RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A

2825/02

Health Physics

Wednesday **26 JANUARY 2005** Morning 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

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 nine questions concern Health Physics. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	4	
2	6	
3	12	
4	7	
5	8	
6	7	
7	7	
8	14	
9	5	
10	20	
TOTAL	90	

This question paper consists of 16 printed pages.

SP (NF/SLM) S72323/5

Registered Charity Number: 1066969

[Turn over

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, $p = \frac{1}{3}\dfrac{Nm}{V}<c^2>$

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

For Examiner's Use

Answer **all** the questions.

1 Fig. 1.1 shows the foot of a person when in a resting position. Fig. 1.2 shows the same foot at the moment of first contact with the ground while taking a stride.

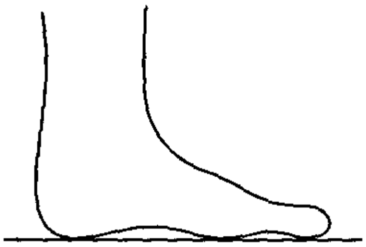

Fig. 1.1

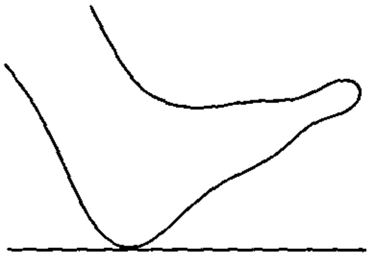

Fig. 1.2

(a) On Figs. 1.1 and 1.2, draw and label arrows to indicate the direction of any forces that act on the foot due to the ground. [3]

(b) State the change in the frictional force acting on the foot which occurs during a stride from the moment of first contact (Fig. 1.2) to the instant when the resting position occurs (Fig. 1.1).

....

....[1]

[Total: 4]

For Examiner's Use

2 Fig. 2.1 shows the variation with frequency of the minimum detectable sound intensity for a patient who has a hearing impairment.

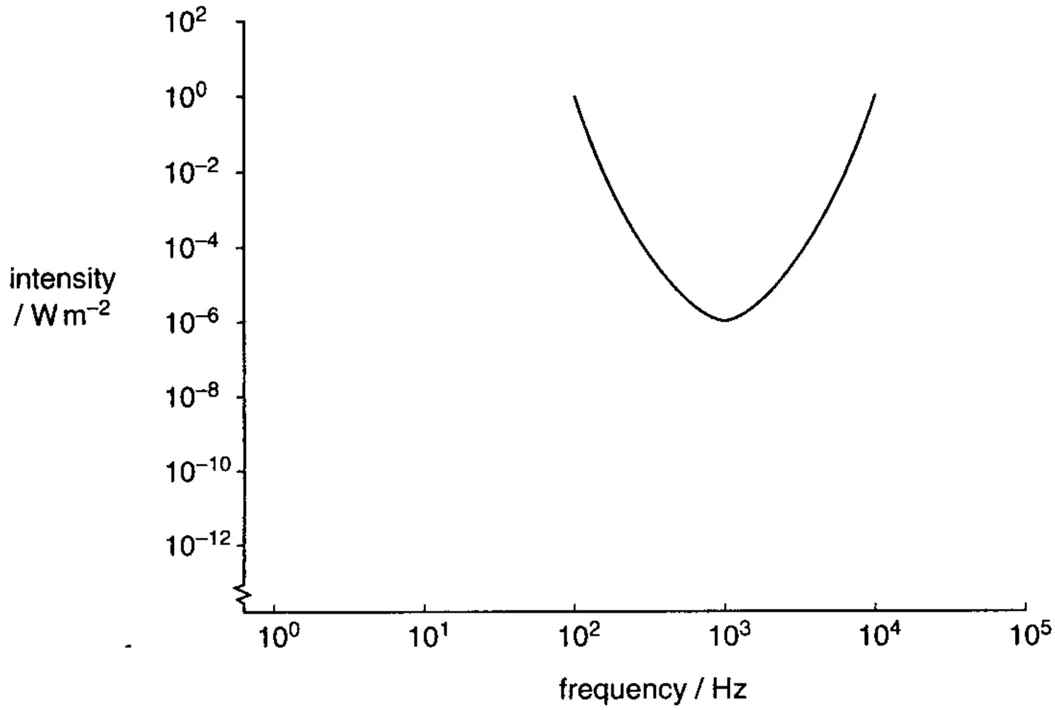

Fig. 2.1

(a) On Fig. 2.1, sketch a graph to show the variation with frequency of the minimum detectable sound intensity for a person who has **normal** hearing. [3]

(b) Describe **three** ways in which the hearing of the patient differs from that of a person who has normal hearing. Refer to numerical values on the axes of Fig. 2.1.

....

....

....

....[3]

[Total: 6]

3 A student has an eye with a near point of 40.0 cm and a far point at infinity.

(a) Explain the term *near point*.

....

....[1]

(b) The power of the student's eye is 59 D when focusing on an object at infinity.

(i) Show that the focal length of the refracting system of this eye is about 17 mm.

[2]

(ii) State the distance of the retina from the cornea. Assume that all of the refraction in the eye occurs at the front edge of the cornea.

distance = ...m [1]

(iii) Use the lens equation to calculate the power of the student's eye when focusing on an object at its near point of 40 cm.

power = ... D [3]

(c) The near point of a **normal** eye is situated at a distance of 25 cm from the eye. Calculate the power of the refracting system of a normal eye with the same cornea-retina distance as the eye in **(b)**, when it is focusing on an object at 25 cm.

power = ... D [2]

(d) Calculate the power of the corrective lens needed for the eye in **(b)** to view comfortably an object at a distance of 25 cm from the eye.

power = ... D [2]

(e) State the defect from which the eye in **(b)** suffers.

....[1]

[Total: 12]

4 A loudspeaker is mounted on a stand 5 m above the ground. It produces a sound of constant volume and frequency. This sound is emitted radially in all directions with the wavefront expanding outwards (Fig. 4.1).

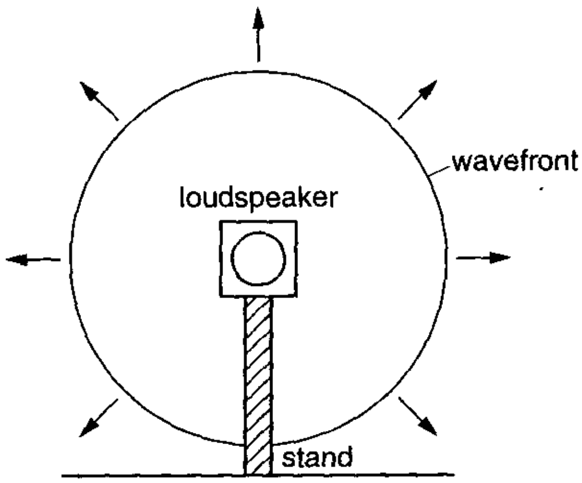

Fig. 4.1

The output power of the loudspeaker is 400 W when delivering sound at full volume.

(a) Show that the intensity of sound at a distance of 3 m from the loudspeaker is about 3.5 W m^{-2}. Ignore any sound reflected from the ground.

surface area of a sphere = $4\pi r^2$

[2]

(b) **(i)** Calculate the intensity level due to the intensity of sound in **(a)**. Give a suitable unit for your answer.

intensity level = ... unit .... [3]

For Examiner's Use

(ii) Comment on the loudness of this sound making reference to a relevant threshold intensity or threshold intensity level.

....

....

....[2]

[Total: 7]

5 Explain and distinguish between scotopic and photopic vision. Your response should make reference to

- the existence of the two types of vision
- the variation with intensity of the response of each type of light receptor cell
- a description and explanation of how vision changes as a bright day turns into a dark night.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....[8]

[Total: 8]

For Examiner's Use

6 Explain with the aid of a suitable example, the use of a contrast medium in the production of an X-ray image on a film. State the property of the atoms in the person being X-rayed which affect the absorption of X-rays.

....

....

....

....

....

....

....

....

....

....

....

....

....[7]

[Total: 7]

7 A student wishes to explain the principles involved in a CT scan. She draws 9 boxes, each representing a unit volume of soft tissue or bone. She draws X-ray beams that pulse units of energy in the way shown in Fig. 7.1 and writes down the energy outputs after passing through three boxes.

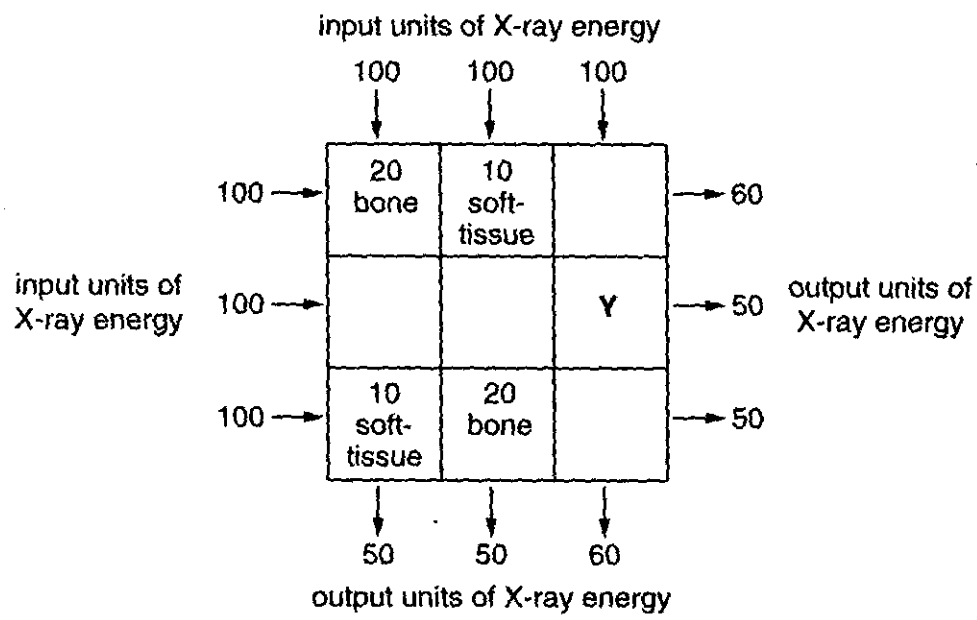

Fig. 7.1

For Examiner's Use

(a) Suggest what the numbers 20 and 10, in the first two boxes of the top row, represent.

....

....[2]

(b) Explain why the student has put the larger number in a box that represents a unit volume of bone.

....

....[1]

(c) Complete Fig. 7.1 by filling in the values for the remaining five boxes and hence determine the material contained in box **Y**.

material = ... [4]

[Total: 7]

[Turn over

8 An endoscope used to view directly the inside of the stomach comprises bundles of coherent and non-coherent optic fibres.

(a) Explain how the arrangement of fibres in a *coherent* bundle of optic fibres differs from the arrangement in a *non-coherent* bundle.

....

....[2]

(b) State the use of

(i) the non-coherent bundle of optic fibres

....[1]

(ii) the coherent bundle of optic fibres.

....[1]

(c) A neodymium-yttrium aluminium garnet (Nd-YAG) laser may be pulsed along an endoscope to 'burn' cancerous tissue found in the oesophagus.

(i) Explain the effect on a tissue cell of exposure to this laser light.

....

....[2]

(ii) Cancerous tissue often contains a black or dark pigment. Suggest why this might make the process of 'burning' the cancerous tissue more efficient.

....

....[1]

(d) During a single pulse from the laser, 0.12 J of energy is delivered to an area of 1.2 mm^2 of tissue in a time interval of 0.75 ms.

Calculate

(i) the intensity of the laser

intensity = ... $W\,m^{-2}$ [3]

(ii) the number of photons in the pulse if the wavelength of the laser light is 1060 nm.

number = ... [4]

[Total: 14]

9 The absorbed dose by a tissue due to ionising radiation may be estimated from the exposure.

(a) Explain the term *exposure*.

....

....[2]

(b) An energy of 5.4×10^{-18} J is required to produce one ion pair in air.

Estimate the absorbed dose for tissue if the exposure is 2.5×10^{-6} C kg^{-1}.
Give an appropriate unit for your answer.

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

[Total: 5]

[Turn over

10 Although the idea for the airbag was first suggested more than fifty years ago, it has only been a compulsory safety feature in the modern motor car since 1998. When a car experiences a serious head-on collision, the seat belt is designed to restrain the driver's body. However, without the cushioning effect of an airbag, the inertia in the driver's head will cause it to carry on moving at the speed of the car until it is stopped by the steering wheel or the windscreen. When activated, the airbag must be fully inflated before the driver's head reaches it so that the head hits a soft target.

One early system stored the gas for the airbag in a cylinder under the driver's seat. When the deceleration of the car was sufficiently large, a sensor caused an electrical circuit to operate and open a valve so that the compressed gas could rush into the airbag on the steering wheel.

The sensor used a steel ball and spring in a cylinder as shown in Fig. 10.1.

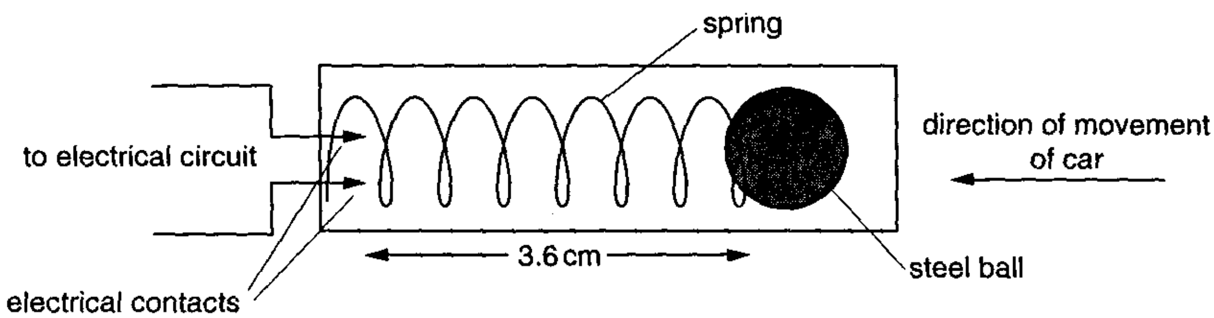

Fig. 10.1

When the car was being driven normally, the spring kept the steel ball apart from the two electrical contacts inside the cylinder. But if the deceleration became large enough, the inertia of the free ball compressed the spring and the ball touched the two contacts, thus activating the electrical circuit.

The method of storing compressed gas in a cylinder was not very reliable because some cylinders slowly leaked gas and so all had to be checked regularly.

The modern method of inflating an airbag is to generate the gas chemically by activating an electrical heater or detonator in an explosive chemical mixture. The heating starts a very rapid chemical reaction which produces nitrogen for the airbag. This means that the folded airbag along with chemicals and heater can all be located together in a compact container and positioned anywhere inside the car.

Consider the following data for a car running head-on into an immovable object.

initial velocity of car	= 54 km hr^{-1}
final velocity of car	= 0
car front crumple distance	= 1.25 m
distance from head to windscreen	= 0.96 m

(a) Show that the car's speed in m s^{-1} just before hitting the object is 15 m s^{-1}.

[2]

For Examiner's Use

(b) Calculate

(i) the deceleration of the car during the collision (assumed to be constant)

deceleration = ... $m\,s^{-2}$ [2]

(ii) the time taken for the car to crumple to rest.

time = ... s [2]

(c) The data for a ball and spring sensor is given below.

mass of ball	= 0.12 kg
spring constant	= 30 $N\,m^{-1}$
distance to be compressed	= 3.6 cm

Calculate

(i) the force necessary to compress the spring by 3.6 cm

force = ... N [2]

(ii) the deceleration which the force in **(c)(i)** would cause in a mass of 0.12 kg.

deceleration = ... $m\,s^{-2}$ [1]

(d) When the airbag was fully inflated from a storage cylinder, the bag had a volume of 0.060 m^3, with the gas inside at a pressure of 250 kPa. If the storage cylinder had a volume of $3.0 \times 10^{-4}\,m^3$, calculate the stored gas pressure, assuming the gas was ideal and at constant temperature.

pressure = ... Pa [2]

(e) Suppose that the pressure inside the cylinder dropped by 20% over a period of 4 weeks. Assuming the mean temperature of the cylinder is 17 °C, calculate the average number of gas molecules leaving per second during this time.

number leaving per second = ... [4]

(f) The data for a modern airbag is given below.

energy required for reaction to start	= 0.96 J
heater wire cross sectional area	= $2.75 \times 10^{-8}\,m^2$
heater wire length	= 2.2 cm
resistivity of heater wire	= $1.5 \times 10^{-6}\,\Omega\,m$
battery voltage	= 12 V

(i) Show that the resistance of the heater filament is 1.2 Ω.

[2]

(ii) Hence calculate the time taken for the heater to start the chemical reaction.

time to start = ... s [3]

[Total: 20]

END OF QUESTION PAPER