OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS
Advanced GCE

PHYSICS A — 2825/02

Health Physics

Monday **27 JUNE 2005** Afternoon 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 eight questions concern Health Physics. The last question concerns general physics.

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

This question paper consists of 22 printed pages and 2 blank pages.

SP (NF/SLM) S87695/5

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,	$p = \frac{1}{3}\frac{Nm}{V}<c^2>$
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,	$= 10 \lg\left(\frac{I}{I_0}\right)$

For Examiner's Use

Answer **all** the questions.

1 A student constructs a model arm to demonstrate how two particular muscles in the upper arm control movement of the lower arm. Fig. 1.1 is a simplified diagram of this model arm.

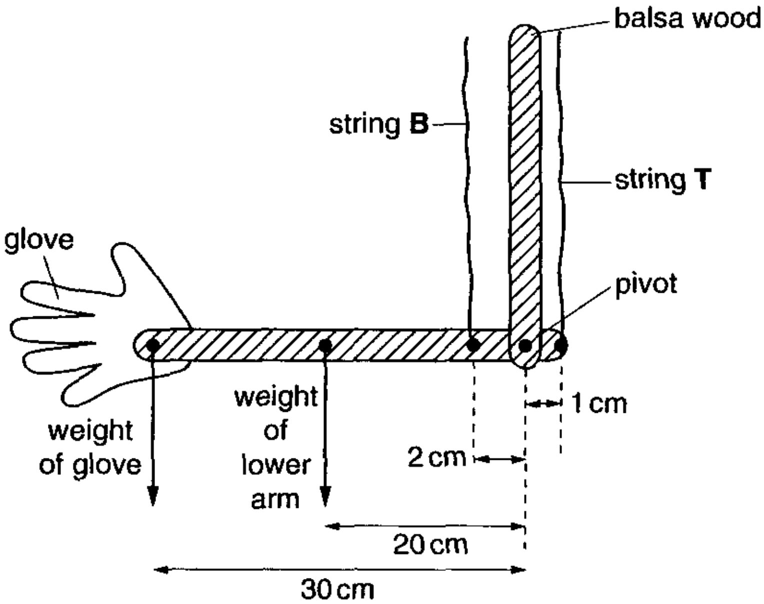

Fig. 1.1

(a) Draw an arrow on Fig. 1.1 to indicate the position on the model arm of a tendon. Label the arrow **X**. [1]

(b) Explain how the model arm may be used to demonstrate the action of the muscles in first lowering and then raising the lower arm. You should make reference to the strings **B** and **T** in your response.

lowering the arm ....

....

raising the arm ....

....[3]

(c) Use the following data for the model to calculate the tension required in string **B** to maintain the arm in the position shown in Fig. 1.1.

mass of lower arm = 75 g
mass of glove = 135 g
distance of centre of mass of lower arm from pivot = 20 cm
distance of centre of mass of glove from pivot = 30 cm
string **B** is attached to lower arm at a distance of 2.0 cm from the pivot
string **T** is attached to the lower arm at a distance from the pivot of 1.0 cm
the tension in string **T** is zero.

tension = ... N [3]

[Total: 7]

2 Figs. 2.1 and 2.2 show the paths of two rays of light that travel from the same point on each object, pass through the refracting system of an eye and converge to a point on the retina.

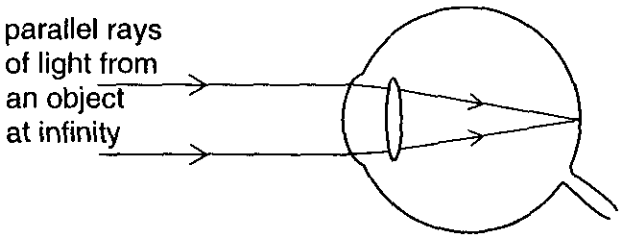

Fig. 2.1

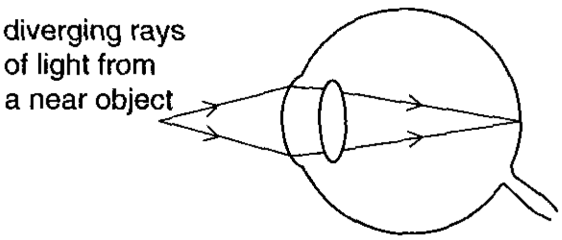

Fig. 2.2

When focusing on an object at infinity (Fig. 2.1) and then focusing on an object near to the eye (Fig. 2.2), the eye is said to undergo accommodation.

(a) Explain the meaning of the term *accommodation*. Your answer should make reference to Figs. 2.1 and 2.2.

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....[3]

(b) Fig. 2.3 shows the relative positions of the near point and far point for one eye of a patient.

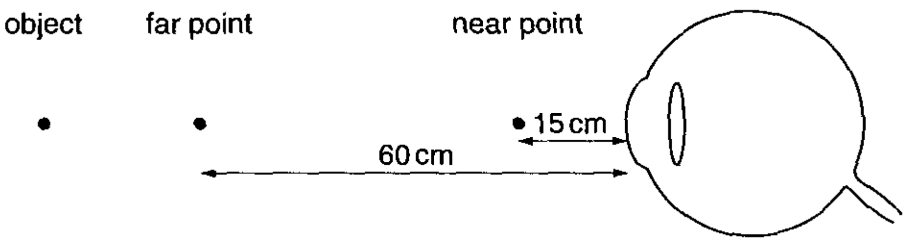

Fig. 2.3

(i) State the defect for this eye.

....[1]

(ii) Draw lines on Fig. 2.3 to show the paths of **two** rays of light from the object, through the refracting system of the eye and onto the retina. [2]

For Examiner's Use

(c) The power of the eye in **(b)** when viewing an object at a distance of 60 cm from the eye is 64 D.

(i) Use the lens equation to calculate the image distance from the front surface of the eye. Treat the refracting system of the eye as a single thin lens positioned at the front surface of the eye.

distance = ... m [3]

(ii) Calculate the power needed by this eye to view clearly an object at infinity.

power = ... D [2]

(iii) Calculate the power of the corrective lens needed for this eye to view clearly an object at infinity.

power = ... D [2]

[Total: 13]

For Examiner's Use

3 (a) Explain what is meant by the 'frequency response' to sound waves of an average person.

....

....

....

....[3]

(b) Describe and explain how this frequency response varies with age.

....

....

....

....[3]

[Total: 6]

For Examiner's Use

4 Explain the eye defect *astigmatism*. Discuss how an appropriate spectacle lens may be employed to correct the defect. Your answer should include

- a possible cause of the defect
- a test for the defect
- a diagram and explanation of the shape of the corrective lens.

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[7]

[Total: 7]

For Examiner's Use

5 Fig. 5.1 shows a simplified X-ray tube.

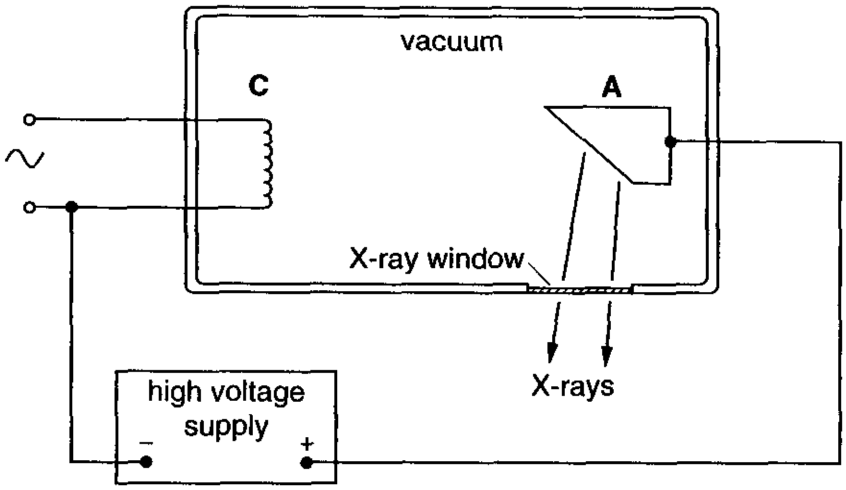

Fig. 5.1

Explain briefly, with reference to the parts labelled **C** and **A**,

- how X-rays are generated
- the energy conversions that occur.

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....[7]

[Total: 7]

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Question 6 over the page.

[Turn over

For Examiner's Use

6 In order to take an X-ray photograph, the X-ray beam is passed through an aluminium filter to remove low energy X-ray photons before reaching the patient.

(a) Suggest why it is necessary to remove these low-energy X-rays.

....

....[1]

(b) The average linear attenuation coefficient for X-rays that penetrate the aluminium is $250\,\text{m}^{-1}$. The intensity of an X-ray beam after travelling through 2.5 cm of aluminium is $347\,\text{W}\,\text{m}^{-2}$.

Show that the intensity incident on the aluminium is about $2 \times 10^5\,\text{W}\,\text{m}^{-2}$.

[3]

(c) The X-ray beam at the filter has a circular cross-section of diameter 0.20 cm. Calculate the power of the X-ray beam emerging from the aluminium filter. Assume that the beam penetrates the aluminium filter as a parallel beam.

power = ... W [2]

For Examiner's Use

(d) The total power of X-rays generated by an X-ray tube is 18 W.
The efficiency of conversion of kinetic energy of the electrons into X-ray photon energy is 0.15%.

(i) Calculate the power of the electron beam.

power = ... W [2]

(ii) Calculate the velocity of the electrons if the rate of arrival of electrons is $7.5 \times 10^{17}\,s^{-1}$. Relativistic effects may be ignored.

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

(iii) Calculate the p.d. across the X-ray tube required to give the electrons the velocity calculated in **(ii)**.

p.d.= .... V [3]

[Total: 13]

[Turn over

For Examiner's Use

7 The ratio of reflected intensity to incident intensity for ultrasound reflected at a boundary is related to the acoustic impedance Z_1 of the medium on one side of the boundary and the acoustic impedance Z_2 of the medium on the other side of the boundary by the following equation.

$$\frac{\text{reflected intensity}}{\text{incident intensity}} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$$

(a) State the **two** factors that determine the value of the acoustic impedance.

....

....[2]

(b) An ultrasound investigation was used to identify a small volume of substance in a patient. It is suspected that this substance is either blood or muscle.

During the ultrasound investigation, an ultrasound pulse of frequency 3.5×10^6 Hz passed through soft tissue and then into the small volume of unidentified substance. A pulse of ultrasound reflected from the front surface of the volume was detected 26.5 μs later. The ratio of the reflected intensity to incident intensity for the ultrasound pulse reflected at this boundary was found to be 4.42×10^{-4}. Fig. 7.1 shows data for the acoustic impedances of various materials found in a human body.

medium	acoustic impedance Z/kg m^{-2} s^{-1}
air	4.29×10^2
blood	1.59×10^6
water	1.50×10^6
brain tissue	1.58×10^6
soft tissue	1.63×10^6
bone	7.78×10^6
muscle	1.70×10^6

Fig. 7.1

(i) Use appropriate data from Fig. 7.1 to identify the unknown medium. You must show your reasoning.

medium = ... [4]

For Examiner's Use

(ii) Calculate the depth at which the ultrasound pulse was reflected if the speed of ultrasound in soft tissue is 1.54 km s^{-1}.

depth = ... cm [2]

(iii) Calculate the wavelength of the ultrasound in the soft tissue.

wavelength = ... m [2]

[Total: 10]

For Examiner's Use

8 A student suggests that a cancer caused by exposure to ionising radiation is an example of a *stochastic* effect.

(a) Explain, with reference to the criteria for classification as a stochastic effect, whether you agree with the student's suggestion.

....

....[1]

(b) A second student suggests that a radiation skin burn is a good example of a *non-stochastic* effect of exposure due to ionising radiation. State **two** properties of a non-stochastic effect and explain whether a skin burn meets the criteria for classification, as suggested by the second student.

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....

....

....[2]

(c) A third student is discussing absorbed dose and dose equivalent.

(i) State how *absorbed dose* and *dose equivalent* are related.

[1]

For Examiner's Use

(ii) A dose equivalent of 28 mSv is received from an alpha source of quality factor 20 and a gamma source of quality factor 1. Half of the dose equivalent is received from each source.

Calculate the absorbed dose due to the alpha source. Give an appropriate unit for your answer.

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

[Total: 7]

9 The London Eye, Fig. 9.1, is the largest observation wheel ever built. It has 32 egg-shaped capsules attached to the outside of the rim of the wheel. Each capsule holds up to 25 passengers and completes one revolution in 30 minutes.

The wheel of diameter 122 m, is driven by a drive system based on tyres gripping the edge of the wheel rim. 16 rubber tyres each supply a tangential force of 12.5 kN to the rim. The tyres are pressed against the rim by hydraulic cylinders.

The design engineers used computer simulations to predict all of the stresses on the structure. These programs modelled the effect of metal fatigue as well as wind and temperature changes over the whole structure. All of the 80 cables between the rim of the wheel and the hub (centre) remain under tension as the wheel rotates. The system acts like a large bicycle wheel suspended in the air.

As the wheel rotates, the tension in each cable changes. The wheel and support as a whole has a natural frequency of oscillation and it is important that the combination is not set in oscillation by the wind.

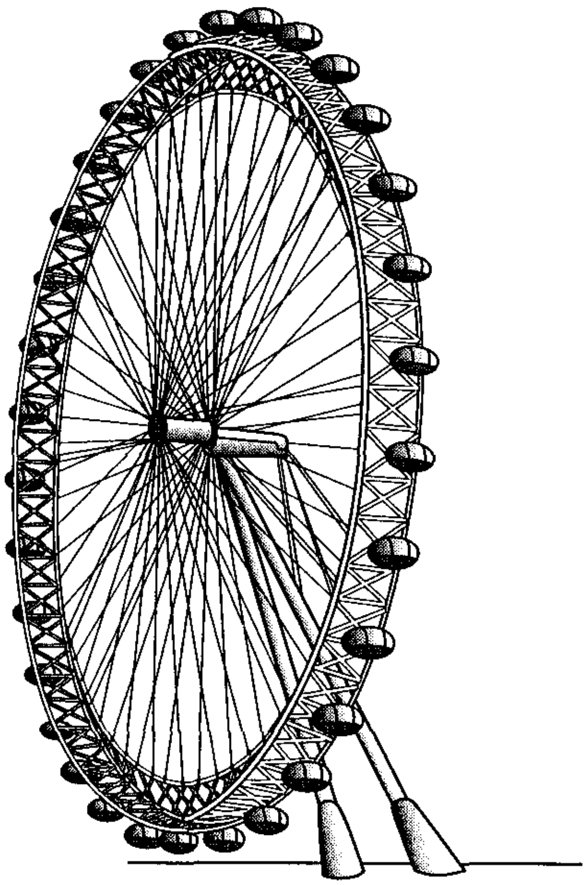

Fig. 9.1

For Examiner's Use

(a) **(i)** Calculate the linear speed of the wheel rim when it is turning normally.

speed = ... m s^{-1} [2]

(ii) Calculate the total force exerted by the drive system.

force = ... N [1]

(iii) Calculate the work done in moving the wheel through one revolution.

work done = ... J [2]

For Examiner's Use

(iv) Calculate the useful power needed for the wheel to turn at the rate of one revolution every 30 minutes.

power = ... W [2]

(v) The wheel turns at a constant speed. Energy is converted as a result of

- friction in the bearings
- friction between the tyres and the rim
- electrical energy supplied to the motor.

Apply the conservation of energy for the rotating wheel and discuss which of the above produces useful work in rotating the London Eye.

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.... [5]

(b) The London Eye behaves like a large bicycle wheel suspended in the air. Fig. 9.2(i) shows the front wheel and fork of a stationary bicycle wheel which is in contact with the ground. Fig. 9.2(ii) shows the front wheel and fork of the same bicycle when lifted off the ground.

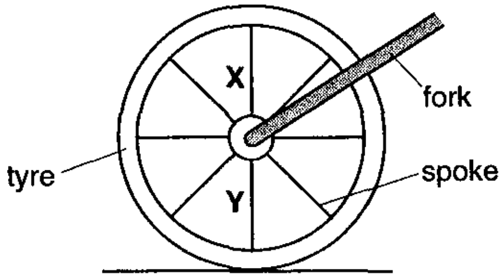

Fig. 9.2(i)

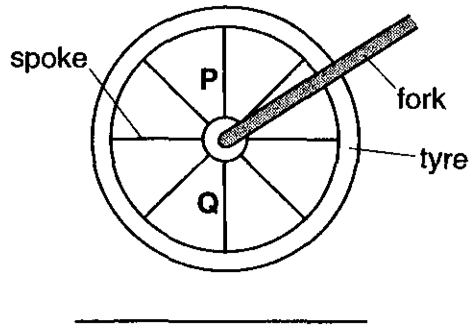

Fig. 9.2(ii)

Assume all spokes are always in tension.
Compare, giving a reason in each case, the magnitude of

(i) the tension in the spokes **X** and **Y**

....

....

(ii) the tension in the spokes **P** and **Q**.

....

....
[2]

(c) This question is concerned with the effect of the wind on the London Eye.

(i) In a storm the wind may exert a horizontal force of 1800 kN on the wheel support, causing it to deflect horizontally by 90 cm. Calculate a value for the spring constant *k* of the wheel support.

k = ...N m^{-1} [2]

[Turn over

For Examiner's Use

(ii) The natural frequency f of oscillation of the wheel is given by the equation

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

where m is the mass of the system.
Calculate the fundamental natural frequency f of oscillation of the wheel support when m is 9.5×10^5 kg.

f = ... Hz [2]

(iii) The wind may cause fluctuations at the frequency calculated in **(c)(ii)**. What problem might this cause and how may this problem be overcome?

....

....

....
[2]

[Total: 20]

END OF QUESTION PAPER

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