p constant

$V \propto T$

$V \rightarrow \frac{V}{2} \therefore T \rightarrow \frac{T}{2}$

0 8 A fixed volume of an ideal gas is heated.

Which row gives quantities that double when the kelvin temperature of the gas doubles?

[1 mark]

increases by $\sqrt{2}$

constant

A	rms speed of the molecules	pressure of the gas	○
B	density of the gas	rms speed of the molecules	○
C	internal energy of the gas	density of the gas	○
D	pressure of the gas	internal energy of the gas	● ✓

0 9 A planet of radius R and mass M has a gravitational field strength of g at its surface.

Which row describes a planet with a gravitational field strength of $4g$ at its surface?

[1 mark]

	Radius of planet	Mass of planet		
A	$2R$	$2M$	○	$\frac{1}{2}g$
B	$R\sqrt{2}$	$\frac{M}{2}$	○	$\frac{1}{4}g$
C	$\frac{R}{\sqrt{2}}$	$\frac{M}{2}$	○	g
D	$\frac{R}{\sqrt{2}}$	$2M$	● ✓	$4g$

$g = \frac{GM}{r^2}$ $\quad g \propto \frac{M}{R^2}$

1 0 The Moon orbits the Earth in 27 days.

What is the angular speed of the Moon's orbit?

[1 mark]

A 4.3×10^{-7} rad s^{-1} ○

B 2.7×10^{-6} rad s^{-1} ● ✓

C 3.7×10^{-2} rad s^{-1} ○

D 2.3×10^{-1} rad s^{-1} ○

$\omega = \frac{\theta}{t} = \frac{2\pi}{27 \times 24 \times 60 \times 60}$

$= 2.69 \times 10^{-6}$

1 1 The radius of the Earth is R and the acceleration due to gravity at the surface of the Earth is g.

What is the escape velocity for a mass m at the surface of the Earth?

[1 mark]

A $\sqrt{gR}$ ○

B $\sqrt{2gR}$ ● ✓

C $\sqrt{2mgR}$ ○

D $\sqrt{\frac{2gR}{m}}$ ○

$\frac{1}{2} m v^2 = \frac{GmM}{R}$

$\frac{v^2}{2} = \frac{GM}{R}$

$\frac{v^2}{2} = \frac{GM}{R^2} . R$

$g = \frac{GM}{R^2}$ $\quad \frac{v^2}{2} = gR$

$v^2 = 2gR$

$v = \sqrt{2gR}$

Do not write outside the box

1 2 A planet has a mass M and a radius R.
Loose material at the equator only just remains in contact with the surface of the planet.
This is because the speed at which the planet rotates is very large.

What is the period of rotation of the planet?

[1 mark]

A $2\pi\sqrt{\dfrac{R^2}{GM}}$ ☐

B $2\pi\sqrt{\dfrac{GM}{R^2}}$ ☐

C $2\pi\sqrt{\dfrac{R^3}{GM}}$ ■ ✓

D $2\pi\sqrt{\dfrac{GM}{R^3}}$ ☐

$F = \dfrac{GmM}{R^2} = \dfrac{mv^2}{R}$ $\quad v = \dfrac{2\pi R}{T}$ $\quad v^2 = \dfrac{4\pi^2 R^2}{T^2}$

$\dfrac{GM}{R} = \dfrac{4\pi^2 R^2}{T^2}$

$T^2 = 4\pi^2 \times \dfrac{R^3}{GM}$ $\quad T = 2\pi\sqrt{\dfrac{R^3}{GM}}$

1 3 Satellites **N** and **F** have the same mass and move in circular orbits about the same planet.
The orbital radius of **N** is less than that of **F**.

Which is smaller for **N** than for **F**?

[1 mark]

A the gravitational force on the satellite ☐

B the speed of the satellite ☐

C the kinetic energy of the satellite ☐

D the orbital period of the satellite ■ ✓

$F \propto \dfrac{1}{r^2}$ ∴ F bigger

$T \propto \sqrt{r^3}$ $\quad r\downarrow \therefore T\downarrow$

Turn over ▶

Do not write outside the box

1 4 When an electron moves at a speed v perpendicular to a uniform magnetic field of flux density B, the radius of its path is R.

A second electron moves at a speed $\frac{v}{2}$ perpendicular to a uniform magnetic field of flux density $4B$.

What is the radius of the path of the second electron?

[1 mark]

- **A** $\frac{R}{8}$ ☒ ✓
- **B** $\frac{R}{4}$ ☐
- **C** $2R$ ☐
- **D** $8R$ ☐

$r_1 = \frac{mv}{Bq}$

$r_2 = \frac{m\frac{v}{2}}{4Bq} = \frac{mv}{8Bq} = \frac{r_1}{8}$

1 5 A particle of mass m and charge Q is accelerated from rest through a potential difference V. The final velocity of the particle is u.

A second particle of mass $\frac{m}{2}$ and charge $2Q$ is accelerated from rest through a potential difference $2V$.

What is the final velocity of the second particle?

[1 mark]

- **A** $\sqrt{2}u$ ☐
- **B** $2\sqrt{2}u$ ☒ ✓
- **C** $4u$ ☐
- **D** $8u$ ☐

$E = QV \quad F = \frac{QV}{d}$

$a_1 = \frac{F}{m} = \frac{QV}{md}$

$a_2 = \frac{2Q \times 2V}{\frac{m}{2} \times d} = \frac{8QV}{md} = 8a_1$

$v^2 = u^2 + 2as$

$v = \sqrt{2as}$

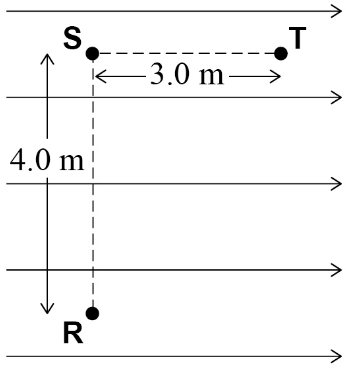
$v \propto \sqrt{a}$

$u \propto \sqrt{a_1} \quad v \propto \sqrt{a_2} \propto \sqrt{8a_1}$

$v = \sqrt{8}.u = 2\sqrt{2}.u$

Do not write outside the box

1 6 The diagram shows a uniform electric field of strength 15 V m^{-1}.
The length **RS** is perpendicular to the field and the line **ST** is parallel to the field.



What is the total change in electrical potential energy for a charge of 3.0 μC moving from **R** to **T**?

[1 mark]

A 135 μJ ☒ ✓

B 180 μJ ☐

C 225 μJ ☐

D 315 μJ ☐

R → S along an equipotential ∴ ΔEp = 0

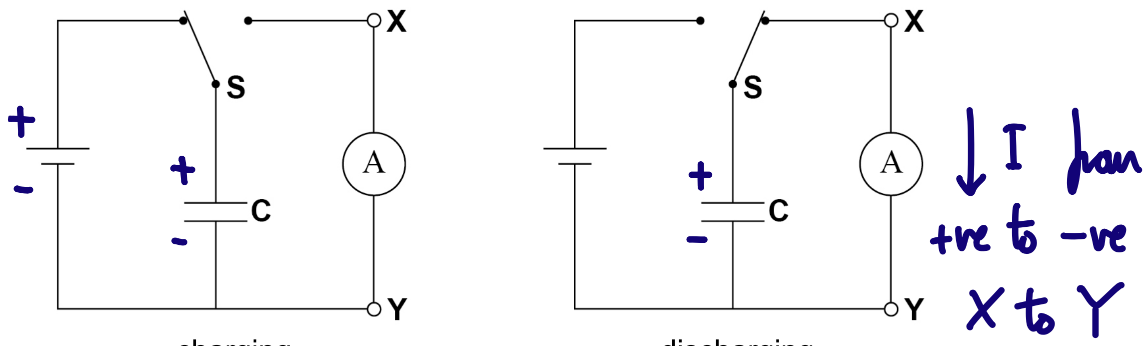
S → T

$E_p = VQ = 15 \times 3.0 \times 3.0 \times 10^{-6}$
$= 135 \times 10^{-6}$ J

Turn over for the next question

Do not write outside the box

1 7 A switch **S** allows capacitor **C** to be completely charged by a cell and then completely discharged through an ammeter.
The emf of the cell is 4.0 V and it has negligible internal resistance.
The capacitance of **C** is 0.40 μF and there are 8000 charge–discharge cycles every second.



What are the magnitude and direction of the average conventional current in the ammeter?
[1 mark]

	Magnitude of current / A	Direction of current	
A	1.3×10^{-2}	**X** to **Y**	● ✓
B	1.3×10^{-2}	**Y** to **X**	○
C	2.0×10^{-10}	**X** to **Y**	○
D	2.0×10^{-10}	**Y** to **X**	○

$C = \frac{Q}{V}$ $Q = CV = 0.40 \times 10^{-6} \times 4.0 = 1.6 \times 10^{-6}$ C

1.6×10^{-6} C per cycle × 8000 cycles s^{-1}

$= 1.28 \times 10^{-2}$ C s^{-1} (= A)

Do not write outside the box

1 8 A $30\ \mu F$ capacitor is charged by connecting it to a battery of emf $4.0\ V$.
The initial charge on the capacitor is Q_0.

The capacitor is then discharged through a $500\ k\Omega$ resistor.
The time constant for the circuit is T.

Which is correct?

[1 mark]

A T is 15 ms. ☐ $RC = 15 s$

B Q_0 is $12\ \mu C$. ☐ $Q = CV = 1.2 \times 10^{-4} = 120 \mu C$

C After a time T the pd across the capacitor is $1.5\ V$. ■ ✓

$t = T$

$V \rightarrow \frac{V_0}{e} = 1.47 V$

D After a time $2T$ the charge on the capacitor is $Q_0 e^2$. ☐

Q_0 / e^2

1 9 Capacitor **X** of capacitance C has square plates of side length l and separation d and is made with a dielectric of relative permittivity ε.

Capacitor **Y** has square plates of side length $3l$ and separation $\frac{d}{3}$ and is made with a dielectric of relative permittivity $\frac{\varepsilon}{3}$.

What is the capacitance of **Y**?

[1 mark]

A $\frac{C}{27}$ ☐

B $\frac{C}{9}$ ☐

C $9C$ ■ ✓

D $27C$ ☐

$C_X = \frac{A \varepsilon_0 \varepsilon_r}{d} = \frac{L^2 \varepsilon_0 \varepsilon_r}{d}$

$C_Y = \frac{(3L)^2 \varepsilon_0 (\varepsilon_r / 3)}{d/3}$

$C_Y = 9 \frac{L^2 \varepsilon_0 \varepsilon_r}{d} = 9 C_X$

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2 0 A parallel plate capacitor is connected across a battery and the energy stored in the capacitor is E.
Without disconnecting the battery, the separation of the plates is halved.

What is the energy now stored in the capacitor?

[1 mark]

A $0.5E$ ○

B E ○

C $2E$ ● ✓

D $4E$ ○

$C = \frac{A \varepsilon_0 \varepsilon_r}{d}$

$d \to d/2 \quad C \to 2C$

$E = \frac{1}{2} C V^2$

$\therefore E \to 2E$

2 1 A fully charged capacitor of capacitance $2.0\ \text{mF}$ discharges through a $15\ \text{k}\Omega$ resistor.

What fraction of the stored energy remains after 1.0 minute?

[1 mark]

A $\frac{1}{4}$ ○

B $\frac{1}{e^2}$ ○

C $\frac{1}{16}$ ○

D $\frac{1}{e^4}$ ● ✓

$RC = 30\text{s} \quad 60\text{s} = 2 \times RC$

$V \to \frac{V_0}{e^2} \quad E = \frac{1}{2} C V^2$

$E = \frac{1}{2} C \left(\frac{V_0}{e^2}\right)^2 = \frac{1}{2} \frac{C V_0^2}{e^4}$

2 2 A horizontal wire of length $0.25\ \text{m}$ carrying a current of $3.0\ \text{A}$ is perpendicular to a magnetic field. The mass of the wire is $3.0 \times 10^{-3}\ \text{kg}$ and the weight of the wire is supported in equilibrium by the magnetic field.

What is the flux density of the magnetic field?

[1 mark]

A $2.6\ \text{T}$ ○

B $3.9 \times 10^{-2}\ \text{T}$ ● ✓

C $2.2 \times 10^{-2}\ \text{T}$ ○

D $4.0 \times 10^{-3}\ \text{T}$ ○

$F = BIL = mg$

$B = \frac{mg}{IL} = \frac{3.0 \times 10^{-3} \times 9.81}{3.0 \times 0.25}$

$= 0.0392\ \text{T}$

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2 3 A coil is rotated at frequency f in a uniform magnetic field.

The magnetic flux linking the coil is a maximum at time t_1 and the emf induced in the coil is a maximum at time t_2.

What is the smallest value of $t_1 - t_2$?

[1 mark]

A 0

B $\frac{1}{4f}$

C $\frac{1}{2f}$

D $\frac{3}{4f}$

Phase difference between max $N\phi$ and max $\mathcal{E}$ is at 90° $\therefore \frac{1}{4}T = \frac{1}{4f}$

2 4 Power P is dissipated in a resistor of resistance R carrying a direct current I.

A second resistor of resistance $2R$ carries an alternating current with peak value I.

What is the power dissipated in the second resistor?

[1 mark]

A $\sqrt{2}P$

B P

C $2P$

D $4P$

$P_1 = I_1^2 R_1$

$I_{rms} = \frac{I_0}{\sqrt{2}} \rightarrow I_2 = \frac{I_1}{\sqrt{2}}$

$R_2 = 2R_1$

$P_2 = I_2^2 R_2 = \left(\frac{I_1}{\sqrt{2}}\right)^2 2R_1$

$P_2 = \frac{I_1^2}{2} \cdot 2R_1 = I_1^2 R_1 = P_1$

2 5 What was deduced or observed in the Rutherford scattering experiment?

[1 mark]

A All gold atoms are not alike.

B Alpha particles are helium nuclei.

C Some particles were deflected through angles greater than 90°.

D The motion of most alpha particles was reversed.

Turn over ▶

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2 6 Which row is correct for α, β and γ radiation?

[1 mark]

Charged (written over the α and β columns)

		α	β	γ	
A	Is it deflected by a magnetic field?	yes	yes	no	⬬ ✓
B	Is it deflected by an electric field?	yes	yes	yes	⬭
C	Does it have a positive charge?	yes	no	yes	⬭
D	Does it come from outside the nucleus?	no	yes	no	⬭

2 7 A sample of radioactive material consists of 200 g of nuclide **P** and 100 g of nuclide **Q**.

Nuclide **P** has a half-life of 2 days and nuclide **Q** has a half-life of 4 days.

What is the total mass of nuclides **P** and **Q** after 12 days?

[1 mark]

A 3.1 g ⬭

B 12.5 g ⬭

C 15.6 g ⬬ ✓

D 18.8 g ⬭

$m_P = \frac{200}{2^6} = 3.125$ ($12 \div 2$)

$m_Q = \frac{100}{2^3} = 12.5$ ($12 \div 4$)

$m_P + m_Q = 15.625\,g$

2 8 A nuclide has a half-life of 10 ms.

The decay constant for this nuclide lies between

[1 mark]

A $1\ s^{-1}$ and $10\ s^{-1}$. ⬭

B $10\ s^{-1}$ and $10^2\ s^{-1}$. ⬬ ✓

C $10^2\ s^{-1}$ and $10^3\ s^{-1}$. ⬭

D $10^3\ s^{-1}$ and $10^6\ s^{-1}$. ⬭

$\lambda = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{10 \times 10^{-3}}$

$\lambda = 69.3\ s^{-1}$

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2 9 Which provides evidence for the existence of energy levels in nuclei?

[1 mark]

A the Rutherford alpha particle scattering experiment

B the existence of X-ray line spectra

C the existence of gamma radiation ✓

D electron diffraction by crystals

3 0 Which is **not** true for gamma radiation?

[1 mark]

A It is more penetrating than alpha or beta radiation of the same energy through the same material.

B Its intensity is inversely proportional to the square of the distance from its source.

C It is emitted with discrete frequencies.

D When it is absorbed it makes the absorber radioactive. ✓

3 1 In a thermal reactor, induced fission occurs when a $^{235}_{92}\mathrm{U}$ nucleus captures a neutron.

Which statement is true?

[1 mark]

A The moderator absorbs excess neutrons.

B A large number of neutrons should be produced per fission to sustain the reaction.

C Slow neutrons are required for this induced fission. ✓

D The control rods slow down neutrons.

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