

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

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Forename(s)

Candidate signature

AS PHYSICS

Paper 1

Tuesday 23 May 2017

Morning

Time allowed: 1 hour 30 minutes

Materials

For this paper you must have:

- a pencil and a ruler
- a scientific calculator
- a Data and Formulae booklet.

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.
- 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 70.
- 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	
TOTAL	



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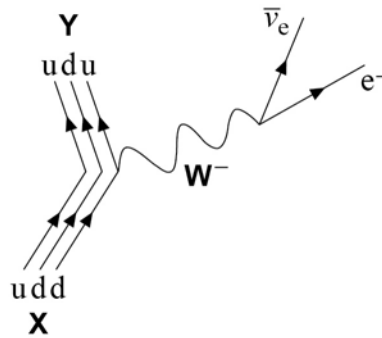
Answer **all** questions.

0 1

Figure 1 represents the decay of a particle **X** into a particle **Y** and two other particles.

The quark structure of particles **X** and **Y** are shown in the diagram.

Figure 1



0 1 . 1

Deduce the name of particle **X**.

[1 mark]

Neutron

0 1 . 2

State the type of interaction that occurs in this decay.

[1 mark]

Weak interaction

0 1 . 3

State the class of particles to which the **W⁻** belongs.

[1 mark]

Bosons (exchange particles)



0 1 . 4

Show clearly how charge and baryon number are conserved in this interaction.

You should include reference to **all** the particles, including the quarks, in your answer.

[2 marks]

Charge: $udd \rightarrow udu + e^- + \text{electron antineutrino}$

$(+2/3 - 1/3 - 1/3) \rightarrow (+2/3 - 1/3 + 2/3) + (-1) + 0$

$0 \rightarrow +1 - 1 + 0 = 0$, so charge is conserved.

Baryon number: $(1/3 + 1/3 + 1/3) \rightarrow (1/3 + 1/3 + 1/3) + 0 + 0$

$1 \rightarrow 1 + 0 + 0 = 1$, so baryon number is conserved.

0 1 . 5

Name the only stable baryon.

[1 mark]

Proton

0 1 . 6

A muon is an unstable particle.

State the names of the particles that are produced when a muon decays.

[1 mark]

An electron, an electron antineutrino and a muon neutrino

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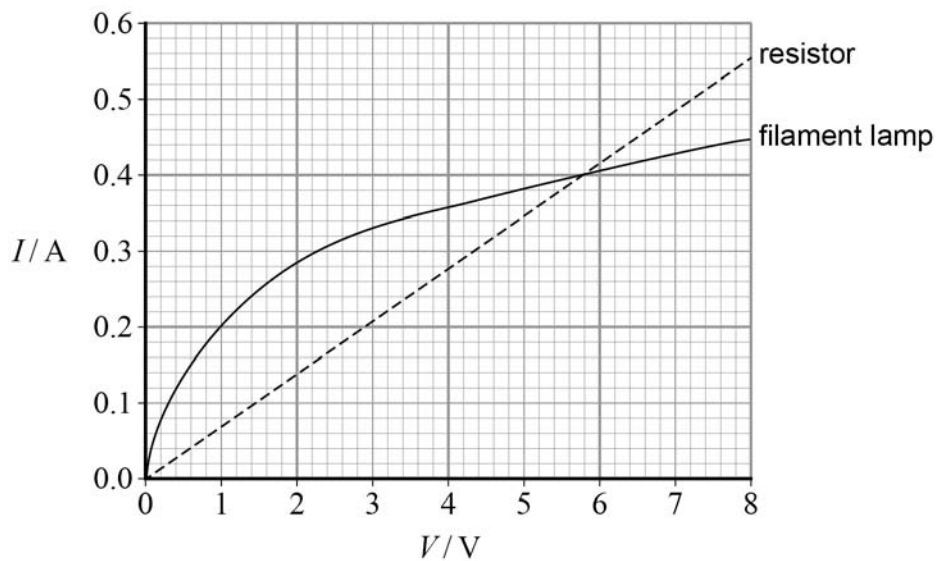
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0 2

Figure 2 shows the current–voltage (I – V) characteristics for a resistor and a filament lamp.

Figure 2



0 2 . 1

Explain, in terms of electron motion, why the I – V characteristic for the filament lamp is a curve.

[4 marks]

As the current (and pd) increases, more heat is generated in the filament, so its temperature increases.

This causes an increase in the vibration (movement) of the lattice ions/atoms of the metal.

Therefore the rate of collisions of the conduction electrons with the lattice ions increases, so the electrons are impeded more.

So the resistance increases, shown by V/I increasing: the current is not proportional to V , so the graph curves.



0 2 . 2

Determine the resistance of the resistor.

[1 mark]

$$R = V/I = 8.0 / 0.56$$

$$R = 14.3 \, \Omega$$

resistance = 14.3 Ω

0 2 . 3

The resistor and the filament lamp are connected in series with a supply of variable emf and negligible internal resistance.

Determine the emf that produces a current of 0.18 A in the circuit.

[3 marks]

$$\text{At } 0.18 \text{ A: pd across lamp (from graph)} = 0.80 \text{ V}$$

$$\text{pd across resistor: } V = IR = 0.18 \times 14.3 = 2.6 \text{ V}$$

$$\text{emf} = 0.80 + 2.6 = 3.4 \text{ V}$$

emf = 3.4 V

0 2 . 4

The resistor and filament lamp are now connected in parallel.

Determine the resistance of the parallel combination when the emf of the supply is adjusted to be 4.0 V.

[3 marks]

$$\text{At } 4.0 \text{ V: current through resistor} = 0.28 \text{ A}$$

$$\text{current through filament lamp} = 0.36 \text{ A (from graph)}$$

$$\text{total current} = 0.28 + 0.36 = 0.64 \text{ A}$$

$$R = V/I = 4.0 / 0.64 = 6.25 \, \Omega$$

resistance = 6.3 Ω

Question 2 continues on the next page

Turn over ►



0 2 . 5

The resistance of the filament lamp at its working temperature is 14Ω .
The filament has a length of 0.36 m and a diameter of $32 \mu\text{m}$.

Calculate the resistivity of the metal that is used for the filament when the lamp is at its working temperature.

Give an appropriate unit for your answer.

[3 marks]

$$A = \pi d^2 / 4 = \pi \times (32 \times 10^{-6})^2 / 4$$

$$A = 8.04 \times 10^{-10} \text{ m}^2$$

$$\rho = RA/L$$

$$\rho = (14 \times 8.04 \times 10^{-10}) / 0.36$$

$$\rho = 3.1 \times 10^{-8} \Omega \text{ m}$$

resistivity = 3.1×10^{-8} unit $\Omega \text{ m}$

14



0 3

An electric wheelchair, powered by a battery, allows the user to move around independently.

One type of electric wheelchair has a mass of 55 kg. The maximum distance it can travel on level ground is 12 km when carrying a user of mass 65 kg and travelling at its maximum speed of 1.5 m s^{-1} .

The battery used has an emf of 12 V and can deliver $7.2 \times 10^4 \text{ C}$ as it discharges fully.

0 3 . 1

Show that the average power output of the battery during the journey is about 100 W.

[3 marks]

$$\text{Energy} = QV = 7.2 \times 10^4 \times 12 = 8.64 \times 10^5 \text{ J}$$

$$\text{Time} = \text{distance} / \text{speed} = 12000 / 1.5 = 8000 \text{ s}$$

$$\text{Power} = \text{energy} / \text{time} = 8.64 \times 10^5 / 8000$$

$$\text{Power} = 108 \text{ W, which is about } 100 \text{ W}$$

0 3 . 2

During the journey, forces due to friction and air resistance act on the wheelchair and its user.

Assume that all the energy available in the battery is used to move the wheelchair and its user during the journey.

Calculate the total mean resistive force that acts on the wheelchair and its user.

[2 marks]

Work done = $F \times d$, and all the energy is used:

$$F \times 12000 = 8.64 \times 10^5$$

$$F = 8.64 \times 10^5 / 12000 = 72 \text{ N}$$

$$(\text{or } F = P/v = 108 / 1.5 = 72 \text{ N})$$

total mean resistive force = 72 N

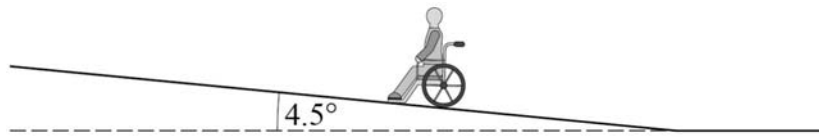
Question 3 continues on the next page

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Figure 3 shows the wheelchair and its user travelling up a hill. The hill makes an angle of 4.5° to the horizontal.

Figure 3



0 3 . 3

Calculate the force that gravity exerts on the wheelchair and its user parallel to the slope.

[1 mark]

$$\begin{aligned} \text{Force parallel to slope} &= mg \sin \theta \\ &= (55 + 65) \times 9.81 \times \sin 4.5^\circ \\ &= 120 \times 9.81 \times 0.0785 = 92 \text{ N} \end{aligned}$$

force parallel to the slope = 92 N

0 3 . 4

Calculate the maximum speed of the wheelchair and its user when travelling up this hill when the power output of the battery is 100 W.

Assume that the resistive forces due to friction and air resistance are the same as in question 03.2.

[2 marks]

$$\begin{aligned} \text{Total resistive force} &= 92 + 72 = 164 \text{ N} \\ P &= Fv \text{ so } v = P/F \\ v &= 100 / 164 \\ v &= 0.61 \text{ m s}^{-1} \end{aligned}$$

maximum speed = 0.61 m s⁻¹



0 3 . 5

Explain how and why the maximum range of the wheelchair on level ground is affected by

- the mass of the user
- the speed at which the wheelchair travels.

[4 marks]

Effect of mass *Increasing the mass of the user reduces the range.*

The normal contact force is larger, so there is more friction in the bearings and more compression of the tyres (rolling resistance), so more energy is wasted per metre. Also more energy is needed to accelerate the user and wheelchair to their final speed, as they have more kinetic energy.

Effect of speed *Increasing the speed reduces the range.*

Air resistance increases with speed, so a larger resistive force acts and more work is done against it for every metre travelled, so the battery's energy is used up over a shorter distance.

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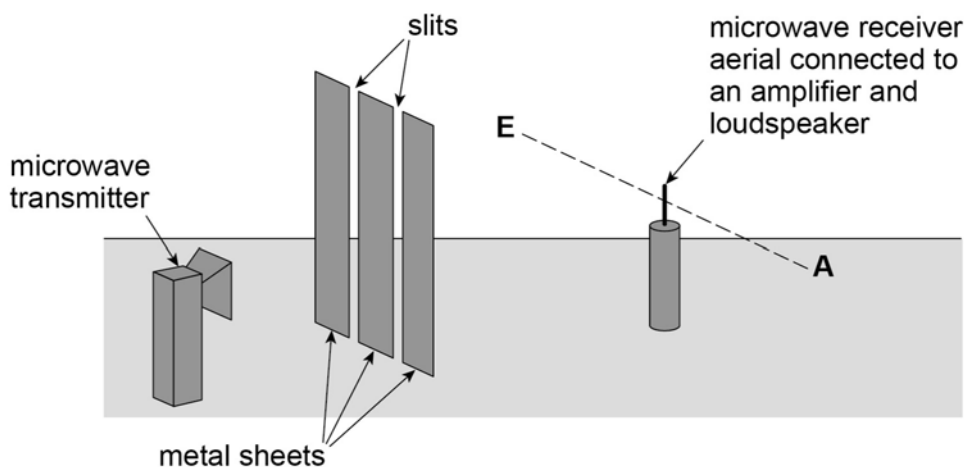
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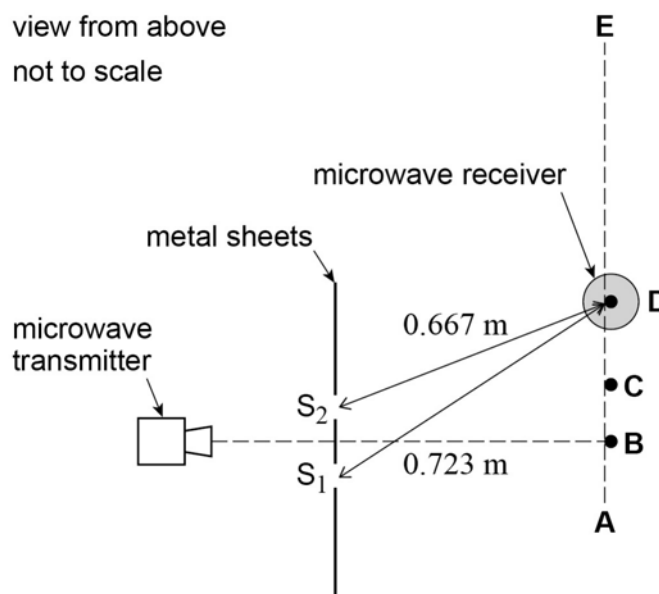


0 4

Figure 4 shows an arrangement used to investigate double slit interference using microwaves. **Figure 5** shows the view from above.

Figure 4**Figure 5**

view from above
not to scale



The microwaves from the transmitter are polarised. These waves are detected by the aerial in the microwave receiver (probe). The aerial is a vertical metal rod.

The receiver is moved along the dotted line **AE**. As it is moved, maximum and minimum signals are detected. Maximum signals are first detected at points **B** and **C**. The next maximum signal is detected at the position **D** shown in **Figure 5**.

Figure 5 shows the distances between each of the two slits, S_1 and S_2 , and the microwave receiver when the aerial is in position **D**.

S_1D is 0.723 m and S_2D is 0.667 m.



0 4 . 1

Explain why the signal strength falls to a minimum between **B** and **C**, and between **C** and **D**.

[3 marks]

The waves from S_1 and S_2 travel different distances to the receiver,
so there is a path difference between the two waves.

This path difference gives rise to a phase difference. At the
minimum points the path difference is an odd number of half
wavelengths ($\frac{1}{2}\lambda$, $1\frac{1}{2}\lambda$), so the waves arrive in antiphase (180° out
of phase).

So destructive interference occurs: the crest of one wave meets the
trough of the other and the waves cancel, giving a minimum signal.

0 4 . 2

Determine the frequency of the microwaves that are transmitted.

[3 marks]

$$\text{Path difference} = 0.723 - 0.667 = 0.056 \text{ m}$$

B is the central maximum, C the first and D the second
maximum, so path difference = 2λ

$$\lambda = 0.056 / 2 = 0.028 \text{ m}$$

$$f = c/\lambda = 3.00 \times 10^8 / 0.028$$

$$f = 1.07 \times 10^{10} \text{ Hz}$$

frequency = 1.1×10^{10} Hz

Question 4 continues on the next page

Turn over ►



0 4 . 3

The intensity of the waves passing through each slit is the same.

Explain why the minimum intensity between **C** and **D** is not zero.

[2 marks]

The intensity (amplitude) of a wave decreases with distance from its source.

Between C and D the wave from S_1 travels further than the wave from S_2 , so at the minimum point the two waves arrive with different amplitudes (intensities).

So the amplitudes are not equal and the waves do not cancel out completely, so the minimum is not zero.

0 4 . 4

The vertical aerial is placed at position **B** and is rotated slowly through 90° until it lies along the direction **AE**.

State and explain the effect on the signal strength as it is rotated.

[3 marks]

The signal strength decreases, falling to zero when the aerial lies along AE.

This is because the microwaves transmitted are (plane) polarised, with the electric field oscillating vertically.

When the aerial is at 90° to the plane (direction) of polarisation of the wave, it cannot detect the wave, so the signal is zero.

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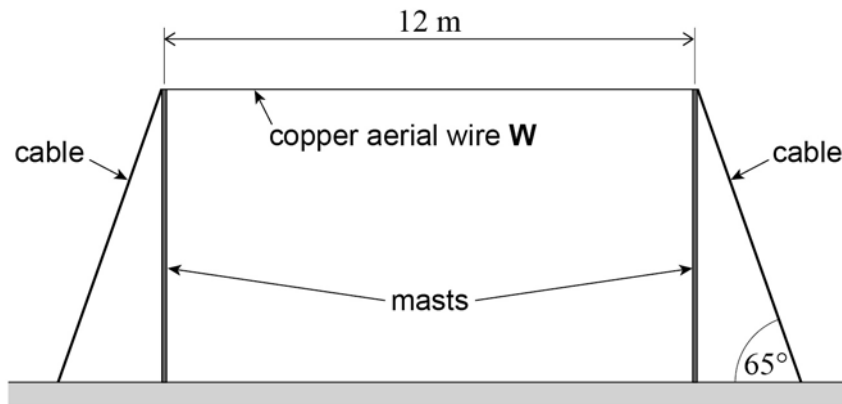
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0	5
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Figure 6 shows a structure that supports a horizontal copper aerial wire **W** used for transmitting radio signals.

Figure 6



The copper aerial wire is 12 m long and its area of cross-section is $1.6 \times 10^{-5} \text{ m}^2$.
The tension in the copper aerial wire is $5.0 \times 10^2 \text{ N}$.

Young modulus of copper = $1.2 \times 10^{11} \text{ Pa}$

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Show that the extension produced in a 12 m length of the aerial wire when the tension is $5.0 \times 10^2 \text{ N}$ is less than 4 mm.

[2 marks]

$$E = FL / (A\Delta L) \quad \text{so} \quad \Delta L = FL / (AE)$$

$$\Delta L = (5.0 \times 10^2 \times 12) / (1.6 \times 10^{-5} \times 1.2 \times 10^{11})$$

$$\Delta L = 6000 / 1.92 \times 10^6$$

$$\Delta L = 3.1 \times 10^{-3} \text{ m} = 3.1 \text{ mm}$$

3.1 mm is less than 4 mm.



0 5 . 2

The cables that support each mast are at an angle of 65° to the horizontal.

Calculate the tension in each supporting cable so that there is no resultant horizontal force on either mast.

[1 mark]

Horizontal component of cable tension = wire tension

$$T \cos 65^\circ = 500 \quad \text{so} \quad T = 500 / \cos 65^\circ = 1183 \text{ N}$$

tension = 1.2×10^3 N

0 5 . 3

When wind blows, stationary waves can be formed on the aerial wire.

Explain how stationary waves are produced and why only waves of specific frequencies can form on the aerial wire.

[4 marks]

The wind produces a wave (disturbance) that travels along the wire.

The wave is reflected at each fixed end (at the masts), so two waves of the same frequency travel along the wire in opposite directions.

The incident and reflected waves superpose (interfere) to form a stationary wave.

The fixed ends of the wire have to be nodes, so a whole number of half wavelengths must fit in the 12 m length. Only certain wavelengths, and so only certain frequencies, can form.

Question 5 continues on the next page

Turn over ►



0 5 . 4

Calculate the mass of a 1.0 m length of the aerial wire.

Density of copper = 8900 kg m^{-3}

[1 mark]

$$\text{mass} = \rho \times \text{volume} = \rho AL$$

$$= 8900 \times 1.6 \times 10^{-5} \times 1.0 = 0.142 \text{ kg}$$

mass = 0.142 kg

0 5 . 5

Calculate the frequency of the wave when the third harmonic is formed on the aerial wire.

[2 marks]

$$f_1 = (1/2L)\sqrt{T/\mu} = (1/24) \times \sqrt{(500 / 0.142)} = 2.47 \text{ Hz}$$

$$\text{Third harmonic: } f_3 = 3 \times 2.47 = 7.4 \text{ Hz}$$

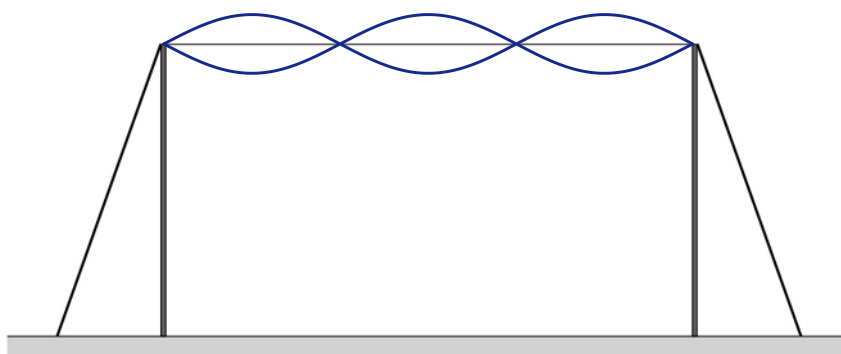
frequency = 7.4 Hz

0 5 . 6

Sketch, on **Figure 7**, the standing wave on the wire when the third harmonic is formed.

[1 mark]

Figure 7



0	5	.	7
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High winds produce large amplitudes of vibration of the aerial wire.

Explain why the wire may sag when the high wind stops.

[2 marks]

*In high winds the copper may be stretched beyond its elastic limit,
so it deforms plastically.*

*This is a permanent deformation: the wire does not return to its
original length (it stays longer), so it sags.*

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0	6
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Which statement suggests that electrons have wave properties?
Tick (✓) the correct answer.

[1 mark]

Electrons are emitted in photoelectric effect experiments.

☐

Electrons are released when atoms are ionised.

☐

Electrons produce dark rings in diffraction experiments.

☒

Electron transitions in atoms produce line spectra.

☐

1

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0 7

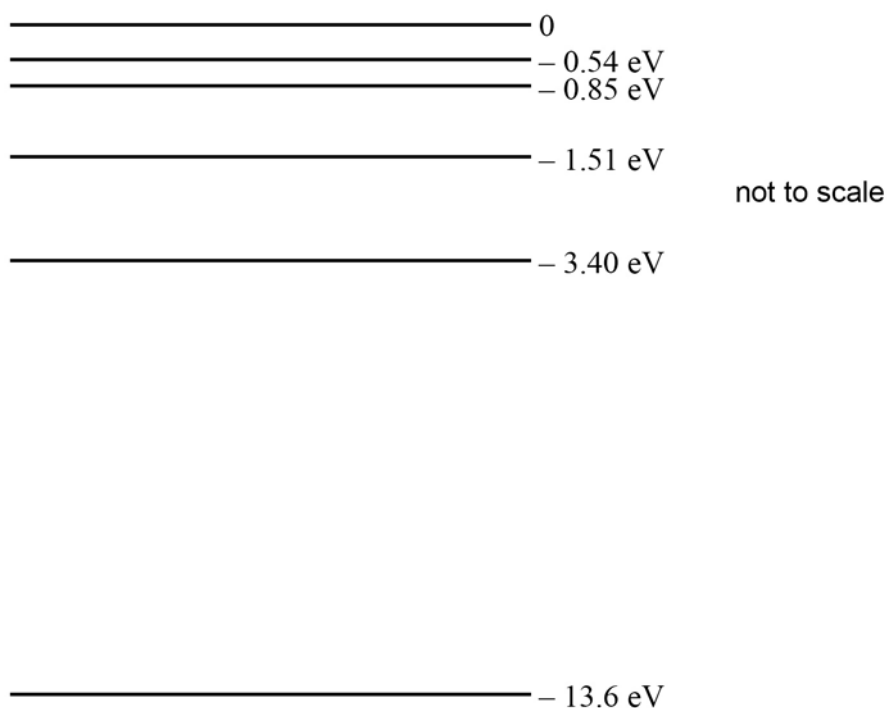
In a discharge tube a high potential difference is applied across hydrogen gas contained in the tube. This causes the hydrogen gas to emit light that can be used to produce the visible line spectrum shown in **Figure 8**.

Figure 8

The visible line spectrum in **Figure 8** has been used to predict some of the electron energy levels in a hydrogen atom.

The energy levels predicted from the visible line spectrum are those between 0 and -3.40 eV in the energy level diagram.

Some of the predicted energy levels are shown in **Figure 9**.

Figure 9

07.1

Calculate the energy, in eV, of a photon of light that has the lowest frequency in the visible hydrogen spectrum shown in **Figure 8**.

[3 marks]

Lowest frequency means longest wavelength: $\lambda = 656 \text{ nm}$

$$E = hc/\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / 656 \times 10^{-9}$$

$$E = 3.03 \times 10^{-19} \text{ J}$$

$$E \text{ in eV} = 3.03 \times 10^{-19} / 1.60 \times 10^{-19} = 1.9 \text{ eV}$$

energy of photon = 1.9 eV

07.2

Identify the state of an electron in the energy level labelled 0.

[1 mark]

The electron is (just) free: it has been released from the atom (the atom is ionised).

07.3

Identify the state of an electron that is in the energy level labelled -13.6 eV .

[1 mark]

This is the ground state: the lowest energy level that an electron can occupy.

07.4

Explain why the energy levels are negative.

[1 mark]

Energy has to be supplied to an electron to remove it from the atom (to make it free, at zero energy), so all the bound levels below zero are negative.

Question 7 continues on the next page

Turn over ►



0 7 . 5

Discuss how the discharge tube is made to emit electromagnetic radiation of specific frequencies.

In your answer you should:

- explain why there must be a high potential difference across the tube
- discuss how the energy level diagram in **Figure 9** predicts the spectrum shown in **Figure 8**
- show how one of the wavelengths of light is related to two of the energy levels in the energy level diagram.

[6 marks]

The high potential difference accelerates the free electrons in the tube to high speeds, giving them high kinetic energy.

These electrons collide with the hydrogen atoms. They have enough energy to excite the atoms, raising the atoms' electrons from the ground state into higher energy levels.

The excited electrons are unstable and move back down to lower energy levels. The visible spectrum is produced by electrons moving down into the -3.40 eV level from higher levels.

Each transition releases the energy as one photon. The energy of the photon is the difference in the energies of the two levels,

$\Delta E = E_1 - E_2 = hf$. Since the levels have fixed (discrete) energies, only certain photon energies, and so only specific frequencies, are emitted, giving lines in the spectrum.

The lowest frequency (656 nm) line is due to a transition from the -1.51 eV level to the -3.40 eV level:

$$\Delta E = 3.40 - 1.51 = 1.89 \text{ eV} = 1.89 \times 1.60 \times 10^{-19} = 3.02 \times 10^{-19} \text{ J}$$

$$\lambda = hc/\Delta E = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / 3.02 \times 10^{-19}$$

$$\lambda = 6.6 \times 10^{-7} \text{ m} = 660 \text{ nm, which matches the 656 nm line.}$$

Similarly -0.85 eV to -3.40 eV gives $\Delta E = 2.55$ eV and $\lambda = 488$ nm, the 486 nm line.



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12

END OF QUESTIONS



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