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Centre number

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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

AS PHYSICS

Paper 1

Tuesday 15 May 2018

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	



J U N 1 8 7 4 0 7 1 0 1

Answer **all** questions.

0 1 . 1

Describe the interaction that is responsible for keeping protons and neutrons together in a stable nucleus.

You should include details of the properties of the interaction in your answer.

[3 marks]

The strong nuclear force (strong interaction) holds the nucleons together.

It is attractive at separations up to about 3 fm, so it overcomes the electrostatic repulsion between protons.

It is repulsive at very short separations (below about 0.5 fm), which stops the nucleus collapsing.

It has a very short range: it is negligible beyond about 5 fm. It only acts on hadrons (baryons and mesons) and is mediated by gluons / pions.

0 1 . 2

Nuclei can decay by alpha decay and by beta decay.

In alpha decay only one particle is emitted but in beta decay there are two emitted particles.

Explain how baryon number is conserved in alpha and beta decay.

[3 marks]

In alpha decay the total number of nucleons (baryons) is unchanged: the baryon number of the parent nucleus equals the baryon number of the daughter nucleus plus that of the alpha particle (4).

In β^- decay a neutron changes into a proton, and both have baryon number +1.

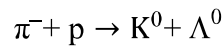
The beta particle (electron) and the antineutrino are leptons, so they both have baryon number 0, so baryon number is conserved.



0 1 . 3

Kaons are mesons that can be produced by the strong interaction between pions and protons.

The equation shows a reaction in which a kaon and a lambda particle are produced.



Deduce the quark structure of the Λ^0

[2 marks]

$$\pi^- = \bar{u}d \quad \text{and} \quad p = uud$$

$$K^0 = d\bar{s}$$

Strangeness is conserved in the strong interaction, so the

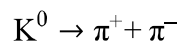
Λ^0 must contain an s quark: $\bar{u}d + uud - d\bar{s}$

quark structure = uds

0 1 . 4

The kaon decays by the weak interaction.

The equation shows an example of kaon decay.



State **one** feature of this decay that shows it is an example of the weak interaction.

[1 mark]

Strangeness is not conserved: it changes by 1 (from +1 to 0).

0 1 . 5

There have been considerable advances in our understanding of particle physics over the past 100 years.

Explain why it is necessary for many teams of scientists and engineers to collaborate in order for these advances to be made.

[2 marks]

Particle accelerators and detectors are very expensive, so collaboration

spreads the cost of building them, and many different skills / disciplines

are needed which one team is unlikely to have.

Results must be independently checked and peer reviewed (validated) by

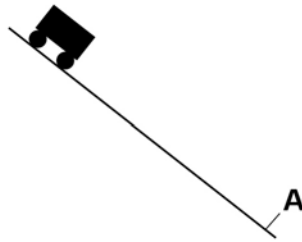
other teams before they are accepted.



0 2 . 1

Figure 1 shows a truck moving freely down a ramp inclined at an angle to the horizontal.

Figure 1



The truck starts from rest at the top of the ramp and reaches point **A**. Friction and air resistance are negligible.

As the truck moves down the ramp to point **A**, its centre of mass has a total vertical displacement of 8.0 m

Calculate the speed of the truck at point **A**.

[2 marks]

$$\text{Gain in } E_k = \text{loss in } E_p$$

$$\frac{1}{2}mv^2 = mgh$$

$$\frac{1}{2}v^2 = 9.81 \times 8.0$$

$$v = \sqrt{(2 \times 9.81 \times 8.0)} = 12.5 \text{ m s}^{-1}$$

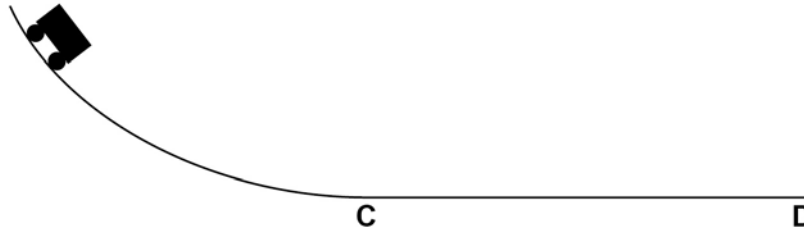
speed = 12.5 m s⁻¹



0 2 . 2

Figure 2 shows the truck moving down a ramp with a varying slope.

Figure 2



The truck starts from rest and moves freely down the ramp. It reaches point **C** and then moves along the horizontal runway to **D**. Friction and air resistance are negligible.

Discuss how the acceleration of the truck in **Figure 2** differs from the acceleration of the truck in **Figure 1**.

[3 marks]

In Figure 1 the slope is constant, so the acceleration of the truck is constant (uniform) all the way down the ramp.

In Figure 2 the acceleration is greatest at the start / top where the slope is steepest, and then the acceleration decreases as the slope becomes less steep.

This is because the component of the weight parallel to the slope ($mg \sin \theta$) decreases as the angle of the slope decreases.

Between C and D the runway is horizontal, so there is zero acceleration and the truck moves at a uniform (constant) velocity.

Question 2 continues on the next page

Turn over ►



0 2 . 3

The total vertical displacement of the centre of mass of the truck in **Figure 2** is also 8.0 m

The speed of the truck when it reaches the horizontal runway is the same as the speed of the truck in **Figure 1** when it reaches point **A**.

Explain why.

[1 mark]

The loss of gravitational potential energy (mgh) is the same in both cases because the vertical drop is 8.0 m, so the gain in kinetic energy is the same and the speed is the same.

0 2 . 4

The horizontal runway in **Figure 2** has negligible friction and air resistance. As the truck moves along the runway, it starts to rain. The rain falls vertically and water collects in the truck.

Discuss whether there are any changes in the momentum of the truck and collected water.

[3 marks]

There is no external horizontal force (impulse) on the system of the truck and water, so the total horizontal momentum of the truck and collected water is conserved: it does not change.

The rain falls vertically, so it has no initial horizontal momentum. The vertical momentum of the rainwater decreases to zero when it lands in the truck (the truck exerts an upward force on it).

As water collects, the mass of the truck and water increases, so the speed / velocity of the truck decreases.

The horizontal momentum of the water increases and the horizontal momentum of the truck decreases by the same amount.



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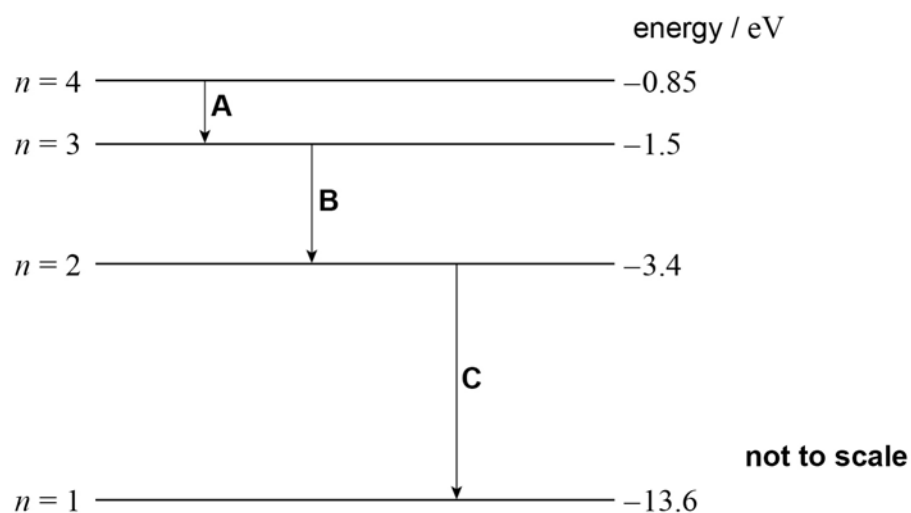
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0 3

Figure 3 shows some of the energy levels for a hydrogen atom.

Figure 3



An excited hydrogen atom can emit photons of certain discrete frequencies. Three possible transitions are shown in **Figure 3**.

0 3 . 1

The transitions shown in **Figure 3** result in photons being emitted in the ultraviolet, visible and infrared regions of the electromagnetic spectrum.

To which region of the spectrum do the emitted photons belong?

Tick (✓) the correct box for each transition, **A**, **B** and **C**.

[1 mark]

Transition	Ultraviolet	Visible	Infrared
A	☐	☐	☒
B	☐	☒	☐
C	☒	☐	☐



0 3 . 2

Two ways to excite a hydrogen atom are by collision with a free electron or by the absorption of a photon.

Explain why, for a particular transition, the photon must have an exact amount of energy whereas the free electron only needs a minimum amount of kinetic energy.

[3 marks]

A transition needs an exact amount of energy: the energy difference between the two levels, to move the electron to a higher level.

In a one to one interaction all of the photon's energy is absorbed, so its energy hf must exactly equal this difference.

A free electron can transfer just part of its kinetic energy to cause the transition and keeps moving with lower kinetic energy (lower speed), so it only needs a minimum energy.

0 3 . 3

The surface of a sample of caesium is exposed to photons emitted in each of the three transitions shown in **Figure 3**.

The threshold frequency of caesium is 5.1×10^{14} Hz

Determine whether any of these transitions would produce photons that would cause electrons to be emitted from the surface of caesium.

[3 marks]

$$\phi = hf_0 = 6.63 \times 10^{-34} \times 5.1 \times 10^{14} = 3.38 \times 10^{-19} \text{ J}$$

$$\phi = 3.38 \times 10^{-19} \div 1.6 \times 10^{-19} = 2.1 \text{ eV}$$

$$\text{Photon energies: } A = 1.5 - 0.85 = 0.65 \text{ eV}$$

$$B = 3.4 - 1.5 = 1.9 \text{ eV}$$

$$C = 13.6 - 3.4 = 10.2 \text{ eV}$$

Only transition C ($n = 2$ to $n = 1$) gives photons with energy greater than the work function of 2.1 eV, so only C causes electrons to be emitted. A and B have too little energy.

Question 3 continues on the next page

Turn over ►



0 3 . 4

Photons each with energy 12.1 eV are incident on the surface of the caesium sample.

Calculate the maximum speed of electrons emitted from the caesium.

[3 marks]

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

$$12.1 \times 1.6 \times 10^{-19} = 2.1 \times 1.6 \times 10^{-19} + E_k$$

$$E_k = 10.0 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-18} \text{ J}$$

$$\frac{1}{2}mv^2 = E_k \text{ so } v = \sqrt{2E_k / m}$$

$$v = \sqrt{2 \times 1.6 \times 10^{-18} \div 9.11 \times 10^{-31}} = 1.87 \times 10^6 \text{ m s}^{-1}$$

maximum speed = 1.9 × 10⁶ m s⁻¹

10



Turn over for the next question

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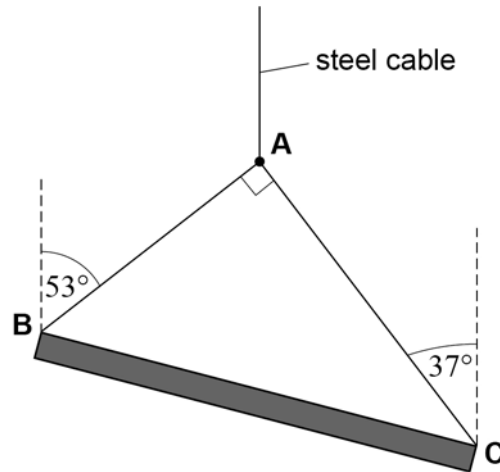
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0 4

Figure 4 shows a uniform beam supported by two light cables, **AB** and **AC**, which are attached to a single steel cable from a crane. The beam is stationary and in equilibrium.

Figure 4



0 4 . 1

State **two** necessary conditions for the beam to be in equilibrium.

[2 marks]

Condition 1 *The resultant force is zero: forces up equal forces down AND forces left equal forces right.*

Condition 2 *The resultant moment is zero: sum of clockwise moments about any point equals sum of anticlockwise moments.*

0 4 . 2

State what is meant by the centre of mass.

[1 mark]

The point where all the mass (weight) of the body can be considered to act / be concentrated.



0 4 . 3

Explain why the centre of mass of the beam in **Figure 4** must be vertically below **A**.

[2 marks]

A acts as the pivot. If the centre of mass were not vertically below A, the weight would have a moment about A.

So there would be a resultant moment (turning effect) and the beam would rotate / swing, so it would not be in equilibrium.

0 4 . 4

The weight of the beam is 12 000 N

Calculate the tension T_1 in cable **AB** and the tension T_2 in cable **AC**.

[4 marks]

Angle at A is 90° , so resolving along the cables:

$$T_1 = 12\,000 \cos 53^\circ = 7222 \text{ N}$$

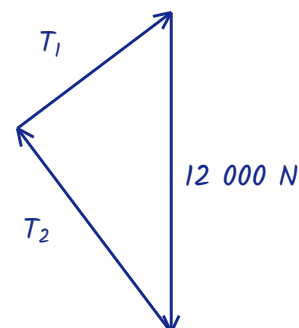
$$T_2 = 12\,000 \sin 53^\circ = 9584 \text{ N}$$

Check: horizontal $T_1 \sin 53^\circ = 5768 \text{ N}$

$$T_2 \sin 37^\circ = 5768 \text{ N}$$

vertical: $7222 \cos 53^\circ + 9584 \cos 37^\circ$

$$= 4346 + 7654 = 12\,000 \text{ N}$$



$$T_1 = \underline{7200} \text{ N}$$

$$T_2 = \underline{9600} \text{ N}$$

Question 4 continues on the next page

Turn over ►



0 4 . 5

The steel cable from the crane has a circular cross-section of diameter 1.5×10^{-2} m
The cable is 12 m long.

Calculate the extension of the cable caused by the weight of the beam. You can assume that the weights of **all cables** are negligible.

Young modulus of steel = 2.0×10^{11} Pa

[3 marks]

$$A = \pi r^2 = \pi \times (0.75 \times 10^{-2})^2 = 1.767 \times 10^{-4} \text{ m}^2$$

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

$$\Delta L = (12\,000 \times 12) \div (1.767 \times 10^{-4} \times 2.0 \times 10^{11})$$

$$\Delta L = 4.07 \times 10^{-3} \text{ m}$$

extension = 4.1×10^{-3} m

12



0 5 . 1 Calculate the weight of an ice cube that has volume $4.0 \times 10^{-6} \text{ m}^3$

density of ice = 920 kg m^{-3}

[2 marks]

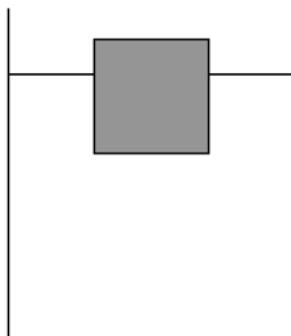
$$m = \rho V = 920 \times 4.0 \times 10^{-6} = 3.68 \times 10^{-3} \text{ kg}$$

$$W = mg = 3.68 \times 10^{-3} \times 9.81 = 3.61 \times 10^{-2} \text{ N}$$

weight = 3.6×10^{-2} N

0 5 . 2 Figure 5 shows the ice cube floating in a beaker of water.

Figure 5



When the ice cube is placed in the beaker, it displaces a volume of water causing the water level to rise.

The weight of water displaced is equal to the weight of the ice cube.

Calculate the volume of water displaced by the ice cube.

density of water = 1000 kg m^{-3}

[1 mark]

$$\text{Mass of water displaced} = 3.68 \times 10^{-3} \text{ kg}$$

$$V = m / \rho = 3.68 \times 10^{-3} \div 1000 = 3.68 \times 10^{-6} \text{ m}^3$$

volume = 3.7×10^{-6} m^3

Question 5 continues on the next page

Turn over ►



0 5 . 3

The ice cube in **Figure 5** is replaced by another cube also with volume $4.0 \times 10^{-6} \text{ m}^3$. This cube is made of ice containing a small piece of iron. The mass of water now displaced is $3.9 \times 10^{-3} \text{ kg}$.

Calculate the volume of the piece of iron.

$$\text{density of iron} = 7800 \text{ kg m}^{-3}$$

[3 marks]

$$\text{Let } V = \text{volume of iron. Mass of iron} = 7800V$$

$$7800V + 920(4.0 \times 10^{-6} - V) = 3.9 \times 10^{-3}$$

$$7800V - 920V = 3.9 \times 10^{-3} - 3.68 \times 10^{-3}$$

$$6880V = 2.2 \times 10^{-4}$$

$$V = 3.2 \times 10^{-8} \text{ m}^3$$

$$\text{volume} = \underline{3.2 \times 10^{-8}} \text{ m}^3$$

6



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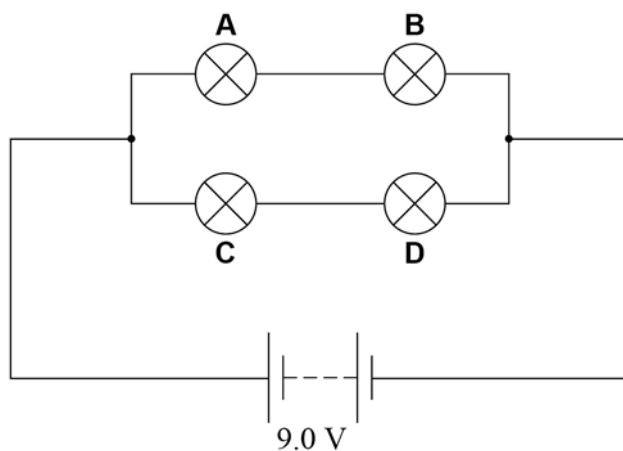
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0	6
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A student connects four lamps **A**, **B**, **C** and **D** in the circuit shown in **Figure 6**. The battery has an emf of 9.0 V and negligible internal resistance.

Figure 6



0 6 . 1

Table 1 shows the operating conditions for the lamps when they are at normal brightness.

Table 1

Lamps	Operating voltage / V	Power / W
A and C	6.0	6.0
B and D	3.5	4.1

The student observes that **two** of the lamps are at their normal brightness. Assume that any changes in resistance of the lamps are negligible.

Determine which **two** lamps are at their normal brightness.

Use calculations to support your answer.

[4 marks]

$$R = V^2 / P$$

$$R_A = R_C = 6.0^2 \div 6.0 = 6.0 \, \Omega$$

$$R_B = R_D = 3.5^2 \div 4.1 = 3.0 \, \Omega \, (2.98 \, \Omega)$$

$$\text{Each branch (A + B or C + D): } R = 6.0 + 3.0 = 9.0 \, \Omega, \, \text{pd} = 9.0 \, \text{V}$$

$$\text{pd across A (and C)} = 6.0/9.0 \times 9.0 = 6.0 \, \text{V}$$

$$\text{pd across B (and D)} = 3.0/9.0 \times 9.0 = 3.0 \, \text{V}$$

$$\text{Current in each branch} = 9.0 \div 9.0 = 1.0 \, \text{A}$$

$$\text{A and C need } 6.0 \, \text{V} \, (I = P/V = 1.0 \, \text{A}): \text{ normal brightness}$$

$$\text{B and D get } 3.0 \, \text{V, less than } 3.5 \, \text{V: dimmer than normal}$$

Lamps A and C are at their normal brightness (6.0 V across each, the operating voltage).

Question 6 continues on the next page

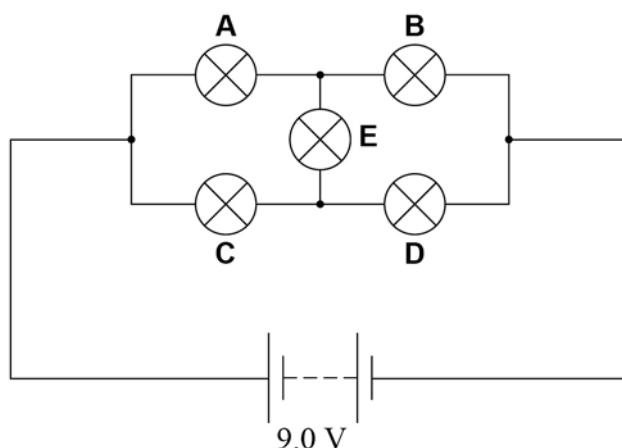
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0 6 . 2

The student connects another lamp **E** in the circuit as shown in **Figure 7**. Lamp **E** is identical to lamps **A** and **C**.

Figure 7



Explain what the student would observe regarding the brightness of the lamps.

Refer to potential differences across lamp **E** in your answer.

[3 marks]

The pd across A equals the pd across C (both 6.0 V), so the two ends of lamp E are at the same potential.

So the pd across the new lamp E is 0 V, so there is no current in E and E does not light.

The current in the other lamps and the pd across them do not change, so lamps A, B, C and D are not affected: A and C stay at normal brightness and B and D stay the same (dim).



0 6 . 3

Lamp **B** in **Figure 7** fails so that it no longer conducts. This change does not affect the resistance of the other lamps.

Deduce the effect on the current in the battery.

Use calculations to support your answer.

[3 marks]

$$\text{Before: total } R = 9.0 \, \Omega \parallel 9.0 \, \Omega = 4.5 \, \Omega$$

$$I = V/R = 9.0 \div 4.5 = 2.0 \, A$$

$$\text{After B fails: A and E in series} = 6.0 + 6.0 = 12 \, \Omega$$

$$\text{in parallel with C: } (1/12 + 1/6)^{-1} = 4.0 \, \Omega$$

$$\text{in series with D: } R = 4.0 + 3.0 = 7.0 \, \Omega$$

$$I = 9.0 \div 7.0 = 1.29 \, A$$

The total resistance increases from $4.5 \, \Omega$ to $7.0 \, \Omega$, so the current in the battery decreases from $2.0 \, A$ to $1.29 \, A$.

10

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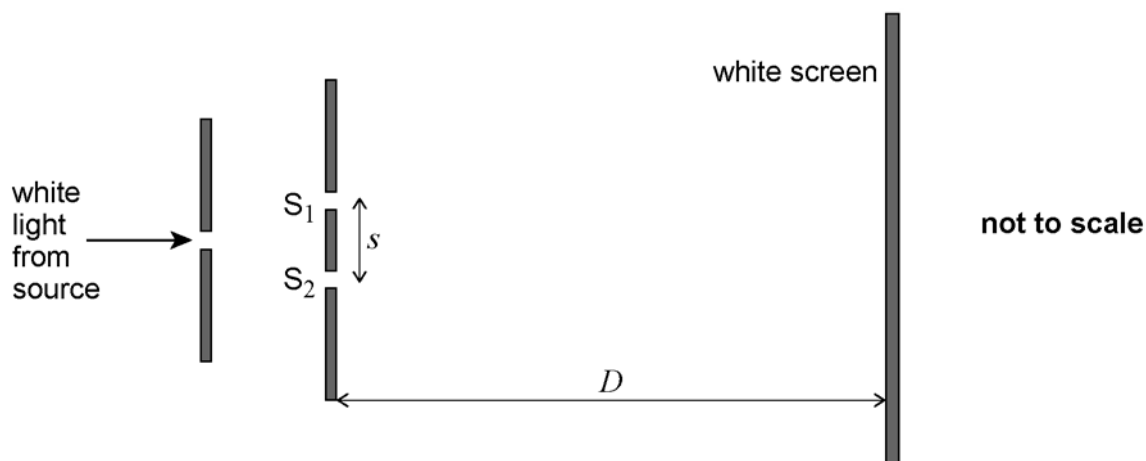
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07

Figure 8 shows a diagram of apparatus used to demonstrate the formation of interference fringes using a white light source in a darkened room. Light from the source passes through a single slit and then through two narrow slits S_1 and S_2 .

Figure 8



07.1

Describe the interference pattern that is seen on the white screen.

[2 marks]

There is a central white fringe (maximum), with dark fringes between bright fringes.

The fringes on either side are spectra (a range of colours), with blue / violet closest to the centre and red furthest from the centre.



0 7 . 2

A filter transmits only green light of wavelength λ and red light of wavelength 1.2λ . This filter is placed between the light source and the single slit.

Describe the interference pattern now seen on the white screen.

Use a calculation to support your answer.

[4 marks]

Fringe spacing $w = \lambda D / s$, so $w \propto \lambda$

$$w_{\text{red}} = 1.2\lambda D / s = 1.2 w_{\text{green}}$$

Red fringe spacing is 20% greater than green fringe spacing.

$$6 \times w_{\text{green}} = 6\lambda D / s \quad \text{and} \quad 5 \times w_{\text{red}} = 5 \times 1.2\lambda D / s = 6\lambda D / s$$

so the 6th green fringe overlaps the 5th red fringe.

The central fringe is a mixture of red and green light (it looks yellow / orange).

On either side separate red and green fringes are seen, with dark gaps between them.

The green fringes are closer together than the red fringes: the spacing of the red fringes is 1.2 times (20% greater than) the spacing of the green fringes, so the green fringes are closer to the middle.

The 6th green bright fringe overlaps (coincides) with the 5th red bright fringe, so a mixed fringe is seen there.

Question 7 continues on the next page

Turn over ►



0 7 3

A student decides to use the apparatus shown in **Figure 8** to determine the wavelength of red light using a filter that transmits only red light.

The student suggests the following changes:

- decrease slit separation s
- decrease D , the distance between the slits and the screen.

The student decides to make each change independently.

Discuss the effects each independent change has on the interference pattern, and whether this change is likely to reduce uncertainty in the determination of the wavelength.

[6 marks]

The wavelength is found using $\lambda = ws / D$, where w is the fringe spacing, s is the slit separation and D is the slit to screen distance. So the uncertainty in λ depends on the uncertainties in w , s and D .

Decreasing s : the fringe spacing $w = \lambda D / s$ increases, so the fringes are further apart. The absolute uncertainty in measuring w (e.g. with a metre rule across several fringes) stays about the same, so the percentage uncertainty in w decreases.

However, s is already very small (less than 1 mm) and is measured with a travelling microscope or vernier calipers, so making s smaller increases the percentage uncertainty in s . The percentage uncertainty in s is probably already the largest of the three.

Decreasing D : the fringe spacing w decreases, so the fringes are closer together and harder to measure, so the percentage uncertainty in w increases. D is also smaller, so the percentage uncertainty in measuring D (with a metre rule or tape measure) increases.

The percentage uncertainties combine: % uncertainty in λ = % uncertainty in w + % uncertainty in s + % uncertainty in D .

So decreasing D is not likely to reduce the uncertainty in the wavelength, because both the % uncertainty in w and in D increase.



Decreasing s reduces the % uncertainty in w but increases the % uncertainty in s , which is likely to be the largest, so overall it is unlikely to reduce the uncertainty in λ . Neither change is likely to give a more accurate value; increasing D (and measuring across many fringes) would be better.

END OF QUESTIONS



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