H157/02 Physics in Depth

SECTION A

Answer **all** the questions.

1 This question is about driving a cylinder into the ground. A block of mass of 200 kg is released from rest at a height of 4.5 m above a steel cylinder already in the ground. The cylinder is driven into the ground a further 8.0 cm by the falling block. It is assumed that the mass of the block is far greater than that of the cylinder.

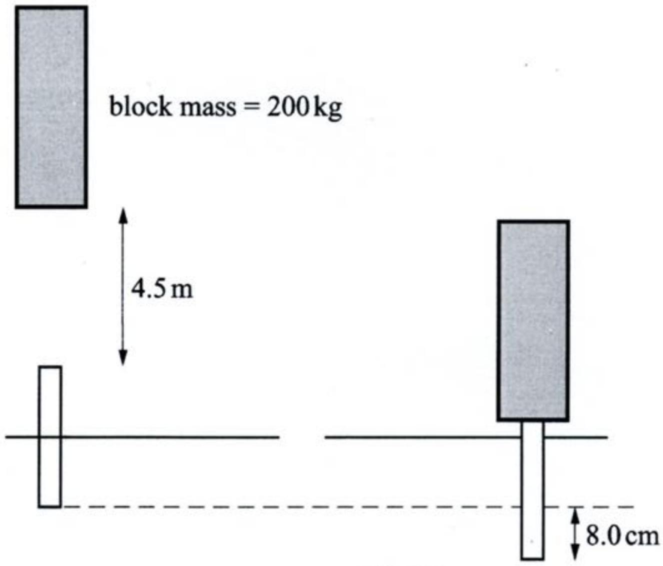


Fig.1.1

(a) Calculate the change in potential energy of the block from release point to the point it comes to rest.

change in GPE = 200 × 9.8 × ~~200~~ 4.58
= 8976.8

change in potential energy = ...8980...... J **[2]**

(b) Use your answer to **(a)** to calculate the average force exerted on the block by the cylinder as it decelerates.

cylinder moves 8×10^{-2} m.

work = force × distance

force = $\frac{8980}{8 \times 10^{-2}}$

average force = ...1.1×10^{5}...... N **[2]**

(c) The process is repeated and the cylinder is pushed into the ground by a further 6.0 cm. Suggest and explain why the depth did **not** increase by 8.0 cm.

The force from the ground on the cylinder has increased. This is probably because the soil underneath the cylinder has become compressed

[2]

2 This question is about momentum and impulse.

(a) The impulse of a force is given by the equation *impulse = force × time*

Show that the units of impulse are equivalent to kg m s^{-1}.

$Ft = Ns = kgms^{-2}s$ (since $F = ma$)

$= kgms^{-1}$

[2]

(b) Fig. 2.1 shows a collision between two balls. Ball **A** has mass 0.60 kg, ball **B** has mass 0.40 kg.

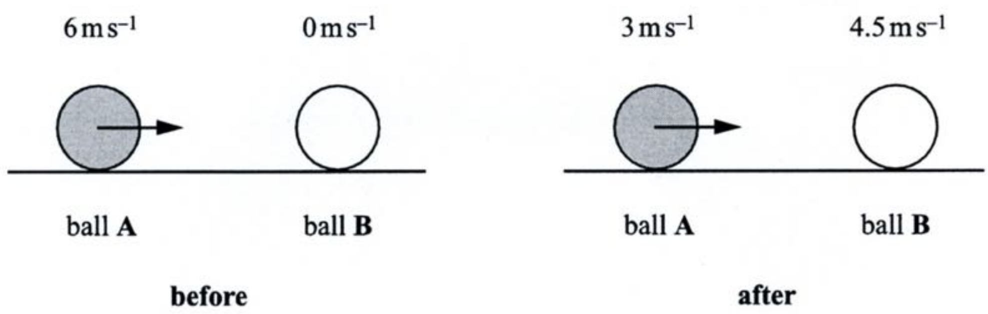


Fig. 2.1

(i) Calculate the total momentum **before** the collision.

$6 \times 0.6 + 0 \times 0.4 = 3.6$

momentum = 3.6 kg m s^{-1} **[2]**

(ii) Show that kinetic energy is **not** conserved in the collision.

Initial KE $= \frac{1}{2} \times 0.6 \times 6^2 = 10.8J$

Final KE $= \frac{1}{2} \times 0.6 \times 3^2 + \frac{1}{2} \times 0.4 \times 4.5^2 = 6.75J$

[3]

(iii) The balls are in contact for 40 ms. Calculate the average force exerted on ball **A** as it decelerated from 6 m s^{-1} to 3 m s^{-1}. Suggest why this is an average value.

$Ft = \Delta mv$

$F \times 40 \times 10^{-3} = (0.6 \times 6) - (0.6 \times 3)$

$F = 45N.$

[3]

This is an average as the force will decrease as the 2nd ball starts to move.

OR $F = ma = 0.6 \times \frac{6-3}{40 \times 10^{-3}} = 0.6 \times 75 = 45N.$

OR

3 This question is about a phone capturing and sending a digital photograph.

Here are some data about the photograph and the broadband system the phone uses.

The image is 640 × 960 pixels.
Each pixel is coded for three colours. Each colour is coded by 8 bits.
The broadband speed is 5×10^6 bits per second.

(a) Calculate the time required to send the uncompressed photograph.

$$\frac{640 \times 960 \times 3 \times 8}{5 \times 10^6} = 2.95$$

time = ...3.......... s **[2]**

(b) The phone's camera can record video at 30 frames per second. The phone can store 6.2 gigabytes of data. Calculate how many seconds of video recording the phone can store if each frame has the same data requirement as a still photograph.

$$\frac{6.2 \times 10^9}{640 \times 960 \times 3} = 3364 \text{ frames}$$

$$\frac{3364}{30} = 112\text{s}$$

recording time = ...112.......... s **[2]**

(c) Digital images can be compressed to reduce the number of bits required to represent the image and they may be manipulated in other ways to edit or change the image. The modified images and videos may then be posted to social media websites. Give a reason for processing images in one of these ways and identify the benefits or any risk associated with this.

Compression → smaller file size but loss of resolution
↓
can store more images

edited image → change opinion, cyber bullying

....

.... **[3]**

(reason + benefit + risk)

SECTION B

Answer **all** the questions.

4 This question is about different models of light.

A coherent beam of light passes through two slits and forms a pattern on a distant screen. The slit spacing is 2.5×10^{-4} m. The distance from the slits to the screen is 2.3 m.

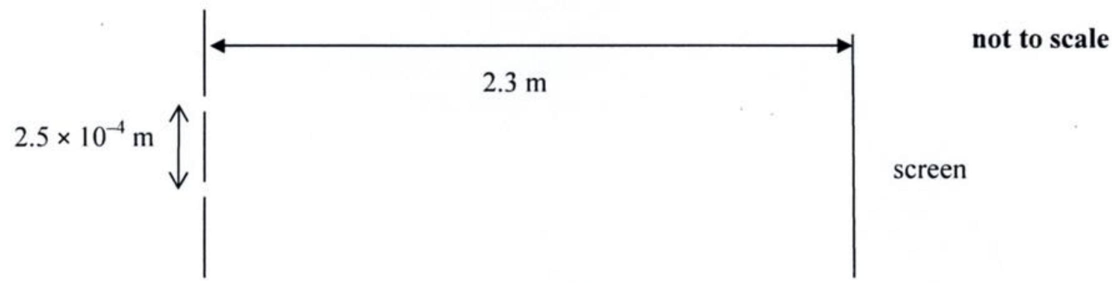


Fig. 4.1

(a) Explain what the term *coherent* means in this context.

All the light waves have a constant phase difference

.... **[1]**

(b) **Fig. 4.2** represents the pattern of bright fringes on the screen.

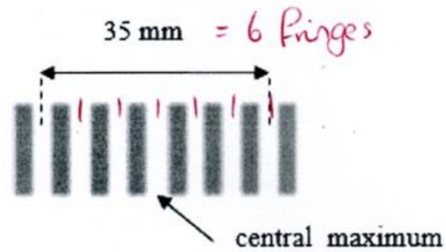


Fig. 4.2

Use the data below and information from **Fig. 4.2** to calculate the wavelength of the light passing through the slits.

slit spacing = 2.5×10^{-4} m
distance from the slits to the screen = 2.3 m.

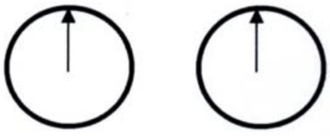
fringe spacing = $35 \times 10^{-3} / 6 = 5.8 \times 10^{-3}$ m

$n\lambda = \frac{dx}{L}$ $(n = 1)$

$\lambda = \frac{2.5 \times 10^{-4} \times 5.8 \times 10^{-3}}{2.3}$

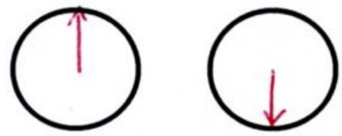
wavelength = 6.3×10^{-7} m **[3]**

(c) Phasors can be represented by rotating arrows. The phasors representing the waves from the two slits reaching the screen at a bright patch at one instant of time are shown in **Fig. 4.3.**



bright patch

Fig. 4.3



dark patch

Fig. 4.4

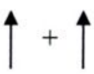
(i) On **Fig. 4.4** draw arrows representing phasors arriving at the same instant of time, for light from the two slits, at a **dark patch** on the screen. **[1]**

2 arrows in opposite directions

(ii) **Fig. 4.5** shows two pairs of phasor arrows meeting at the screen. Draw a scale diagram showing the resultant phasor arrow in both cases.

case 1:

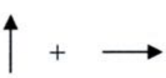
phasor arrows:



resultant phasor arrow:

case 2:

phasor arrows



resultant phasor arrow:

Fig. 4.5

[2]

(iii) Use the relationship *probability of arrival of photon* α *(phasor amplitude)*^{2} to find the ratio of the probabilities of arrival of photons for the two resultant phasors.

$$\text{ratio } \frac{\textit{probability of arrival of photons in case 1}}{\textit{probability of arrival of photons in case 2}} = \frac{2^2}{(\sqrt{2})^2} = \frac{4}{2} = 2.$$

[2]

must give final ratio as 2 for 2nd mark.

When interference patterns were first observed in the nineteenth century they were interpreted as evidence for the wave picture of light. Early in the twentieth century, Albert Einstein showed that light interacts as small quanta of energy, photons. This idea is supported by images such as **Fig. 4.6.** This shows an image of a girl's face gradually building up as more light falls on the photographic film. Image (1) is the least exposed and (6) the most. In the early stages of building up an image the pattern is quite random.

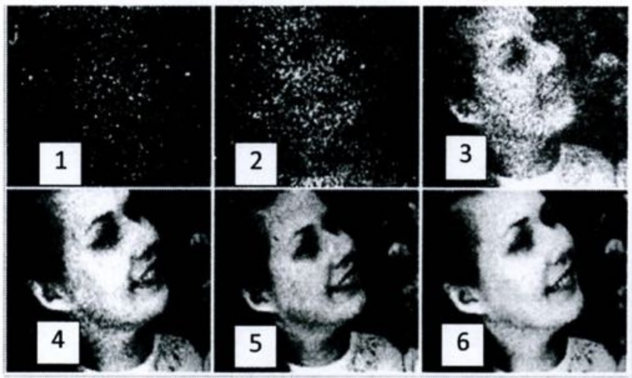


Fig. 4.6

Photons can be modelled as small quanta of energy that have a probability of arrival at a point. This probability is found by using phasors to combine the amplitude and phase for all possible paths to that point.

(d)* Describe how this phasor model can explain the gradual build-up of images such as **Fig. 4.6** and also explain two-slit interference. In your description you should also explain why a wave model cannot explain the effect shown in **Fig 4.6** and why a simple particle model cannot explain interference effects.

Phasor model.

Interference explained because resultant phasors can produce light and dark regions eg → → gives bright while → ← gives dark.

Image explained because amplitude of resultant phasor gives the probability of the arrival and this leads to randomness.

Wave model can't explain random pattern as the incomplete image would have the same intensity throught

Particle model can't explain superposition as particles can't superpose to give a dark region. **[6]**

5 This question is about the properties and microscopic structure of metal wire. **Fig. 5.1** shows a graph of force against extension for a steel wire.

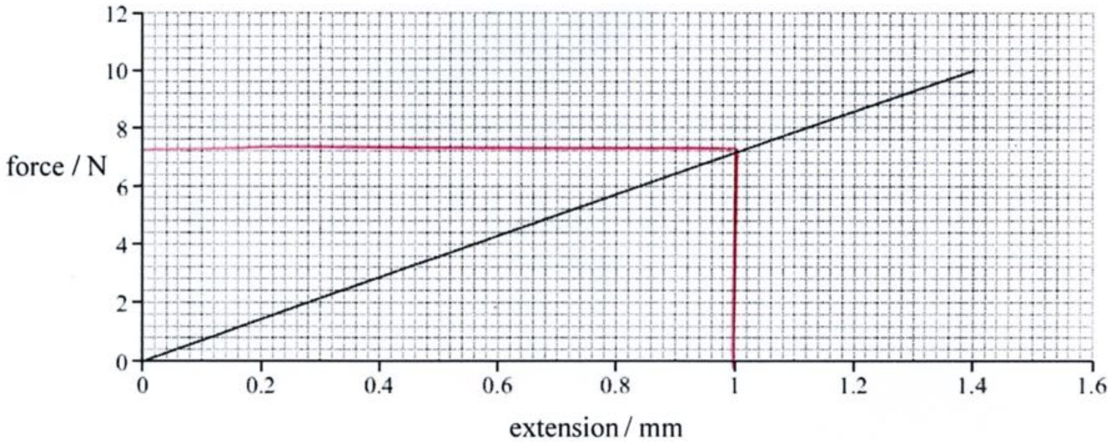


Fig. 5.1

(a) State how the graph shows that the wire is behaving elastically.

Force ∝ extension.

.... **[1]**

(b) The wire has a diameter of 0.40 mm. The original length of the wire is 3.85 m.

Use data from **Fig. 5.1** to calculate the Young modulus of the steel.

$r = 0.4 \times 10^{-3}/2 = 0.2 \times 10^{-3}$ m. Area $= \pi r^2 = 1.256.. \times 10^{-7}$ m^2

Choose point from graph eg (1, 7.2)

$E = \frac{FL}{Ax} = \frac{7.2 \times 3.85}{1.257 \times 10^{-7} \times 1 \times 10^{-3}} = 2.2 \times 10^{11}$

Young modulus = 2.2×10^{11} N m^{-2} **[4]**

(c) **Fig. 5.2** shows a stress–strain graph of the same material, obtained from a tensile testing machine.

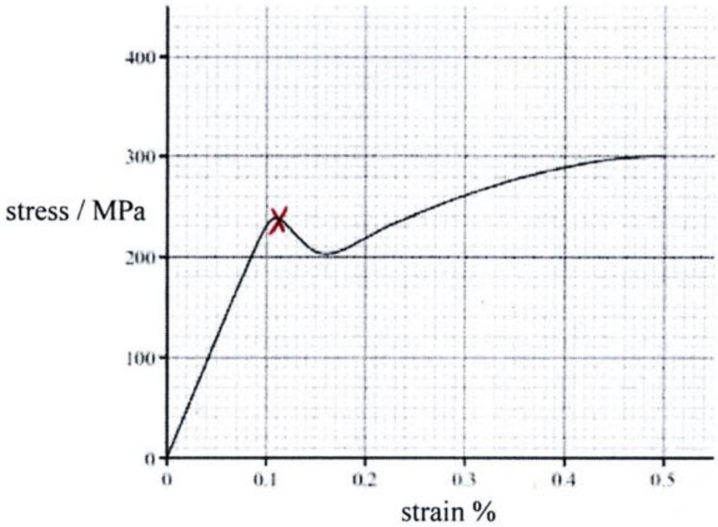


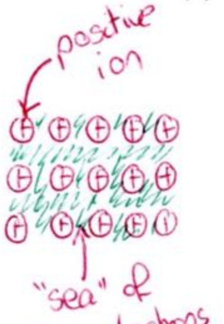
Fig. 5.2

(i) Mark with an X the point on the graph in **Fig. 5.2** where plastic deformation begins. **[1]**

(ii) State the feature of the graph that represents the stiffness of the material and describe how the stiffness varies between a strain of 0.2% and 0.5%.

stiffness = stress / strain (= gradient)
stiffness decreases from 0.2 → 0.5% (because the gradient decreases) **[2]**

(d)* Steel is an alloy. Its main constituent is iron. Using ideas about dislocations and metallic structure explain why the steel first shows elastic behaviour (up to point X) and then shows plastic behaviour (beyond point X). Explain how the presence of atoms other than iron makes the resulting metal harder and less plastic than pure iron.



Metals consist of a regular lattice of positive ions surrounded by a "sea" of electrons. When the iron is under tension, the distance between the ions increases regularly and when the force is removed, the ions go back to their original position - this is elastic behaviour and no energy is lost in the process.
If the tension is high enough, plastic behaviour occurs and the planes of ions slide over each other. **[6]**
Dislocations form where atoms of other elements are in the lattice. They may slip less likely because it is harder for the planes to move very far.

SECTION C

Answer **all** the questions.

6 This question is about an experiment performed in AS physics to determine the internal resistance of a battery (two cells combined in series). The experiment can be set up as shown in **Fig. 6.1.**

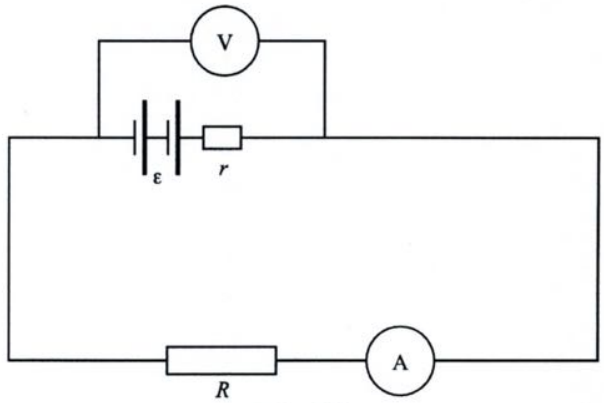


Fig. 6.1

Measurements of p.d. V and current I for a range of values of resistors R are taken in order to determine a value for the combined internal resistance of the cells.
In planning the experiment it is important to select suitable equipment.

(a) Explain why the following equipment was chosen

- A voltmeter with very high internal resistance.
- An ammeter with negligible internal resistance.

(V) negligable current should flow through the voltmeter
(A) no energy/pd should be lost across the ammeter (so the current is not reduced).

[2]

(b) A student suggests that using much higher value resistors will improve the quality of measurements by reducing the uncertainty in the current readings.

Comment on this suggestion. Explain your reasoning.

Increasing the resistance will lower the current
The absolute uncertainty of the readings will not change but the % uncertainty will increase.

[3]

(c) Data obtained from the experiment on page 12 is given in the table below

p.d. / V	***I* /mA**
2.86	286
2.82	352
2.78	462
2.66	666
2.40	1200

Plot a graph of the values on **Fig. 6.2**. Draw a suitable line.

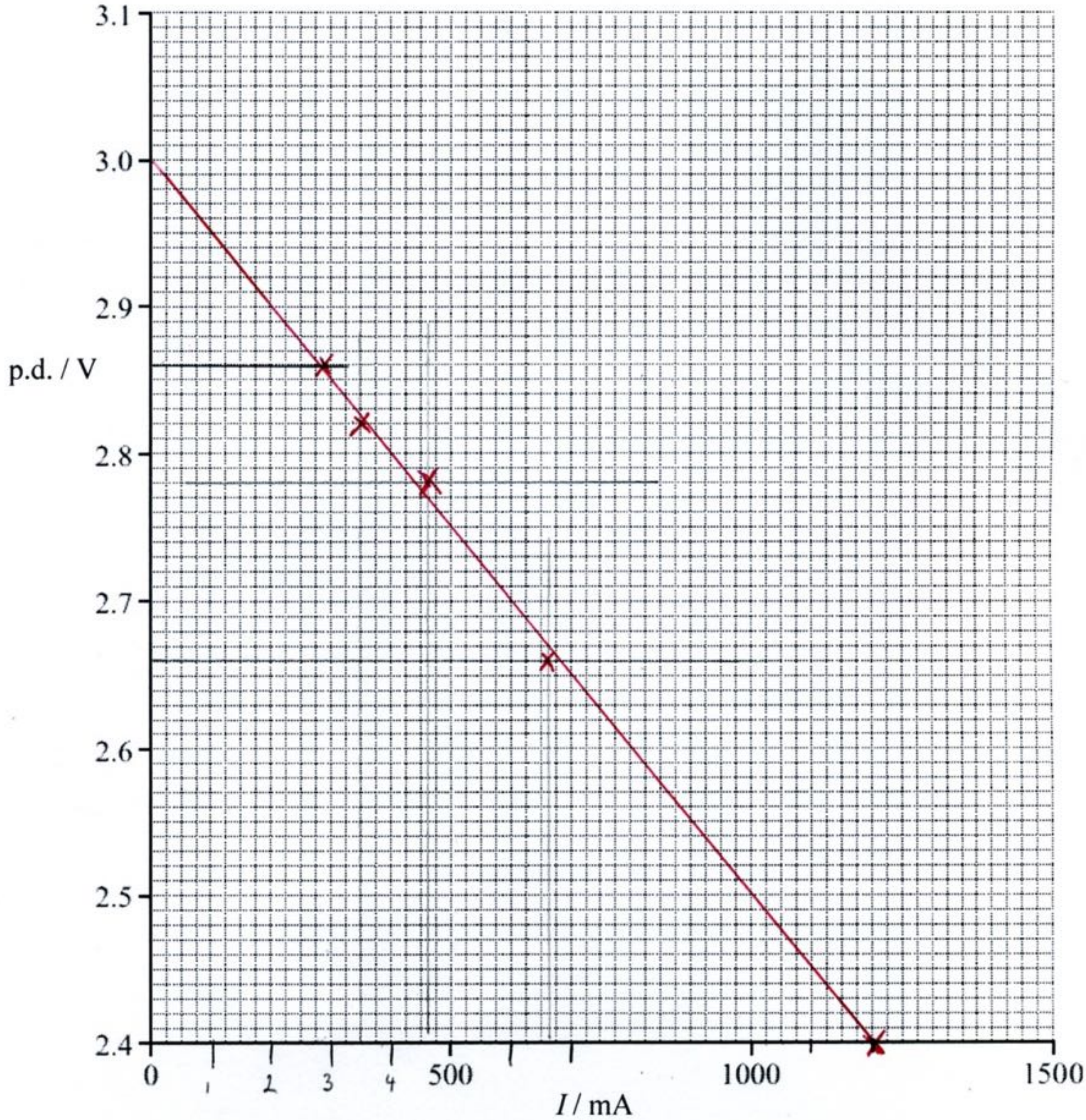


Fig. 6.2

[2]

The equation relating p.d. V and current is

$V = \varepsilon - Ir$

Where ε is the e.m.f. of the battery and r is the internal resistance of the battery.

(d) Use the graph to determine a value for the e.m.f. ε for the cells. Show your working clearly and include the unit in your answer.

when current = 0 V = ε

from graph, line intercepts y axis at V = 3.0V

emf ε = 3.0 V. **[2]**

(e) Determine a value for the internal resistance.

r = gradient

$= \frac{0.6}{1200 \times 10^{-3}}$

$= 0.5\ \Omega$

internal resistance = 0.5 Ω Ω **[3]**

(f)* A student suggests three possible variations to extend the experiment.

1) Adding a switch into the circuit so that the circuit can be disconnected between readings.
2) Adding another cell.
3) Reversing one of the cells.

Discuss the effect that each of these three suggested changes would have on the accuracy of the experiment, the uncertainty of measurement and the data collected.

① Less energy lost draining the cells when they are not in use
There will be less heat generated in the battery

② Increasing the pd will increase the current and lead to a lower % uncertainty in the current reading
The graph would have a steeper gradient and higher intercept.

③ pd would decrease, so current would decrease.
% uncertainty in readings would increase.

[6]

END OF QUESTION PAPER