Please write clearly in block capitals.

Centre number						Candidate number					

Surname ______________________________

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	

AS Physics data and formulae

For use in exams from the June 2016 Series onwards

DATA – FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^8	$\mathrm{m\ s^{-1}}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$\mathrm{H\ m^{-1}}$
permittivity of free space	ε_0	8.85×10^{-12}	$\mathrm{F\ m^{-1}}$
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\mathrm{N\ m^2\ kg^{-2}}$
the Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\ K^{-1}\ mol^{-1}}$
the Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\ K^{-1}}$
the Stefan constant	σ	5.67×10^{-8}	$\mathrm{W\ m^{-2}\ K^{-4}}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	$\frac{e}{m_e}$	1.76×10^{11}	$\mathrm{C\ kg^{-1}}$
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	9.58×10^7	$\mathrm{C\ kg^{-1}}$
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	$\mathrm{N\ kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\ s^{-2}}$
atomic mass unit (1u is equivalent to 931.5 MeV)	u	1.661×10^{-27}	kg

ALGEBRAIC EQUATION

quadratic equation $$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

ASTRONOMICAL DATA

Body	Mass/kg	Mean radius/m
Sun	1.99×10^{30}	6.96×10^8
Earth	5.97×10^{24}	6.37×10^6

GEOMETRICAL EQUATIONS

arc length	$= r\theta$
circumference of circle	$= 2\pi r$
area of circle	$= \pi r^2$
curved surface area of cylinder	$= 2\pi rh$
area of sphere	$= 4\pi r^2$
volume of sphere	$= \frac{4}{3}\pi r^3$

Particle Physics

Class	Name	Symbol	Rest energy/MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	π meson	$\pi^\pm$	139.576
		π^0	134.972
	K meson	$K^\pm$	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

antiquarks have opposite signs

Type	Charge	Baryon number	Strangeness
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

Properties of Leptons

		Lepton number
Particles:	$e^-, \nu_e; \mu^-, \nu_\mu$	+1
Antiparticles:	$e^+, \overline{\nu_e}, \mu^+, \overline{\nu_\mu}$	−1

Photons and energy levels

photon energy $E = hf = \frac{hc}{\lambda}$

photoelectricity $hf = \phi + E_{k\,(max)}$

energy levels $hf = E_1 - E_2$

de Broglie Wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

Waves

wave speed $c = f\lambda$ *period* $f = \frac{1}{T}$

first harmonic $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

fringe spacing $w = \frac{\lambda D}{s}$ *diffraction grating* $d \sin\theta = n\lambda$

refractive index of a substance s, $n = \frac{c}{c_s}$

for two different substances of refractive indices n_1 *and* n_2,

law of refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

critical angle $\sin\theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

Mechanics

moments moment $= Fd$

velocity and acceleration $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$

equations of motion $v = u + at$ $s = \left(\frac{u+v}{2}\right)t$

$v^2 = u^2 + 2as$ $s = ut + \frac{at^2}{2}$

force $F = ma$

force $F = \frac{\Delta(mv)}{\Delta t}$

impulse $F\,\Delta t = \Delta(mv)$

work, energy and power $W = F s \cos\theta$

$E_k = \frac{1}{2} m v^2$ $\Delta E_p = mg\Delta h$

$P = \frac{\Delta W}{\Delta t}$, $P = Fv$

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

Materials

density $\rho = \frac{m}{V}$ *Hooke's law* $F = k\,\Delta L$

Young modulus $= \frac{tensile\ stress}{tensile\ strain}$ *tensile stress* $= \frac{F}{A}$

tensile strain $= \frac{\Delta L}{L}$

energy stored $E = \frac{1}{2}F\Delta L$

Electricity

current and pd	$I = \frac{\Delta Q}{\Delta t}$ $\quad V = \frac{W}{Q}$ $\quad R = \frac{V}{I}$
resistivity	$\rho = \frac{RA}{L}$
resistors in series	$R_{\mathrm{T}} = R_1 + R_2 + R_3 + \ldots$
resistors in parallel	$\frac{1}{R_{\mathrm{T}}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$
power	$P = VI = I^2R = \frac{V^2}{R}$
emf	$\varepsilon = \frac{E}{Q}$ $\quad \varepsilon = I(R + r)$

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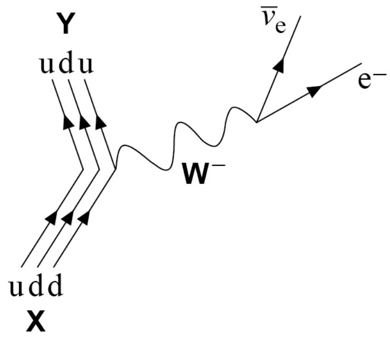
Answer **all** questions.

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]

____

0 1 . 2 State the type of interaction that occurs in this decay.

[1 mark]

____

0 1 . 3 State the class of particles to which the **W**$^-$ belongs.

[1 mark]

____

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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]

0 1 . 5 Name the only stable baryon.

[1 mark]

0 1 . 6 A muon is an unstable particle.

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

[1 mark]

7

Turn over for the next question

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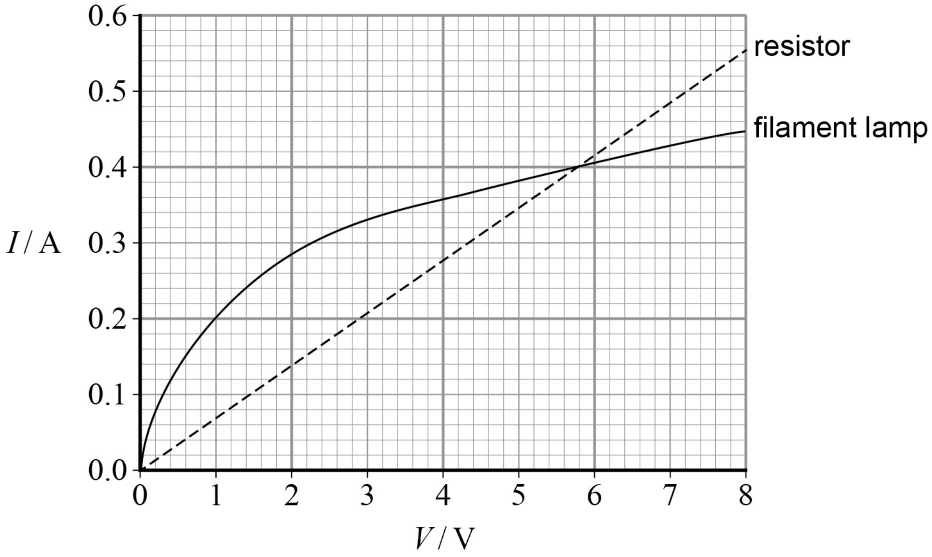
0 2 **Figure 2** shows the current–voltage (I–V) characteristics for a resistor and a filament lamp.

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]

0 2 . 2 Determine the resistance of the resistor.

[1 mark]

resistance = ________________________ 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]

emf = ________________________ 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]

resistance = ________________________ Ω

Question 2 continues on the next page

0 2 . 5 The resistance of the filament lamp at its working temperature is $14\ \Omega$.
The filament has a length of $0.36\ \mathrm{m}$ and a diameter of $32\ \mu\mathrm{m}$.

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]

resistivity = ______________________ unit __________

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

The battery used has an emf of $12\ \text{V}$ 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 $100\ \text{W}$.

[3 marks]

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]

total mean resistive force = ____________________ N

Question 3 continues on the next page

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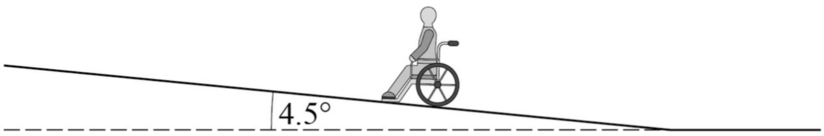
Figure 3 shows the wheelchair and its user travelling up a hill. The hill makes an angle of $4.5°$ to the horizontal.

Figure 3



0 3 . 3 Calculate the force that gravity exerts on the wheelchair and its user parallel to the slope.

[1 mark]

force parallel to the slope = ________________________ 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]

maximum speed = ________________________ $m\ s^{-1}$

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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 ____

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Effect of speed ____

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12

Turn over for the next question

0 4 **Figure 4** shows an arrangement used to investigate double slit interference using microwaves. **Figure 5** shows the view from above.

Figure 4

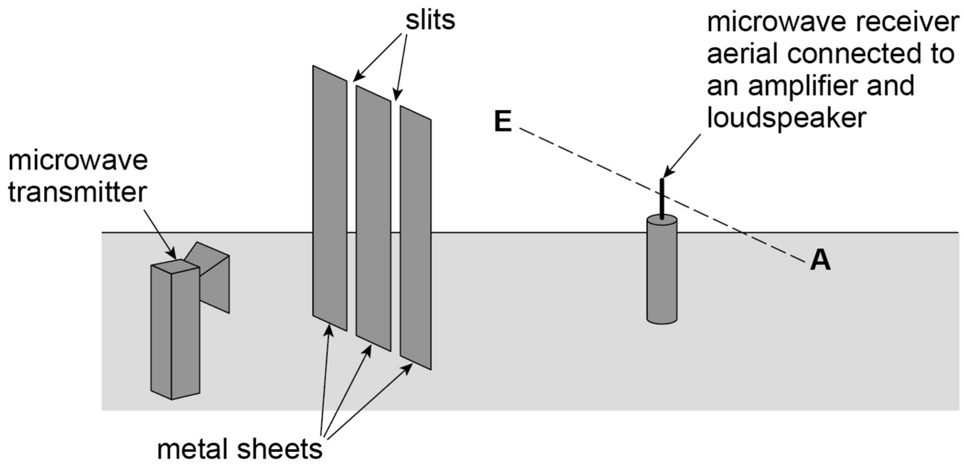
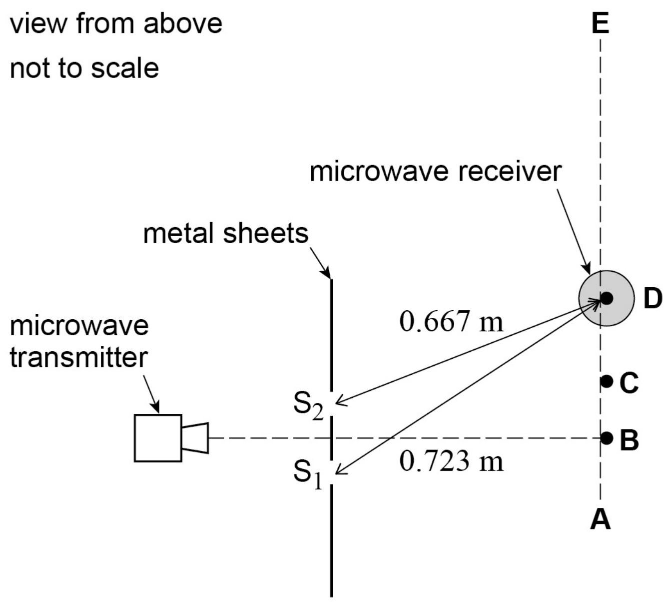


Figure 5



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.

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0 4 . 1 Explain why the signal strength falls to a minimum between **B** and **C**, and between **C** and **D**.

[3 marks]

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0 4 . 2 Determine the frequency of the microwaves that are transmitted.

[3 marks]

frequency = ______________________ Hz

Question 4 continues on the next page

Turn over ►

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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]

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]

11

Turn over for the next question

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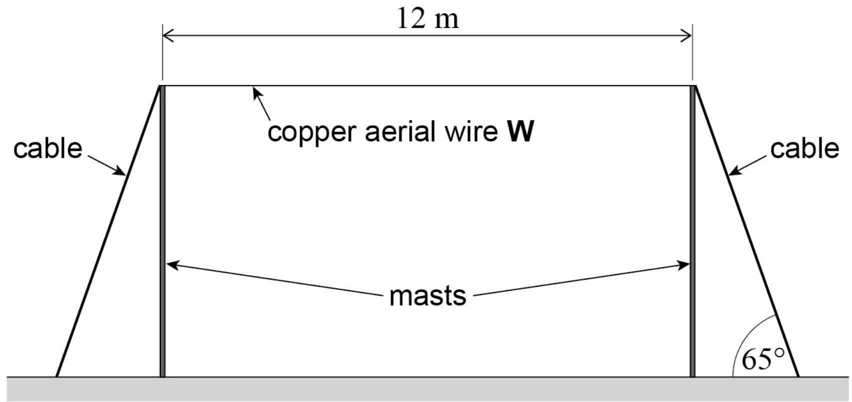
0 5 **Figure 6** shows a structure that supports a horizontal copper aerial wire **W** used for transmitting radio signals.

Figure 6



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

Young modulus of copper = 1.2×10^{11} Pa

0 5 . 1 Show that the extension produced in a 12 m length of the aerial wire when the tension is 5.0×10^2 N is less than 4 mm.

[2 marks]

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]

tension = ________________________ 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]

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Question 5 continues on the next page

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0 5 . 4 Calculate the mass of a 1.0 m length of the aerial wire.

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

[1 mark]

mass = ____________________ kg

0 5 . 5 Calculate the frequency of the wave when the third harmonic is formed on the aerial wire.

[2 marks]

frequency = ____________________ Hz

0 5 . 6 Sketch, on **Figure 7**, the standing wave on the wire when the third harmonic is formed.

[1 mark]

Figure 7

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

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

[2 marks]

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13

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0 6 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. ☐

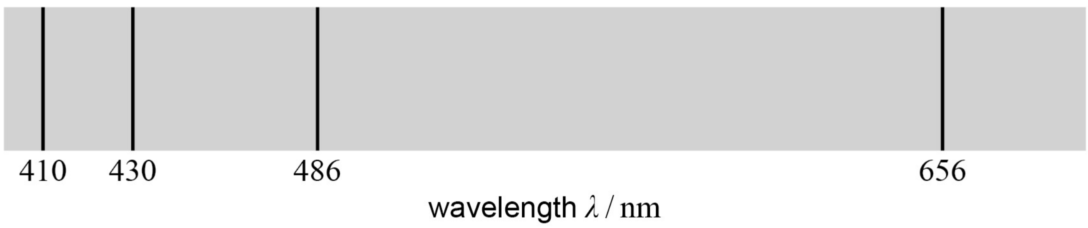
Electron transitions in atoms produce line spectra. ☐

1

Turn over for the next question

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

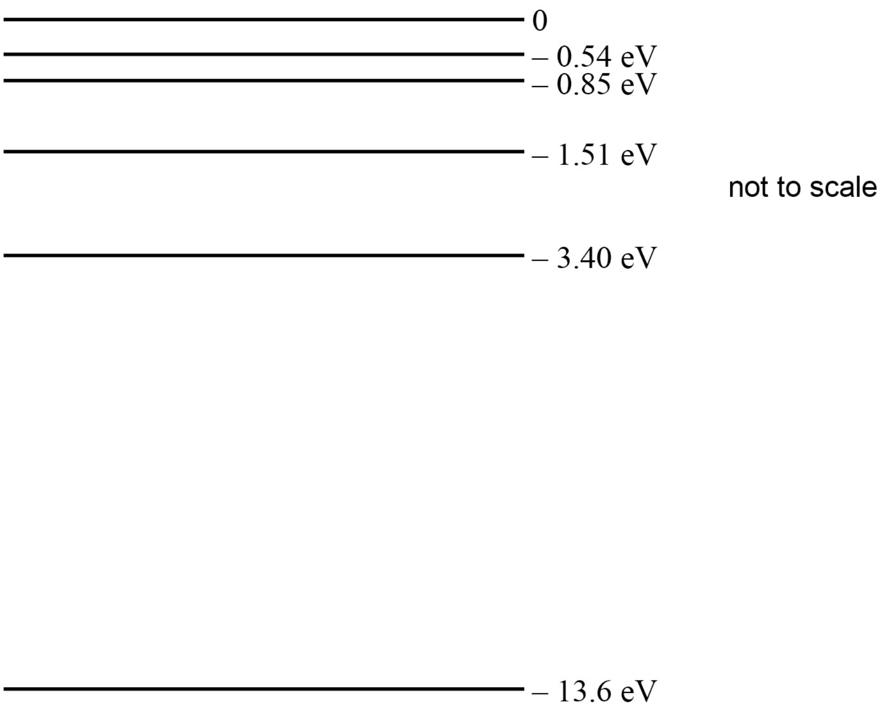


The visible line spectrum in **Figure 8** has been used to predict some of the electron energy levels in a hydrogen atom.

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



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0 7 . 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]

energy of photon = ______________________ eV

0 7 . 2 Identify the state of an electron in the energy level labelled 0.

[1 mark]

____

____

0 7 . 3 Identify the state of an electron that is in the energy level labelled –13.6 eV.

[1 mark]

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0 7 . 4 Explain why the energy levels are negative.

[1 mark]

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Question 7 continues on the next page

Turn over ►

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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]

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END OF QUESTIONS

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