THIS IS A LEGACY SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE
PHYSICS A
Health Physics

2825/02

Candidates answer on the question paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator

Tuesday 27 January 2009
Morning

Duration: 1 hour 30 minutes

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **90**.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The first six questions concern Health Physics. The last question concerns general physics.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**6**	
2	**14**	
3	**15**	
4	**11**	
5	**14**	
6	**10**	
7	**20**	
TOTAL	**90**	

Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \mathrm{m\,s^{-1}}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \mathrm{H\,m^{-1}}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \mathrm{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \mathrm{J\,s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$
molar gas constant,	$R = 8.31\ \mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall,	$g = 9.81\ \mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

refractive index, $n = \dfrac{1}{\sin C}$

capacitors in series, $\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

capacitor discharge, $x = x_0 e^{-t/CR}$

pressure of an ideal gas, $p = \frac{1}{3}\dfrac{Nm}{V}\langle c^2 \rangle$

radioactive decay, $x = x_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \dfrac{0.693}{\lambda}$

critical density of matter in the Universe, $\rho_0 = \dfrac{3H_0^2}{8\pi G}$

relativity factor, $= \sqrt{(1 - \dfrac{v^2}{c^2})}$

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

sound intensity level, $= 10\lg\left(\dfrac{I}{I_0}\right)$

Answer **all** the questions.

1 A person of mass 72 kg is balanced on one foot on tip-toe as shown in Fig. 1.1. Fig. 1.2 shows the forces acting on the foot. The calf muscles are in tension and provide the effort **E**. **R** is the contact force between the floor and the foot and is equal in magnitude but opposite in direction to the weight **W** of the person. **F** is the overall downward force on the foot. The lines of action of **F** and **E** are at perpendicular distances of 6.0 cm and 17.0 cm respectively from the line of action of **R**.

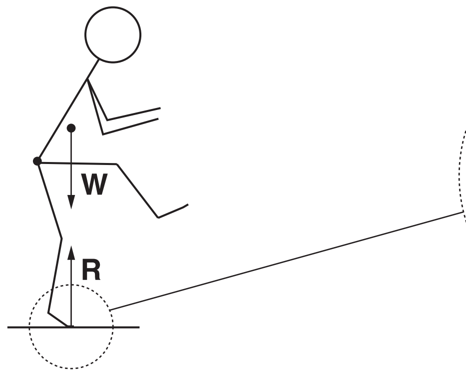

Fig. 1.1

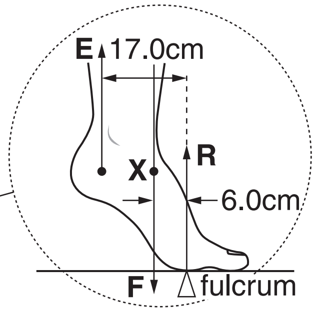

Fig. 1.2

(a) **(i)** Find the value of **R**.

R = ... N **[1]**

(ii) By taking moments about **X**, calculate the effort **E** required to maintain the position in Fig. 1.1.

E = ... N **[3]**

(iii) Hence calculate **F**.

F = ... N **[1]**

(b) Suggest why **F** is greater than **W**.

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.... **[1]**

[Total: 6]

2 (a) Outline the physical principles employed in the production of a magnetic resonance imaging (MRI) scan.

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(b) Describe and explain

- one example where an MRI scan might be used in preference to a CT scan
- one example where an MRI scan should not be used.

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.... **[4]**

[Total: 14]

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3 A beam of X-rays is used to target malignant cells in a deep set tumour. A slice of aluminium of thickness 3.5 mm is used to remove low-energy X-rays from the beam. It reduces the overall intensity of the high energy X-rays from an initial value I_0 of 1.0 I_0 to 0.20 I_0.

(a) Calculate the linear attenuation coefficient, μ, for the high energy X-ray beam in aluminium. Give a unit for your answer.

μ = ... unit .... **[4]**

(b) As the high energy X-rays pass through the soft tissue, the intensity of the beam drops further. Fig. 3.1 is a table of the transmitted intensity I of the X-rays in **(a)** after penetration through x cm of soft tissue. The incident intensity I_S on the soft tissue is $2.2 \times 10^9\,W\,m^{-2}$.

I / Wm^{-2}	x / cm	ln (I / I_S)
1.60×10^9	2.0	–0.318
1.16×10^9	4.0	
8.42×10^8	6.0	
6.12×10^8	8.0	
4.44×10^8	10.0	–1.600

Fig. 3.1

(i) Fill in the missing values in Fig. 3.1. **[1]**

(ii) On Fig. 3.2, plot a graph of ln (I / I_S) against thickness x. **[3]**

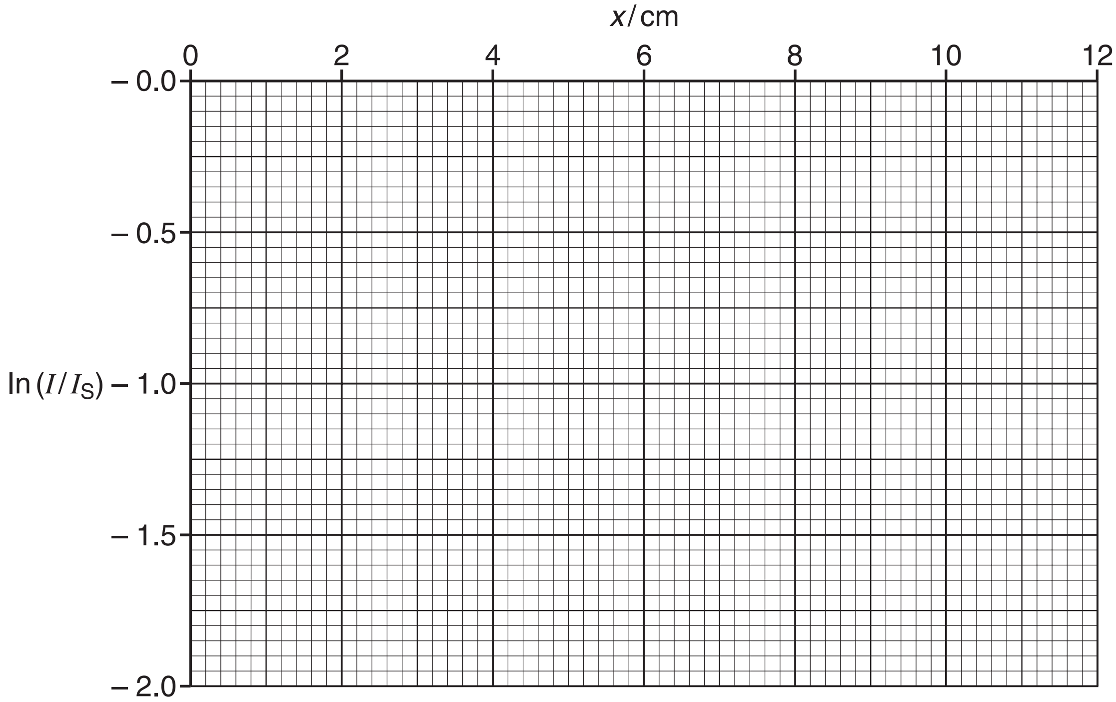

Fig. 3.2

(iii) Use your graph to show that the attenuation coefficient μ, for the X-ray beam in soft tissue is about $16\,m^{-1}$.

[3]

(c) The tumour being targeted is situated at a depth of 2.3 cm in soft tissue. The area of the X-ray beam at the tumour is $4.1\,mm^2$. The energy required to be absorbed by the tumour is 3000 J. 12% of the photon energy arriving at the tumour is absorbed by the tumour.

Calculate the time of exposure if the energy is to be delivered in one single pulse of X-rays.

time = ... s **[4]**

[Total: 15]

4 The output power of sound from one earpiece of an MP3 player is 2.0 μW. All of this power is incident on an eardrum of area $6.5 \times 10^{-5}\,m^2$.

(a) Show that the intensity of sound at the eardrum is $0.031\,W\,m^{-2}$.

[1]

(b) **(i)** Calculate the intensity level of this sound at the eardrum.

intensity level = ... dB **[2]**

(ii) An increase in loudness is just detected when the intensity level in **(i)** increases by 0.8 dB. Calculate the % increase in sound power to the earpiece required to just detect a change in loudness.

% increase = ... **[3]**

(c) The ear is most sensitive to a frequency of about 2 kHz. A student suggests that this is due to resonance in the outer ear and that this resonant frequency in the ear of a child will change as the child grows. Fig. 4.1 shows apparatus that might be used in an experiment to demonstrate resonance of sound in a tube closed at one end.
Explain, with reference to the standing waves set up in this experiment, how and why the resonant frequency in the outer ear might change as a child grows.

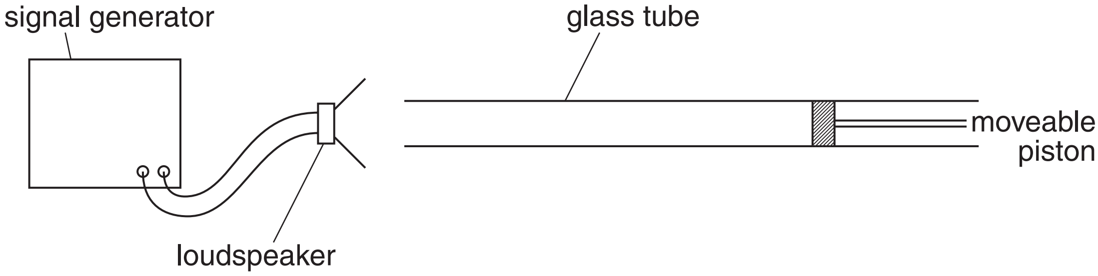

Fig. 4.1

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.... **[5]**

[Total: 11]

5 Fig. 5.1 shows the path of two rays from a point object **X** to the retina of an eye. When the eye focuses on this object the image is formed on a part of the retina called the *fovea*. The light-sensitive cells which cover the retina may be classified into two groups: rods and cones. A single nerve fibre connects each cone to the brain via the optic nerve. For rods, a single nerve fibre connects several rods to the brain.

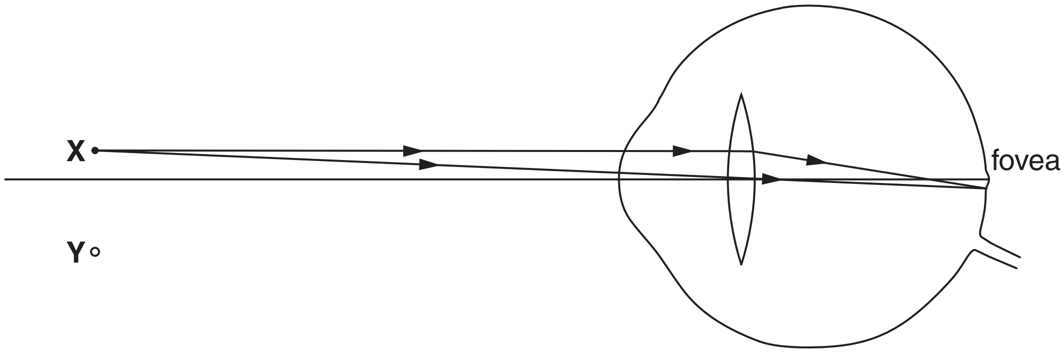

Fig. 5.1

(a) While focusing on the object **X** in bright light (Fig. 5.1), an image of a point object **Y** is also formed on the retina.

(i) On Fig. 5.1, draw the path of two rays from **Y** through the eye to the retina, showing a possible position for the image of **Y** on the retina. **[3]**

(ii) Using your knowledge of rods and cones together with the information above, suggest why objects in the direct line of vision (i.e. those which lie on the optic axis of the eye lens) are seen clearly while those on either side are not well defined.

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(b) (i) On Fig. 5.2 sketch and label graphs to represent the relative responses of rods and cones to light intensity as it varies from zero intensity to an intensity equivalent to that on a bright sunny day. **[3]**

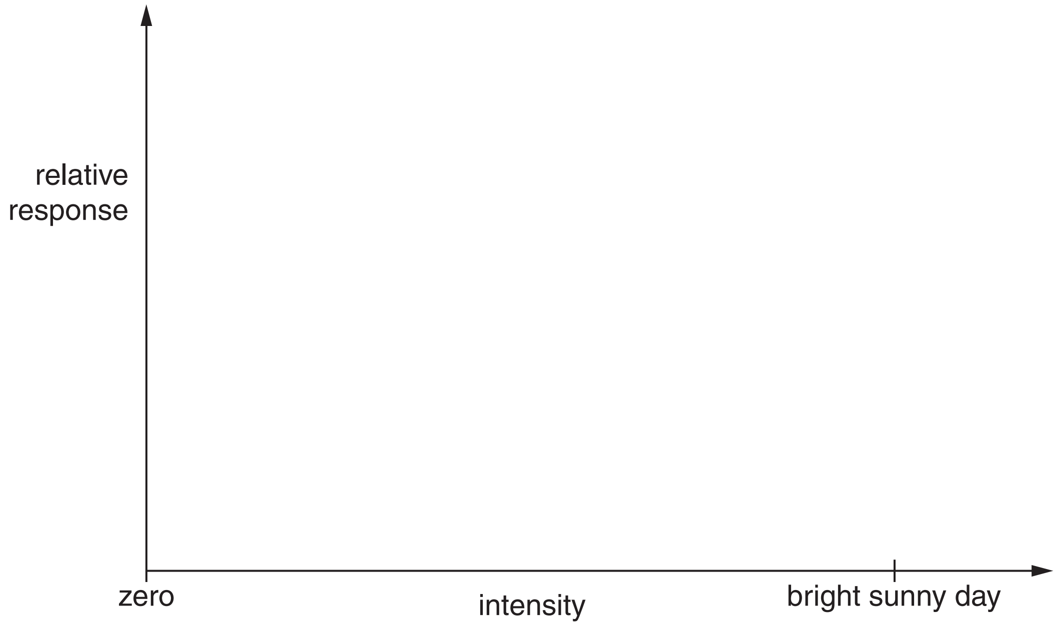

Fig. 5.2

(ii) Explain, with reference to your graphs, why in dim lighting conditions vision is both monochrome and peripheral.

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[Total: 14]

6 When ionising radiation was first discovered, the measurement of its effects was made by recording the positive charge deposited per kg of air, otherwise known as the *exposure*.

Absorbed dose is a measurement of the effects of ionising radiation on living tissue. Its value depends on both the exposure and a conversion factor *f*, which varies with the type of absorbing medium.

(a) State how exposure and absorbed dose are related.

.... **[1]**

(b) Fig. 6.1 shows how the conversion factor *f* in different media varies with photon energy.

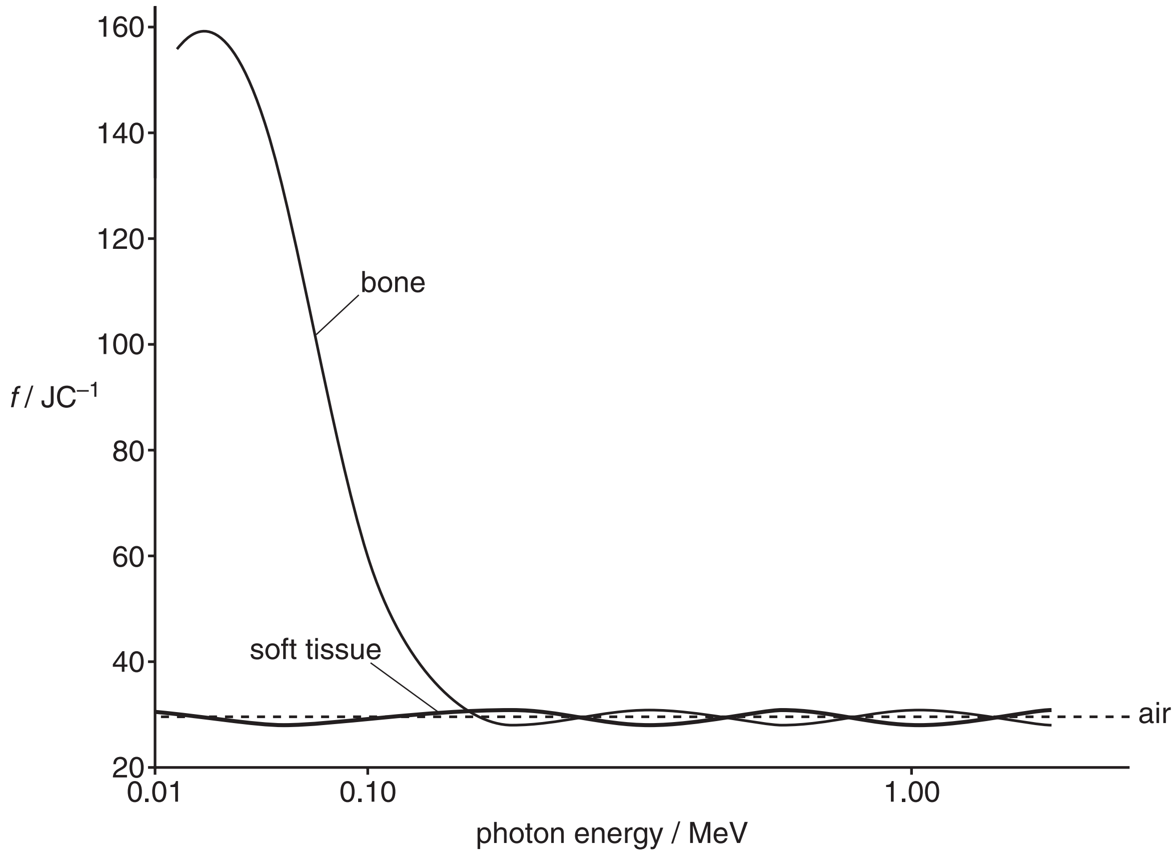

Fig. 6.1

In a sample of 0.25 kg of air, the 0.10 MeV photons produced 3.0×10^{18} ion pairs.

Calculate

(i) the exposure

exposure = ... C kg^{-1} **[3]**

(ii) the absorbed dose for these photons in bone.

absorbed dose = ... unit .... **[2]**

(c) A student recalls that when treating a tumour in bone, photons of energy less than 0.10 MeV are employed. The student suggests that this is because higher energy photons will penetrate through the bone and not be absorbed.

The student also suggests that if treating a tumour in soft tissue which is close to bone, photons of low energy should also be used.

Explain, giving reasons, whether you agree with each of these suggestions.

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.... **[4]**

[Total: 10]

7 The speed with which a bullet emerges from the barrel of a gun can be measured by a number of different techniques. This question relates to **two** experiments performed using the same rifle and bullets.

Data:

- mass of rifle 4.3 kg
- mass of bullet 28 g
- length of rifle barrel 72 cm

(a) Fig. 7.1 shows the first experiment where the rifle fires the bullet into a measured distance D between two fast optical sensors each of which is connected to a timer.

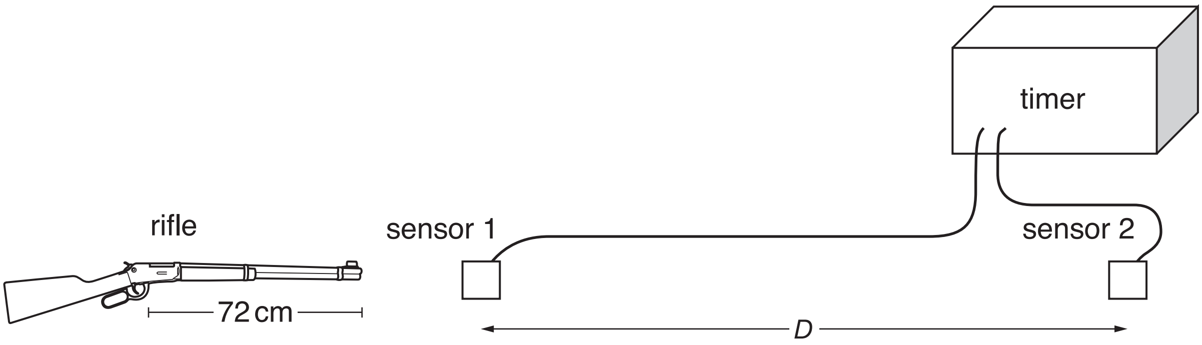

Fig. 7.1

When the bullet reaches sensor 1 the timer starts and when the bullet passes sensor 2 the timer stops.

distance D = 1.28 m
time t = 1.50 ms

(i) Show that the speed of the bullet is about $850\,\mathrm{m\,s^{-1}}$.

[1]

(ii) The bullet accelerates as it travels along the rifle barrel. Show that the average acceleration in the barrel is about $5 \times 10^5\,\text{m}\,\text{s}^{-2}$.

[2]

(iii) Calculate the average force on the bullet in the barrel.

average force on bullet = ... N **[2]**

(iv) Discuss the effect this force has on the rifle.

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.... **[2]**

(b) Fig. 7.2 shows the second experiment where the same rifle fires the bullet horizontally into the middle of a block of lead resting on top of a vertical support.

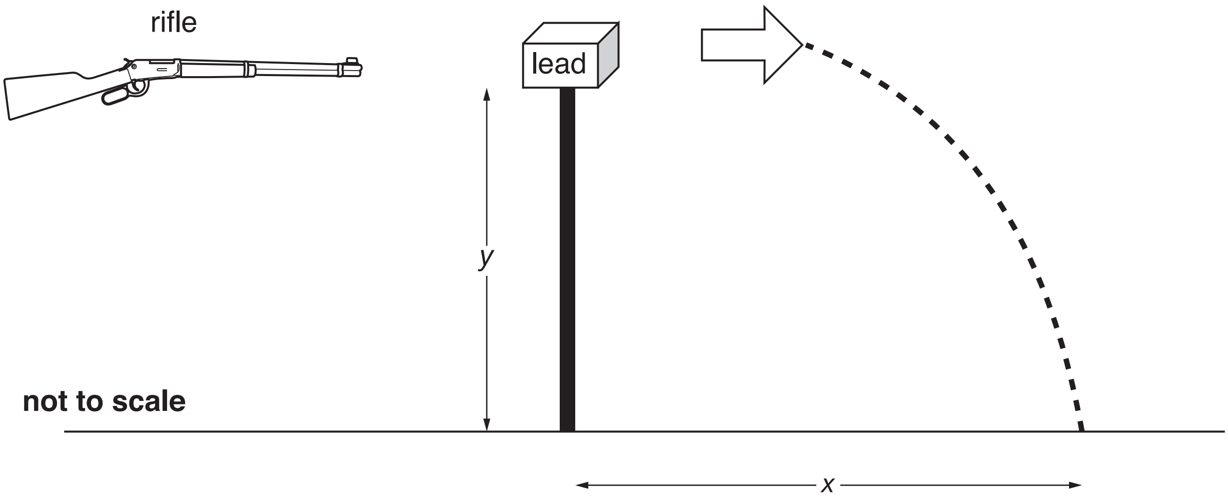

Fig. 7.2

When the bullet reaches the block it becomes embedded in the lead and the block is projected a horizontal distance *x* and falls a vertical distance *y* as shown. The following measurements are made;

mass of bullet	28 g
mass of lead block	3.60 kg
vertical distance *y*	2.41 m
horizontal distance *x*	4.60 m

(i) Show that the time taken for the block to fall through the vertical distance *y* is about 0.70 s.

[2]

(ii) Show that the horizontal projection speed of the block from the support is about 6.6 m s^{-1}.

[1]

(iii) Show that the speed of the bullet given by this collision experiment is also about 850 m s^{-1}.

[3]

(c) The initial kinetic energy of the bullet is transferred to the block as kinetic energy and thermal energy.

(i) Estimate the rise in temperature of the lead block. The specific heat capacity of lead is $126\,\mathrm{J\,kg^{-1}\,K^{-1}}$.

rise in temperature = ... K **[5]**

(ii) Explain **two** assumptions you made in this calculation.

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.... **[2]**

[Total: 20]

END OF QUESTION PAPER

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