

Please write clearly in block capitals.

Centre number

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Candidate number

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AS PHYSICS

Paper 1

Tuesday 14 May 2019

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	
TOTAL	



Answer **all** questions in the spaces provided.

Do not write
outside the
box

0 1 . 1

Deuterium is an isotope of hydrogen. Its nucleus contains one proton and one neutron.

Calculate the specific charge of the deuterium nucleus.

[2 marks]

$$\text{specific charge} = \text{charge} \div \text{mass}$$

$$\text{mass of deuterium nucleus} = m_p + m_n$$

$$= 1.673 \times 10^{-27} + 1.675 \times 10^{-27} = 3.348 \times 10^{-27} \text{ kg}$$

$$\text{specific charge} = 1.60 \times 10^{-19} \div 3.348 \times 10^{-27}$$

$$= 4.78 \times 10^7 \text{ C kg}^{-1}$$

$$\text{specific charge} = \underline{4.8 \times 10^7} \text{ C kg}^{-1}$$



0 1 . 2

The proton and neutron in the deuterium nucleus are held together by the strong nuclear force.

Which is an exchange particle of the strong nuclear force?

Tick (✓) **one** box.

[1 mark]

muon

☐

photon

☐

pion

☒ W^+ boson☐

0 1 . 3

The deuterium nucleus is stable.

Describe how the variation of the strong nuclear force with distance contributes to the stability of the deuterium nucleus.

[3 marks]

The strong nuclear force is attractive between the proton and neutron for separations from about 0.5 fm up to about 3 fm, so it holds them together.

At separations less than about 0.5 fm it becomes repulsive.

So there is an equilibrium separation where the force is zero, which prevents the proton and neutron moving closer together or further apart, so the nucleus does not collapse or fly apart.

Question 1 continues on the next page

Turn over ►



0 1 . 4

Tritium is an isotope of hydrogen. Its nucleus contains one proton and two neutrons. Tritium undergoes radioactive decay.

Three modes of radioactive decay are

- alpha decay
- beta minus (β^-) decay
- electron capture.

Deduce which of these modes could produce the nucleus of another element when the tritium nucleus decays.

[3 marks]

Alpha decay is not possible: an alpha particle is a helium-4 nucleus (2 protons and 2 neutrons), but tritium only has 1 proton and 3 nucleons in total.

Electron capture is not possible: a proton would capture an electron and become a neutron, leaving a nucleus with 0 protons and 3 neutrons, which is not the nucleus of any element.

Beta minus decay is valid: a neutron changes into a proton, emitting an electron and an antineutrino, so the nucleus becomes helium-3 (2 protons, 1 neutron), the nucleus of another element.

9



0 2

A battery of emf 7.4 V and negligible internal resistance is used to power a heating element inside a glove. The heating element has a resistance of 3.7 Ω .

0 2 . 1

The designers state that the battery can produce a current of 2.0 A in the heating element for 240 minutes.

Calculate the energy dissipated in the heating element in this time.

[3 marks]

$$P = VI = 7.4 \times 2.0 = 14.8 \text{ W}$$

$$t = 240 \times 60 = 14\,400 \text{ s}$$

$$W = P\Delta t = 14.8 \times 14\,400$$

$$= 2.13 \times 10^5 \text{ J}$$

energy dissipated = 2.1×10^5 J

0 2 . 2

The length of the heating element needed is about 0.85 m.
The designer considers using a carbon fibre tape for the heating element.
Table 1 gives information for the carbon fibre tape.

Table 1

Cross-sectional area / m^2	Resistivity / $\Omega \text{ m}$
4.9×10^{-6}	2.0×10^{-5}

Deduce whether the carbon fibre tape is suitable for making the heating element for the glove.

[2 marks]

$$\rho = RA \div L, \text{ so } L = RA \div \rho = (3.7 \times 4.9 \times 10^{-6}) \div 2.0 \times 10^{-5}$$

$$L = 0.91 \text{ m}$$

This is close to (slightly more than) the 0.85 m needed, so the carbon fibre tape is suitable for the heating element.

Question 2 continues on the next page

Turn over ►



0 2 . 3

A light emitting diode (LED) is used to indicate that the switch in the glove is closed, as shown in **Figure 1**. Resistor R limits the current in the LED.

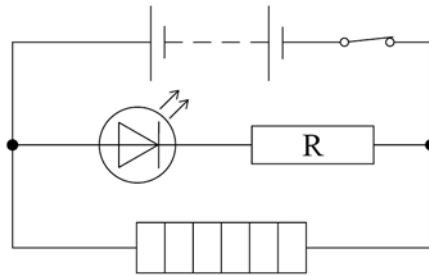
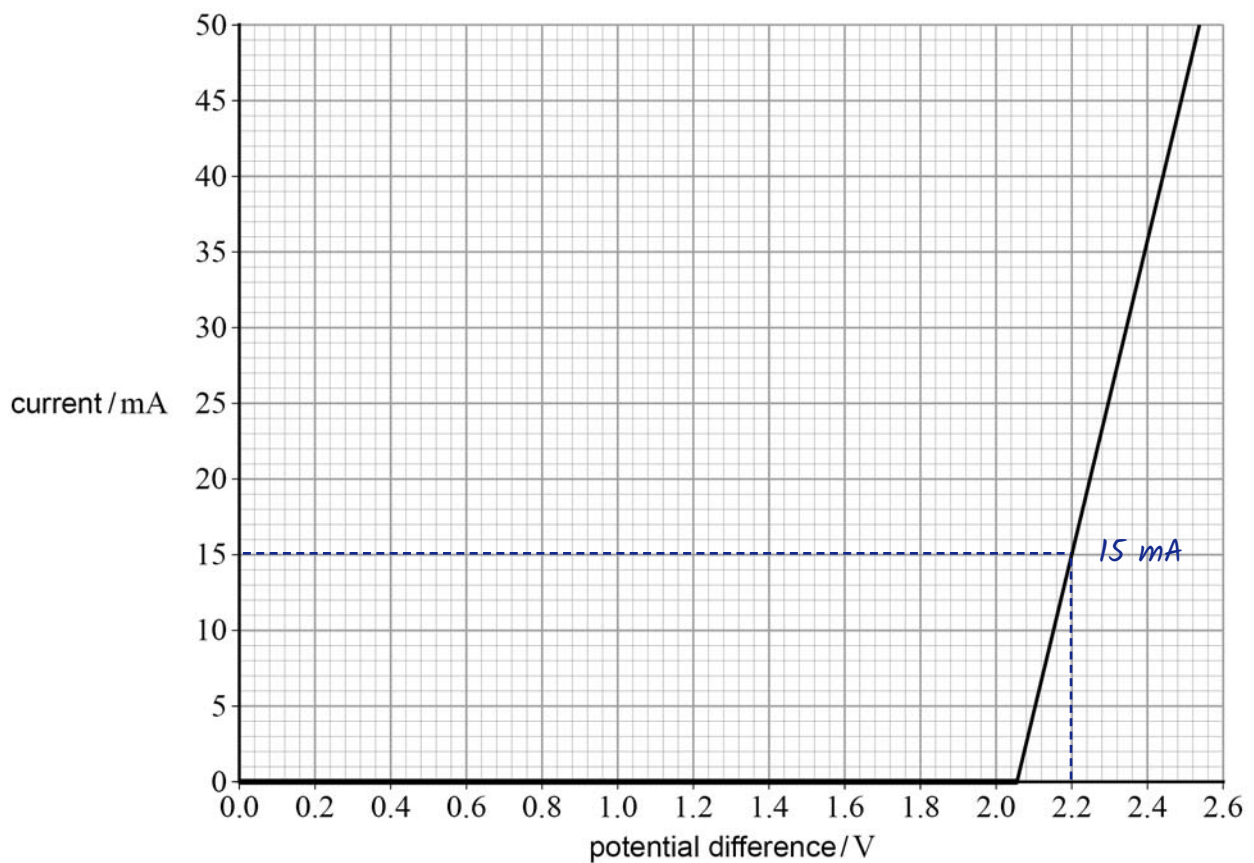
Figure 1

Figure 2 shows part of the characteristic graph for the LED.

Figure 2

The circuit is designed so that the potential difference across the LED is 2.2 V when the switch is closed.

Calculate the resistance of R.

[4 marks]

From the graph, at 2.2 V the current $I = 15 \text{ mA} = 0.015 \text{ A}$

pd across R = $7.4 - 2.2 = 5.2 \text{ V}$

Same current in R as in the LED (series)

$$R = V \div I = 5.2 \div 0.015$$

$$= 347 \Omega$$

resistance = 350 Ω

9

Turn over for the next question

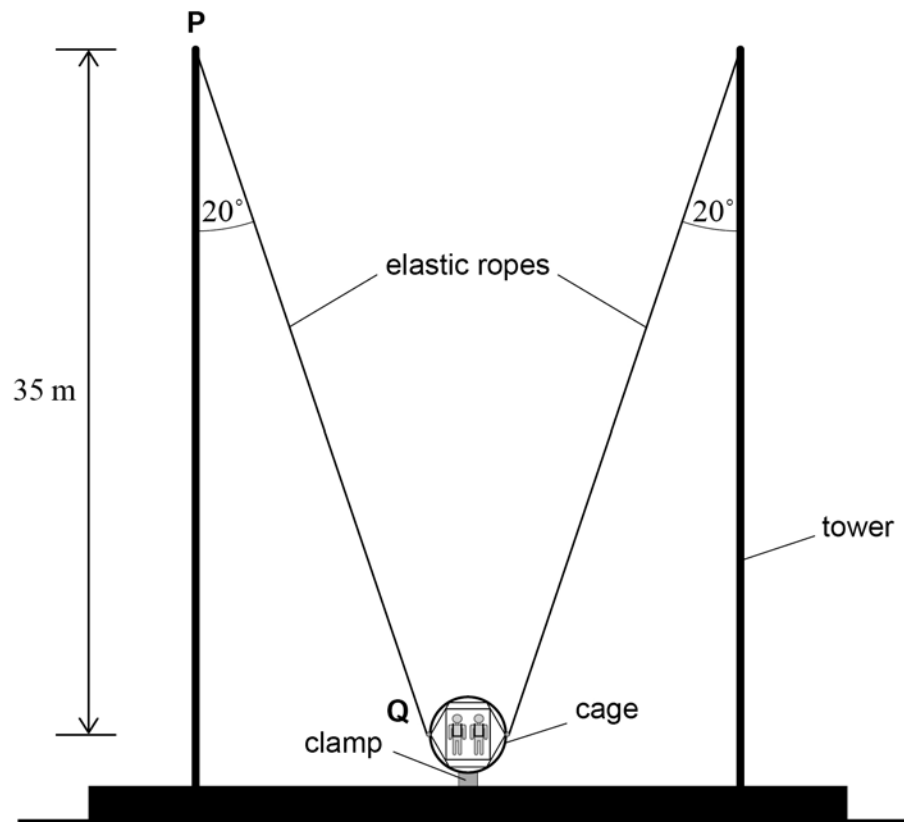
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0 3

Figure 3 shows a fairground ride called a 'reverse bungee'.

Figure 3



Two identical stretched elastic ropes are fixed to a cage with passengers inside. The loaded cage is held in place by a clamp. When the clamp is released the elastic ropes accelerate the loaded cage vertically into the air.

P is the point where the rope attaches to the top of the vertical tower.

Q is the point where the rope attaches to the cage. **Q** is level with the centre of mass of the loaded cage.

Before release, the tension T in each elastic rope is $3.7 \times 10^4 \text{ N}$ and each rope makes an angle of 20° with the vertical tower.

The total mass M of the loaded cage is $1.2 \times 10^3 \text{ kg}$ and the mass of the elastic ropes is negligible.



0 3 . 1

Show that the downward force F exerted by the clamp on the loaded cage is about $6 \times 10^4 \text{ N}$.

[4 marks]

$$\text{Weight of cage } W = Mg = 1.2 \times 10^3 \times 9.81 = 1.18 \times 10^4 \text{ N}$$

Vertical component of tension in one rope:

$$T_V = T \cos 20^\circ = 3.7 \times 10^4 \times \cos 20^\circ = 3.48 \times 10^4 \text{ N}$$

$$\text{Total upward force from both ropes} = 2 \times 3.48 \times 10^4 = 6.95 \times 10^4 \text{ N}$$

$$\text{Equilibrium: } 2T_V = W + F$$

$$F = 6.95 \times 10^4 - 1.18 \times 10^4$$

$$F = 5.8 \times 10^4 \text{ N} \approx 6 \times 10^4 \text{ N}$$

0 3 . 2

Calculate the initial acceleration of the loaded cage when the clamp is released.

[2 marks]

$$\text{On release, resultant force} = F = 6 \times 10^4 \text{ N}$$

$$F = ma, \text{ so } a = F \div M = 6 \times 10^4 \div 1.2 \times 10^3$$

$$a = 50 \text{ m s}^{-2}$$

acceleration = 50 m s⁻²

Question 3 continues on the next page

Turn over ►



0 3 . 3

The unstretched length of each elastic rope is 24 m. The ropes obey Hooke's Law for all extensions used in the ride.

The **vertical** distance between points **P** and **Q** on **Figure 3** is 35 m.

Show that the total elastic potential energy stored in both ropes before the loaded cage is released is about 5×10^5 J.

[4 marks]

$$\text{Stretched length of one rope} = 35 \div \cos 20^\circ = 37.2 \text{ m}$$

$$\text{Extension of one rope } \Delta L = 37.2 - 24 = 13.2 \text{ m}$$

$$E = \frac{1}{2}F\Delta L = \frac{1}{2} \times 3.7 \times 10^4 \times 13.2 = 2.44 \times 10^5 \text{ J per rope}$$

$$\text{Total for both ropes} = 2 \times 2.44 \times 10^5$$

$$= 4.9 \times 10^5 \text{ J} \approx 5 \times 10^5 \text{ J}$$

0 3 . 4

The designers of the ride claim that the loaded cage will reach a height of 50 m above **Q**.

Deduce whether this claim is justified.

[3 marks]

Maximum height if all the elastic energy becomes E_p :

$$E_{\text{lost}} = \Delta E_p = Mgh: 1.2 \times 10^3 \times 9.81 \times h = 5 \times 10^5$$

$$h = 5 \times 10^5 \div (1.2 \times 10^3 \times 9.81) = 42 \text{ m}$$

$42 \text{ m} < 50 \text{ m}$, so the claim is not justified.



0 3 . 5

The designers also claim that the loaded cage reaches a maximum speed of at least 90 km h^{-1} .

Calculate, in J, the kinetic energy of the loaded cage when it travels at 90 km h^{-1} .

[3 marks]

$$90 \text{ km h}^{-1} = 90\,000 \text{ m} \div 3600 \text{ s} = 25 \text{ m s}^{-1}$$

$$E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 1.2 \times 10^3 \times 25^2$$

$$= 3.75 \times 10^5 \text{ J}$$

kinetic energy = 3.8×10^5 J

0 3 . 6

Deduce without further calculation whether the maximum speed claim is justified.

[1 mark]

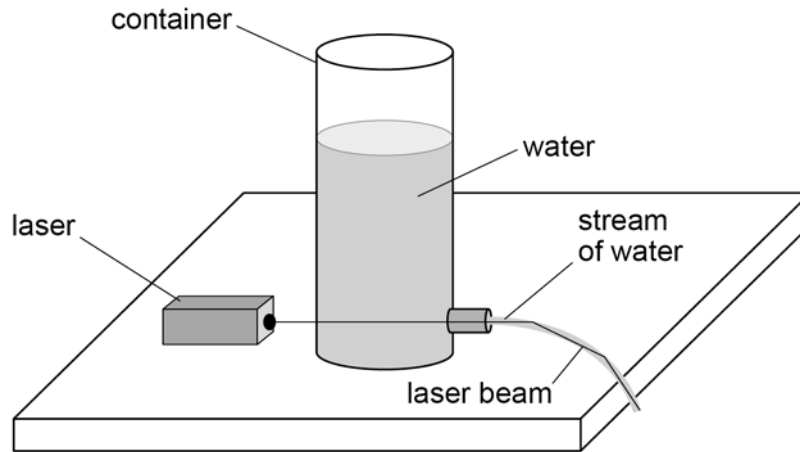
The kinetic energy needed ($3.8 \times 10^5 \text{ J}$) is less than the $5 \times 10^5 \text{ J}$ of elastic energy stored, so the claim may be justified, depending on how much energy goes into gravitational potential energy gained (and losses due to air resistance) by the time maximum speed is reached.



0 4

In 1870 John Tyndall sent a beam of light along a stream of water.
Figure 4 shows a modern version of Tyndall's experiment using a laser beam.
 Water has a refractive index of 1.33

Figure 4



0 4 . 1

Explain why the laser beam stays inside the stream of water.

[2 marks]

The refractive index of water is greater than that of air.

The laser beam hits the water to air boundary at an angle of incidence greater than the critical angle, so total internal reflection occurs and the beam stays inside the stream.



0 4 . 2

Calculate the speed of the laser light in the water.
Give your answer to an appropriate number of significant figures.

[3 marks]

$$n = c \div c_s, \text{ so } c_s = c \div n$$

$$c_s = 3.00 \times 10^8 \div 1.33$$

$$= 2.256 \times 10^8 \text{ m s}^{-1}$$

speed = 2.26 × 10⁸ m s⁻¹

0 4 . 3

Calculate the critical angle for the water–air boundary.

[1 mark]

$$\sin \theta_c = n_2 \div n_1 = 1 \div 1.33 = 0.752$$

$$\theta_c = 48.8^\circ$$

critical angle = 49 degrees

Question 4 continues on the next page

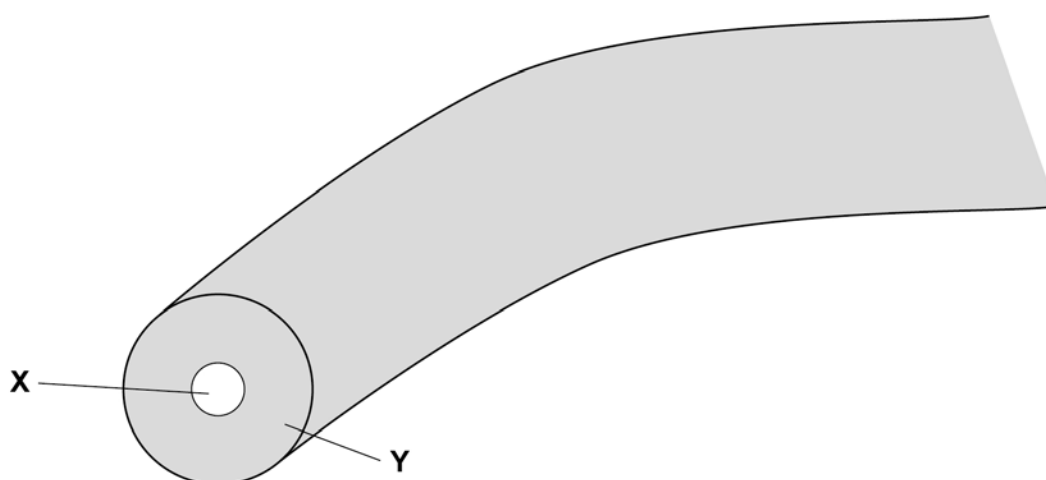
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0 4 . 4

Tyndall's experiment led to the development of optical fibres.
Figure 5 shows a step-index optical fibre.

Figure 5



Discuss the properties of a step-index optical fibre.

Your answer should include:

- the names of part **X** and part **Y**
- a description of the functions of **X** and **Y**
- a discussion of the problems caused by material dispersion and modal dispersion and how these problems can be overcome.

[6 marks]

X is the core and Y is the cladding.

Function of X: the core carries (propagates) the light along the fibre by total internal reflection at the core to cladding boundary. It is made of very pure glass so that there is low absorption (attenuation) of the signal. The refractive index of the core is greater than that of the cladding, which is needed for total internal reflection.

Function of Y: the cladding protects the core from damage (scratches), which would let light escape. It provides a clean boundary for total internal reflection, and it prevents crosstalk, so signals cannot pass between touching fibres.

Both types of dispersion cause pulse broadening: a pulse spreads out as it travels, so neighbouring pulses can overlap and the signal is distorted.



This limits the bandwidth (the rate at which pulses can be sent).

Material dispersion: the light contains a range of wavelengths. Different wavelengths have different refractive indices in the core, so they travel at different speeds and arrive at different times. This is overcome by using monochromatic light (a single wavelength, e.g. a laser).

Modal dispersion: light rays entering the fibre at different angles take different paths of different lengths, so rays that reflect more often travel further and take longer along the fibre. This is overcome by using a single-mode fibre with a very narrow core, so only light travelling (almost) straight along the axis can pass, or by making the difference in refractive index between core and cladding small.

Pulse broadening can also be reduced by using optical regenerators (repeaters) at regular intervals along the fibre to reshape the pulses.

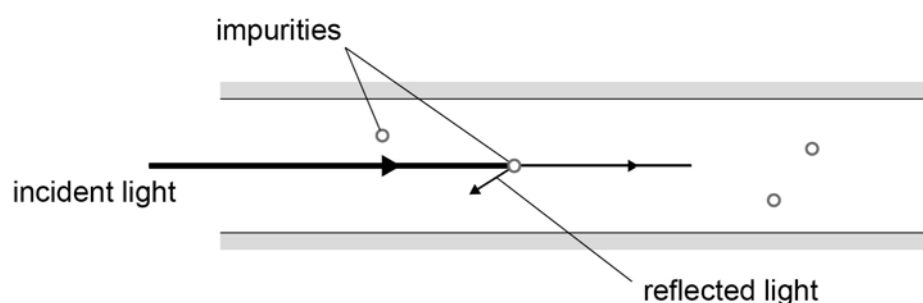
Question 4 continues on the next page

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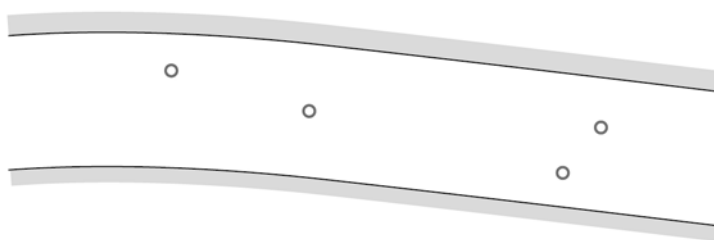


0 4 . 5

Scientists use optical fibres to monitor earthquakes. Light travelling through an optical fibre can be reflected by impurities in the fibre, as shown in **Figure 6**.

Figure 6

Earthquakes bend the optical fibre slightly, as shown in **Figure 7**. This changes the amount of reflected light.

Figure 7

Suggest why the amount of reflected light changes as the fibre bends. You may draw on **Figure 7** as part of your answer.

[2 marks]

When the fibre bends, the light meets the impurities at different positions and at different angles, so it is reflected in different directions.

The light may also meet a different number of impurities, and at the bend the angle of incidence at the core boundary may become less than the critical angle, so some light is refracted out of the fibre instead.



0	4	.	6
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The waves caused by earthquakes can be longitudinal or transverse.

Describe the difference between longitudinal waves and transverse waves.

[2 marks]

Transverse waves: the oscillations (displacements) are perpendicular to the direction of energy transfer.

Longitudinal waves: the oscillations are parallel to (along) the direction of energy transfer.

16

Turn over for the next question

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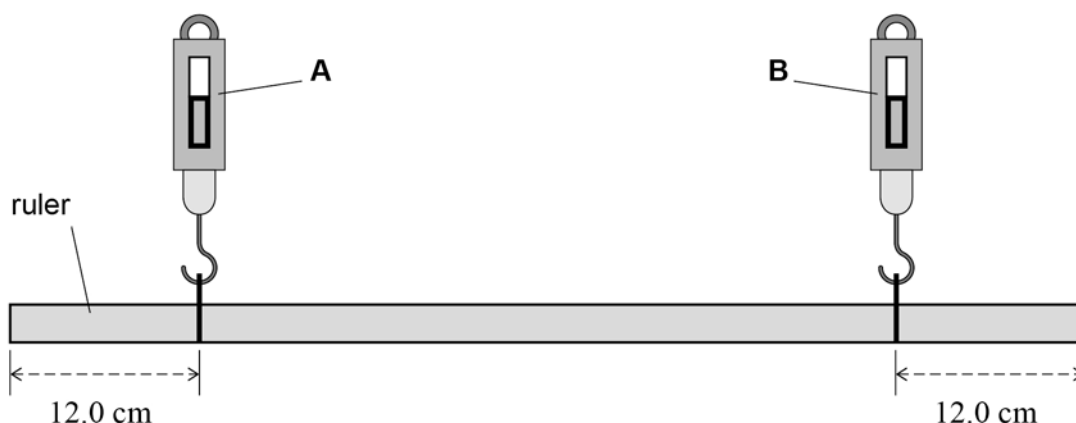


0 5

A student investigates moments by suspending a 100 cm ruler from two force meters, **A** and **B**. **A** and **B** are attached to the ruler 12.0 cm from each end. Their supports are adjusted to make **A** and **B** vertical and the ruler horizontal.

Figure 8 is a simplified diagram of the experiment.

Figure 8



0 5

1

The ruler is uniform and weighs 1.12 N.

Determine the reading on **A**.

[1 mark]

A and B are symmetrical, so each takes half the weight: $1.12 \div 2$

reading = 0.56 N

0 5

2

The student suggests that the forces exerted on the ruler by **A** and **B** act as a couple.

Discuss whether his suggestion is correct.

[2 marks]

A couple is a pair of equal forces acting in opposite directions (not along the same line), so they produce rotation only.

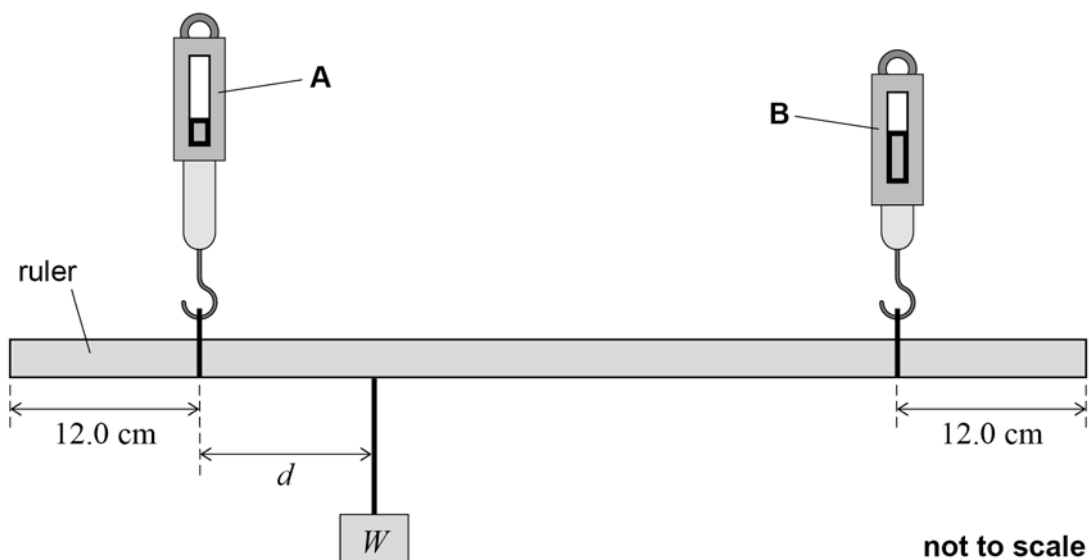
The forces from A and B are equal (0.56 N each) but both act upwards, in the same direction, so they are not a couple and the suggestion is not correct.



0 5 . 3

The student hangs a mass of weight W on the ruler between **A** and **B**, as shown in **Figure 9**.
He adjusts the supports so that **A** and **B** are again vertical and the ruler is horizontal.
The mass hangs at a distance d from **A**.

Figure 9



The reading on **A** is 0.82 N and the reading on **B** is 0.62 N.

Determine

- W
- d .

[4 marks]

Total upward force = total downward force

$$0.82 + 0.62 = 1.12 + W, \text{ so } W = 1.44 - 1.12 = 0.32 \text{ N}$$

Moments about A (ruler weight 0.38 m from A, B 0.76 m from A):

$$\text{clockwise} = \text{anticlockwise: } 1.12 \times 0.38 + 0.32 \times d = 0.62 \times 0.76$$

$$0.4256 + 0.32d = 0.4712, \text{ so } 0.32d = 0.0456$$

$$d = 0.0456 \div 0.32 = 0.14 \text{ m}$$

$$W = \underline{0.32} \text{ N}$$

$$d = \underline{0.14} \text{ m}$$

Question 5 continues on the next page

Turn over ►



0 5 . 4

A second student sets up the same apparatus as shown in **Figure 9**. She suspends the mass in the same position on the ruler as in question **05.3**. She moves the supports to make **A** and **B** vertical but does not make the ruler horizontal.

Discuss whether the readings on **A** and **B** taken by this student are different to those in question **05.3**.

[2 marks]

The readings on A and B would be the same as before (0.82 N and 0.62 N), as the total downward force (weight) is the same, so $A + B$ is still 1.44 N.

When the ruler is tilted, all the perpendicular distances from the pivot to the lines of action of the vertical forces are reduced by the same factor ($\cos \theta$), so the moments still balance with the same forces.

9



0 6

Scientists at CERN have produced atoms of antihydrogen.
An atom of antihydrogen contains the antiparticle of the proton and the antiparticle of the electron.

0 6 . 1

State what is meant by an antiparticle.

[2 marks]

A particle with the same (rest) mass (rest energy) as its corresponding particle, but with the opposite charge (and opposite baryon number or lepton number).

0 6 . 2

Complete **Table 2** with the names of the antiparticles in an atom of antihydrogen.

[2 marks]

Table 2

Name of particle	Name of antiparticle
proton	<i>antiproton</i>
electron	<i>positron</i>

Question 6 continues on the next page

Turn over ►



0 6 . 3

The particles in antihydrogen can be made by pair production.

Calculate the total minimum energy, in J, needed to produce the particles in one atom of antihydrogen.

[3 marks]

Minimum energy = rest energy of antiproton + rest energy of positron

$$= 938.257 \text{ MeV} + 0.510999 \text{ MeV} = 938.768 \text{ MeV}$$

$$1 \text{ MeV} = 1.60 \times 10^{-13} \text{ J}$$

$$E = 938.768 \times 1.60 \times 10^{-13}$$

$$= 1.50 \times 10^{-10} \text{ J}$$

energy = 1.5 × 10⁻¹⁰ J



0 6 . 4

Line emission spectra of hydrogen and antihydrogen have been compared.

Explain in terms of energy changes how line emission spectra are produced.

[3 marks]

Electrons in the atom can only exist in discrete energy levels. When an electron is excited it moves to a higher level, then it moves down (de-excites) to a lower energy level, emitting a photon.

The photon energy equals the difference between the two levels, $\Delta E = hf = hc \div \lambda$, so each photon has a specific frequency and wavelength.

As only certain energy differences exist, only certain discrete wavelengths are produced, giving a spectrum of separate lines.

10

END OF QUESTIONS

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