RECOGNISING ACHIEVEMENT

ADVANCED GCE **2825/02**

PHYSICS A

Health Physics

TUESDAY 17 JUNE 2008

Afternoon

Time: 1 hour 30 minutes

Candidates answer on the question paper
Additional materials (enclosed): None

Additional materials (required):
Electronic calculator

CUP/T46195

Candidate Forename		Candidate Surname	
Centre Number		Candidate Number	

INSTRUCTIONS TO CANDIDATES

- Write your name in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use blue or 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.

INFORMATION FOR CANDIDATES

- The number of marks for each question 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.
- The first six questions concern Health Physics. The last question concerns general physics.
- You are advised to show all the steps in any calculations.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**12**	
2	**11**	
3	**10**	
4	**13**	
5	**11**	
6	**13**	
7	**20**	
TOTAL	**90**	

This document consists of **19** printed pages and **1** blank page.

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, $n = \frac{1}{\sin C}$

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

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

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

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

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

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

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

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

current, $I = nAve$

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

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

Answer **all** the questions.

1 The maximum sensitivity of the hearing of a young person occurs at a frequency of about 2 kHz.

(a) On Fig. 1.1 draw a sketch graph to show the variation of the threshold of hearing for a person with normal hearing across the audible frequency range. Add a scale to each axis with appropriate values. [4]

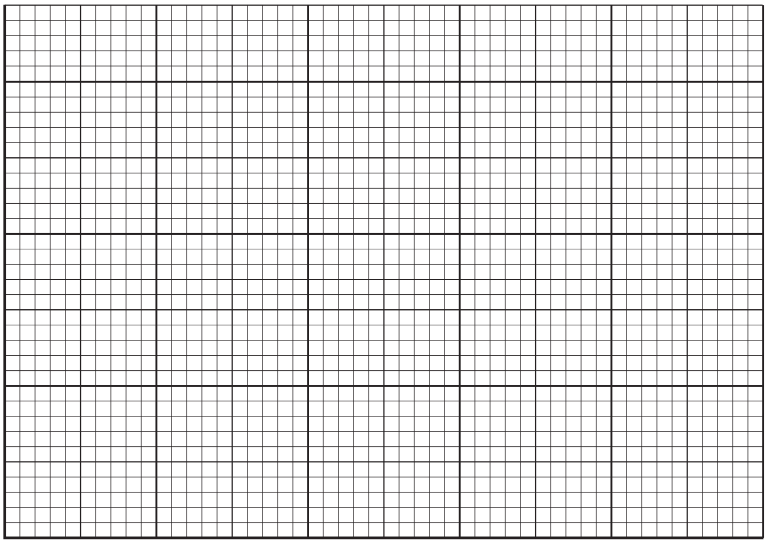

Fig. 1.1

(b) A student measures the intensity level 1 m from a ticking clock and records a value of 20 dB. When an alarm bell from the clock sounds, the intensity level is recorded as 80 dB. The student concludes that the alarm bell is 4 times louder than the clock tick.

(i) Calculate the factor by which the intensity changes when the alarm bell sounds.

$$\text{factor} = \frac{\text{intensity of alarm bell from clock}}{\text{intensity of ticking clock}}$$

factor = ... [4]

(ii) Explain the difference between *loudness* and *intensity*.

....

....

.... [2]

(iii) Explain, giving reasons, whether you agree with the student's conclusion.

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.... [2]

[Total: 12]

2 Certain defects of the eye may be corrected by laser surgery. Fig. 2.1 shows a cross-section through the cornea, aqueous humour and lens. The part of the cornea to be removed by laser surgery is shown.

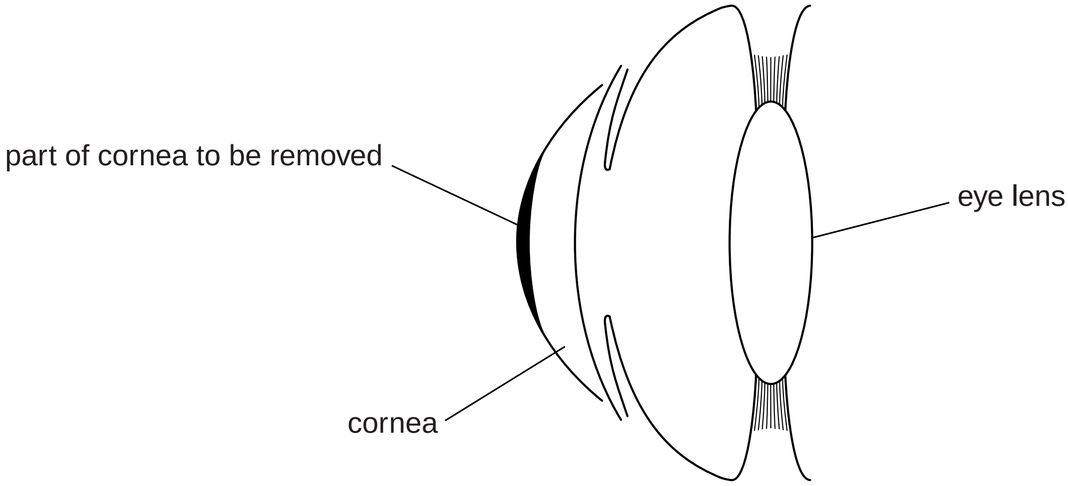

Fig. 2.1

(a) **(i)** Suggest the defect that would be corrected by the removal of the part of the cornea shown in Fig. 2.1.

.... [1]

(ii) Explain your answer.

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.... [3]

(b) Explain the advantages of laser surgery compared with surgery using scalpels.

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.... [7]

[Total: 11]

3 A student suggests that MRI (magnetic resonance imaging) scans are safer than X-ray scans because no electromagnetic radiation passes through a patient during the scan.

Describe in outline the physics of magnetic resonance imaging and explain whether you agree with the student.

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.... [10]

[Total: 10]

4 **(a)** State the equation that relates the transmitted intensity I of a beam of X-rays after passing through a medium of thickness x to the incident intensity I_o. Give the meaning of any additional terms which have not already been defined above.

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....

.... [2]

(b) **(i)** The table in Fig. 4.1 contains data of the transmitted intensity I through a medium for varying thickness x of the medium. Complete the table in Fig. 4.1.

intensity I after passing through thickness x / $W\,m^{-2}$	thickness x of medium / m	$\ln(I / W\,m^{-2})$
1.32×10^8	0.5×10^{-2}	
4.14×10^6	1.0×10^{-2}	
1.29×10^5	1.5×10^{-2}	
4.06×10^3	2.0×10^{-2}	
1.27×10^2	2.5×10^{-2}	

[1]

Fig. 4.1

(ii) On Fig. 4.2 plot $\ln I$ against thickness x and draw the line of best fit. [3]

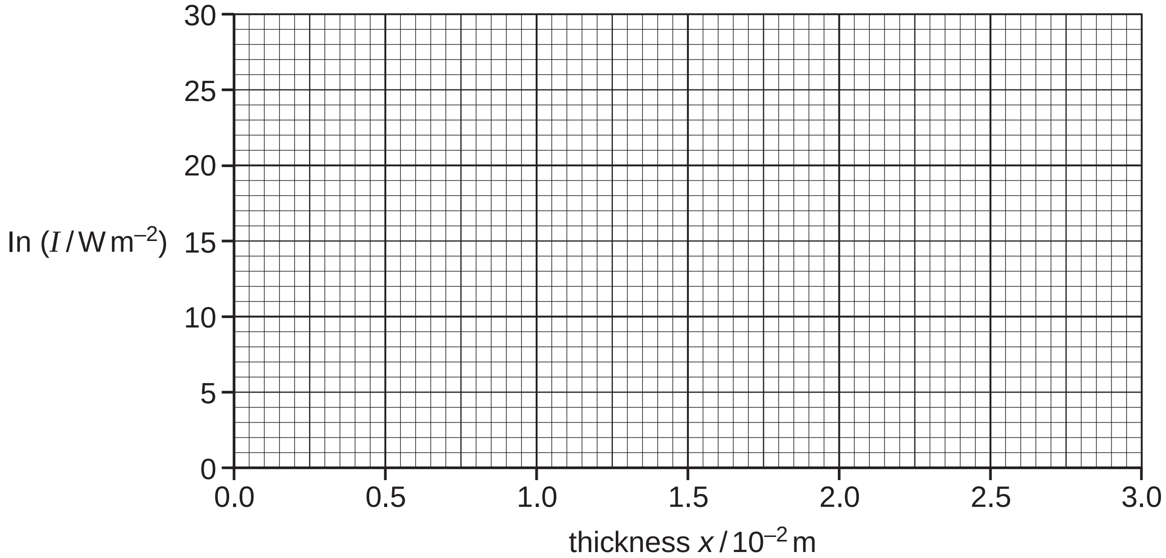

Fig. 4.2

(iii) Determine the gradient.

gradient = ... [2]

(iv) Use your graph to find the incident intensity I_o.

I_o = ... $W m^{-2}$ [2]

(v) Calculate the thickness *x* of the medium that would reduce the transmitted intensity to $\frac{1}{4}$ of its original intensity.

x = ... m [3]

[Total: 13]

5 **(a)** The dose equivalent due to a period of exposure to X-rays of quality factor 2 is 3.0 mSv.

(i) Explain what is meant by *dose equivalent*.

....

....

.... [1]

(ii) Calculate the absorbed dose due to the period of exposure to the X-rays. Give an appropriate unit.

absorbed dose = ... unit .... [3]

(iii) Calculate the energy absorbed by a 1.6 kg mass of muscle due to the dose equivalent of 3.0 mSv.

energy = ... J [2]

(b) The exposure in **(a)** was calculated to provide minimal risk to the patient with any adverse effect being stochastic in nature.

(i) Explain the effect on living matter of exposure to ionising radiation.

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.... [3]

(ii) Explain what is meant by the term *stochastic*.

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.... [2]

[Total: 11]

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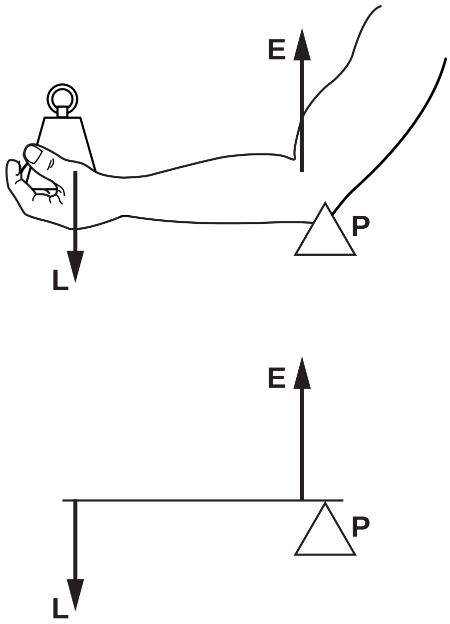
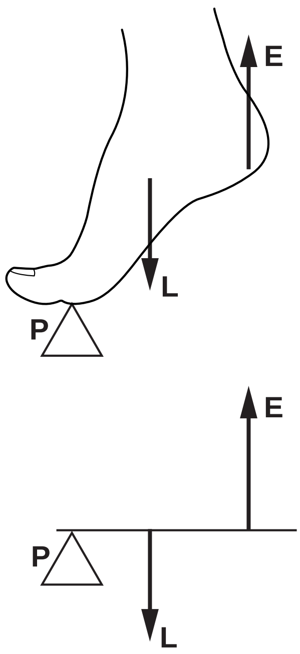
6 Movement in the body occurs through the use of lever systems. Muscles apply forces to bones which rotate about pivots. The relative positions of *effort*, *load* and *pivot* affect the class of the lever system. Fig. 6.1 shows an example within the body in which the effort **E** lies between the load **L** and the pivot **P**. This is called a *third-class* lever system. The foot as shown in Fig. 6.2 is a *second-class* lever system with **L** situated between **P** and **E**.



third-class lever

Fig. 6.1



second-class lever

Fig. 6.2

(a) Without numerical calculation, fill in the table in Fig. 6.3 to describe how the size of **L** compares with the size of **E** for each system and thus how the *mechanical advantage* (MA) compares with 1.0. Use the words 'greater than' , 'smaller than' or 'equal to'.

system	comparison of **L** with **E**	comparison of MA with 1.0	class of lever system
arm	**L** .... **E**	MA 1.0	third
foot	**L** .... **E**	MA 1.0	second

[3]

Fig. 6.3

(b) Fig. 6.4 shows a lower leg of weight 55 N, shown as **L**, held at an angle of 60° to the vertical by a horizontal tension **E** in the thigh muscle. The centre of mass of the lower leg is at a point in the bone 25 cm from the pivot **P** at the knee. The thigh muscle is attached to the bone 2 cm from **P**.

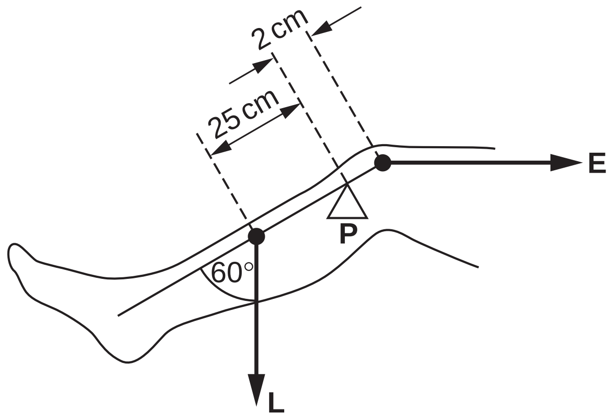


Fig. 6.4

Calculate

(i) the anticlockwise moment provided by **L** about **P**

moment = ... unit = ... [4]

(ii) the effort **E** which the thigh muscle must apply to maintain the leg in equilibrium in the position shown in Fig. 6.4

E = ... N [2]

(iii) the mechanical advantage of the lever system.

mechanical advantage = ... [1]

(iv) How does the effort **E** change as the lower leg is raised from vertical to almost horizontal? Explain your answer.

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.... [3]

[Total: 13]

7 A photo-voltaic cell is an electrical component which can generate a current proportional to the intensity of light incident on its light-sensitive surface. One type of solar panel uses a number of photo-voltaic cells in series to provide a sufficient voltage to power a practical device.

(a) The measured intensity of the solar radiation received on the upper atmosphere of the Earth is $1400\,\mathrm{W\,m^{-2}}$. The mean radius of the Earth's orbit round the Sun is $1.5 \times 10^{11}\,\mathrm{m}$.

(i) Show that

1 the surface area of a sphere of radius $1.5 \times 10^{11}\,\mathrm{m}$ is about $3 \times 10^{23}\,\mathrm{m^2}$

[1]

2 the Sun emits radiation with a total power of about $4 \times 10^{26}\,\mathrm{W}$ into the surrounding space.

[1]

(ii) Calculate the rate of conversion of mass to energy in the Sun.

rate of conversion = ... $\mathrm{kg\,s^{-1}}$ [2]

(b) Explain why, when the Sun is directly overhead at the equator

(i) the maximum intensity received on the surface of the Earth is less than $1000\,\mathrm{W\,m^{-2}}$

....

.... [1]

(ii) the maximum intensity decreases with distance North and South of the equator.

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.... [1]

(c) An ornamental water fountain is driven by a pump powered by the electrical output of a solar panel. The following data is relevant to the operation of the system, which is arranged to give maximum solar power input.

area of light-sensitive surface of panel:	$0.080\,m^2$
solar intensity at the location of the panel:	$750\,W\,m^{-2}$
voltage output of panel:	17 V
current delivered to the pump:	270 mA
delivery rate of the fountain:	$0.50\,m^3$ per hour
efficiency of pump:	35%
density of water:	$1000\,kg\,m^{-3}$

Calculate

(i) the solar power input to the panel

power input = ... W [1]

(ii) the electric power generated by the panel

power generated = ... W [1]

(iii) the efficiency of the panel in converting solar power to electrical power

efficiency = ... [2]

(iv) the height of the fountain of water.

maximum height = ... m [5]

(d) A solar panel of greater area than the one in **(c)** supplies 80 W of electrical power to a heating coil immersed in water.

(i) Calculate the time required to heat 0.50 kg of water from 25 °C to 100 °C, assuming no loss of heat to the surroundings. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

time = ... s [3]

(ii) Suggest **two** reasons why this type of solar panel is unlikely to replace conventional mains-powered electric kettles as a means of boiling water, even when the solar power is a maximum.

1. ....

....

....

2. ....

....

.... [2]

[Total: 20]

END OF QUESTION PAPER

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