OCR
RECOGNISING ACHIEVEMENT

ADVANCED GCE UNIT **2825/02**

PHYSICS A

Health Physics

FRIDAY 26 JANUARY 2007 Morning

Time: 1 hour 30 minutes

Additional materials: Electronic calculator

Candidate Name

Centre Number

Candidate Number

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre Number and Candidate number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED. ANSWERS WRITTEN ELSEWHERE WILL NOT BE MARKED.

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.
- You are advised to show all the steps in any calculations.
- The first eight questions concern Health Physics. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	12	
2	12	
3	6	
4	5	
5	10	
6	13	
7	5	
8	7	
9	20	
TOTAL	90	

This document consists of **17** printed pages and **3** blank pages.

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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, $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \dots$

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

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

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

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

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Answer **all** the questions.

1 A gymnast of mass 75 kg is performing a press-up as part of his exercise routine. The gymnast raises his centre of mass through a vertical distance of 250 mm in 0.85 s during this exercise.

(a) **(i)** Calculate the work done by his muscles in performing this exercise.

work done = ... J [2]

(ii) Calculate the average output power of the muscles during this exercise.

power = ... W [2]

(iii) Suggest why the actual rate of supply of energy to the muscles is greater than your answer to **(a)(ii)**.

....

....

....[1]

(b) The gymnast stands with his back and the heels of his feet touching a wall (Fig.1.1). Explain why, when bending at the waist, he **cannot** achieve and sustain the position shown in Fig.1.2.

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....[2]

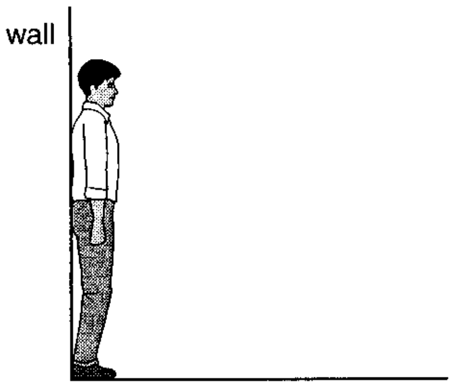

Fig. 1.1

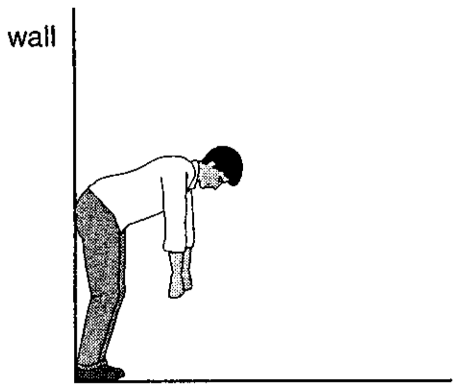

Fig. 1.2

(c) Sketch a diagram to show the posture which a person should adopt to minimise the possibility of damage to the back when lifting a heavy object from the ground onto a table.
Explain the important features of this posture.

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....[5]

[Total: 12]

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2 Fig. 2.1 shows a diagram of a cylindrical lens. Figs. 2.2 and 2.3 show the view from above the lens and from one side of the lens respectively. Three light rays parallel to the principal axis are shown on each of Fig. 2.2 and Fig. 2.3.

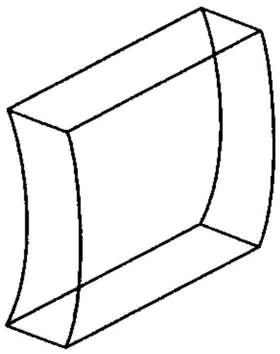

Fig. 2.1

view from above

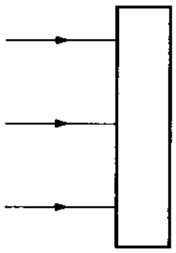

Fig. 2.2

view from one side

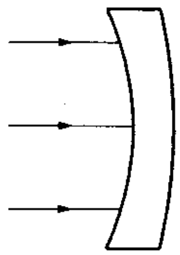

Fig. 2.3

(a) **(i)** State the eye defect that this type of lens corrects. .... [1]

(ii) Explain how an eye that suffers from the defect in **(i)** differs from a healthy normal eye.

....

....

.... [2]

(iii) Complete Fig. 2.2 and Fig. 2.3 to show the paths of the rays emerging from each view of the lens.

[2]

(b) A person can focus using one eye on objects situated at distances ranging from infinity to 500 mm from the eye. When focusing on an object at her near point, the power of the eye is 55 D. Assume that all of the refraction in the eye occurs at the front surface of the cornea. Calculate

(i) the distance from the cornea to the retina

distance = ... mm [3]

(ii) the necessary power required for this eye to view an object at a normal near point of 250 mm

power = ... D [2]

(iii) the power of the corrective lens required to allow this eye to see clearly an object at 250 mm.

power = ... D [2]

[Total: 12]

3 Describe how the perception of intensity of light and of colour has social implications in advertising. Your answer should make reference to the intensity and colour of light used in **two** very different advertising situations.

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....[6]

[Total: 6]

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4 Laser light can be used to cut body tissue. Describe the processes involved and outline the advantages of laser surgery compared with conventional surgery using a scalpel.

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....[5]

[Total: 5]

5 A sound engineer is monitoring the sound levels before an open-air concert so that the audience at the back may hear the whole range of frequencies during a piano solo. The piano produces sound in the frequency range 28 Hz – 14000 Hz.

Fig. 5.1 shows the frequency response of an average healthy ear.

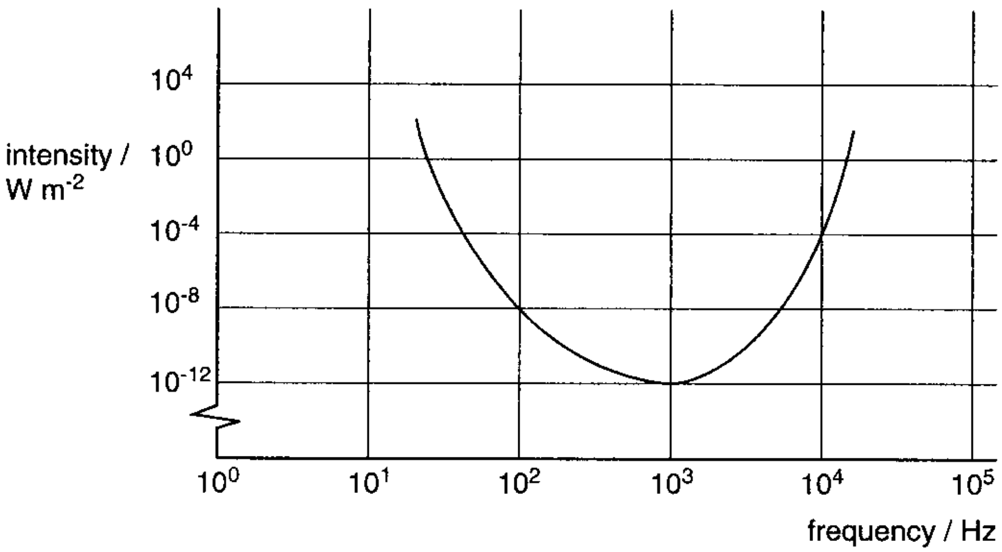

Fig. 5.1

(a) Explain the significance of the intensity 10^{-12} W m^{-2}.

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....

....[1]

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(b) The piano produces a sound of frequency 100 Hz. The intensity level of this sound 4.0 m from the piano is 63.0 dB.
Show that the intensity of this sound at this distance is about $2 \times 10^{-6}\,\text{W m}^{-2}$.

[2]

(c) The intensity of sound I, is proportional to the inverse square of the distance d from the source.

(i) Use information from **(b)** to calculate the intensity of this sound at a distance 32 m from the piano.

intensity = ... W m^{-2} [2]

(ii) Calculate the intensity level for the sound calculated in **(i)**.

intensity level = ... dB [2]

(iii) State with reference to Fig. 5.1 whether the 100 Hz sound can be heard at a distance of 32 m. Discuss any other factors which the sound engineer should consider.

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....

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....[3]

[Total: 10]

6 **(a)** Fig. 6.1 is a block diagram of the energy changes that occur after electrons are emitted from the cathode of a simple X-ray tube.

Complete Fig. 6.1. [3]

.... energy of the electrons just outside the cathode	→	.... energy of electrons as they strike the target	→	.... energy in the target	+	X-ray photons

Fig. 6.1

(b) The energy of an electron as it arrives at the target of a particular X-ray tube is 1.40×10^{-14} J. The number of electrons incident each second on the target is 3.75×10^{17}.

Calculate the power of the electron beam striking the target.

power = ... W [2]

(c) The X-ray tube has an efficiency of 0.5%.
Explain the significance of this in the design of an X-ray tube.

....

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....[2]

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(d) In order to halve the intensity of an X-ray beam, the beam is passed through an aluminium filter of thickness 3.0 mm.
Calculate the linear attenuation coefficient μ for aluminium.
Give an appropriate unit for your answer.

μ = ... unit .... [4]

(e) Explain **two** advantages of the use of X-rays compared with MRI for the imaging of a broken bone.

....

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....[2]

[Total: 13]

7 Ionising radiation has both a direct and indirect effect on living matter.

(a) Explain the difference between a *direct* effect and an *indirect* effect on a microscopic scale.

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....[4]

(b) State one possible effect of exposure to ionising radiation.

....[1]

[Total: 5]

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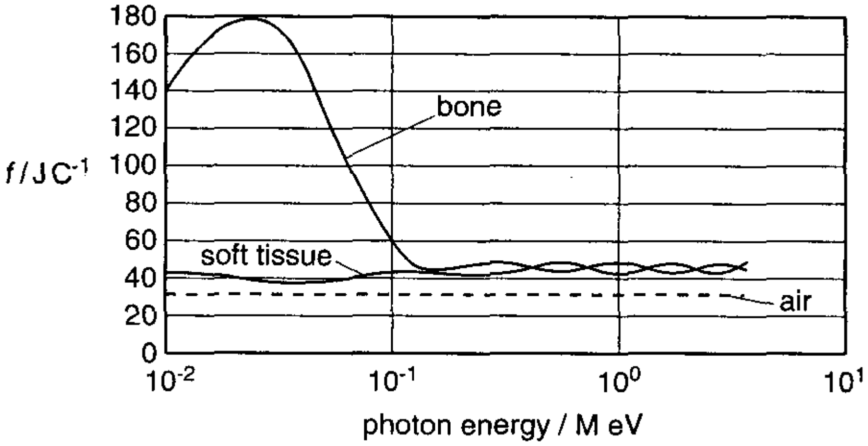
8 The absorbed dose for X-ray photons is equal to a factor *f* multiplied by the exposure. The factor *f* depends on both the energy of the absorbed photons and on the type of absorbing material. Fig. 8.1 shows the variation of *f* with photon energy for bone, soft tissue and air.



From *Medical Physics* by Jean Pope.

Fig. 8.1

(a) Calculate the absorbed dose, giving appropriate units, for an exposure of 0.050 C kg^{-1} when X-rays of photon energy 100 keV are deployed to image

(i) bone

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

(ii) soft tissue.

absorbed dose = ... unit..........[1]

(b) It is suggested that using less energetic X-ray photons would be an advantage. By considering the absorbed dose, the effect on the image contrast and the detection efficiency of the film, explain whether you agree.

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....[3]

[Total: 7]

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TURN OVER FOR QUESTION 9

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9 A champion BMX cyclist wishes to become a professional and seeks help from an A-level Physics student in creating an act. The student suggests two stunts; one involving a horizontal take-off on to a sloping ramp and the other involving a loop-the-loop manoeuvre.

(a) The student begins by finding out the maximum speed the cyclist can produce on level ground. Two flags are positioned 240 m apart on a flat road. The cyclist is told to accelerate to the first flag and to pedal as hard as he can until the second flag is passed. This is shown in Fig. 9.1.

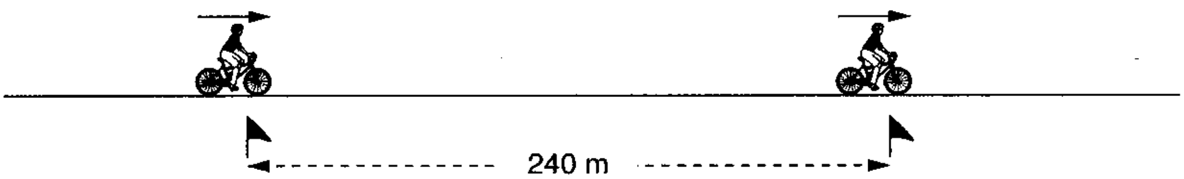

Fig. 9.1

The student gets the cyclist to repeat the test three times and records the following results :

14.8 s 17.2 s 15.6 s

Show that the mean speed the cyclist can maintain over the 240 m is about $15\,m\,s^{-1}$.

[2]

(b) The student designs the stunt shown in Fig. 9.2 where the cyclist must take off at $15\,m\,s^{-1}$ from a horizontal launch pad and land smoothly just at the edge of a sloping ramp.

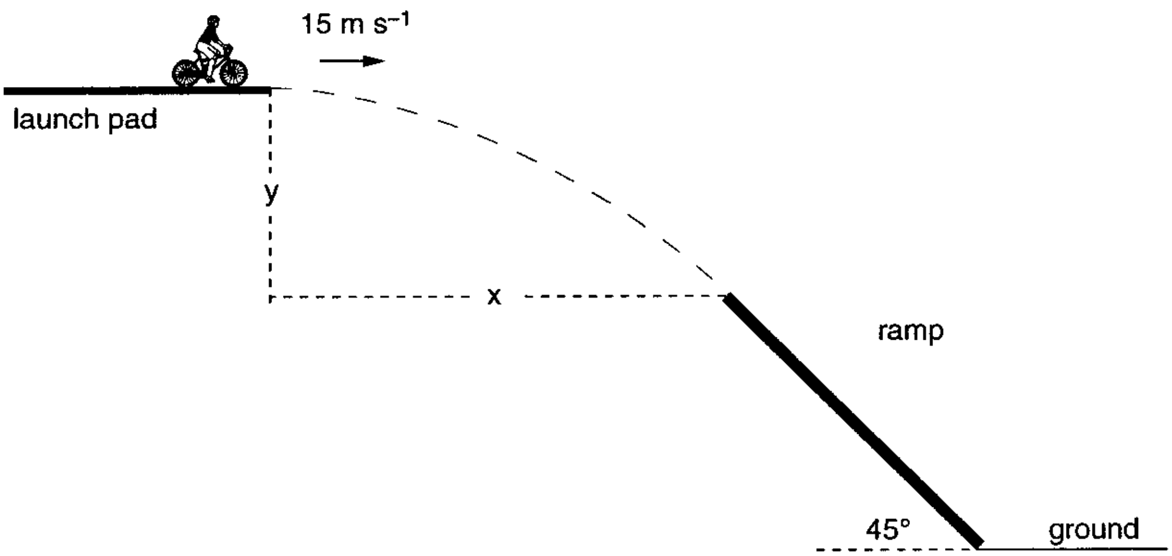

Fig. 9.2

The student reasons that in order to land smoothly, the direction of the velocity of the cyclist on reaching the edge of the ramp must be at the same 45° angle as the ramp itself.
Ignore air resistance in all calculations.

(i) Explain why the vertical component of the velocity on reaching the ramp must be $15\,m\,s^{-1}$.

....

....

....[1]

(ii) The student calculated the vertical fall y to the ramp to be about 11 m. Show how he arrived at this result.

[2]

(iii) The student calculated the horizontal jump x to the ramp to be about 23 m. Show how he arrived at this result.

[1]

(iv) The total mass of the cyclist and bike is 86 kg. Show that the kinetic energy of the cyclist on reaching the ramp is about 19 kJ.

[3]

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(c) The student next designs a loop-the-loop stunt shown in Fig. 9.3. The cyclist must enter the circular runway at the same $15\,m\,s^{-1}$ speed in order to exit from it smoothly.

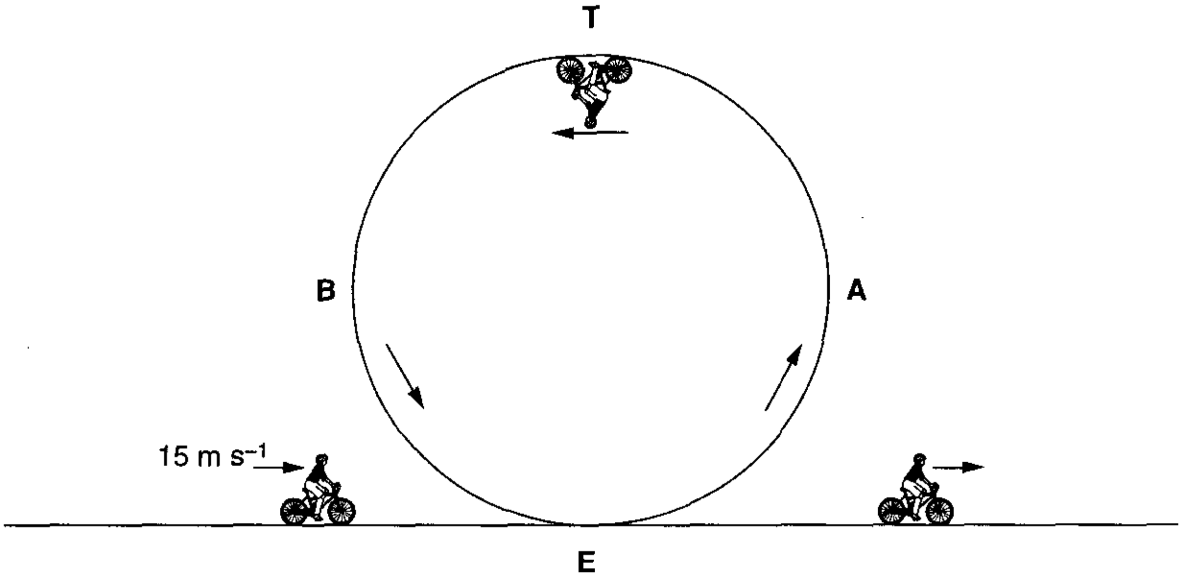

Fig. 9.3

In order to calculate the maximum diameter of loop in which the cyclist can safely execute the manoeuvre, the student makes the following assumptions

- the cyclist stops pedalling once he enters the loop at **E**
- the normal reaction of the runway on the tyre just becomes zero at the top of the loop **T**
- therefore the centripetal force at the top **T** is provided by the force of gravity only
- air resistance and runway friction can be ignored.

As a result, the student calculates the diameter of the track to be 9.17 m.

(i) Show that the speed of the cyclist at the top **T** of the loop should be $6.7\,m\,s^{-1}$.

[3]

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(ii) The total mass of the cyclist and bike is 86 kg. Calculate

1 the kinetic energy of the cyclist at the top **T**

kinetic energy = ... J [2]

2 the gravitational potential energy of the cyclist at the top **T**. Take the gravitational potential energy at **E** to be zero.

potential energy = ... J [2]

(iii) Show that the sum of the kinetic and potential energies at the top **T** of the loop is equal to the kinetic energy of the cyclist as he enters the loop at **E**.

[2]

(iv) The cyclist suggests that removing the top half or semicircle of the loop from **A** to **B** would allow him to fly in a semi-circular arc through the air and thus make a more spectacular stunt. How should the student should respond to this suggestion? Explain your reasoning.

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....

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....[2]

[Total: 20]

END OF QUESTION PAPER

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