Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

For Examiner's Use

General Certificate of Education
June 2007
Advanced Level Examination

PHYSICS (SPECIFICATION A) **PA10**
Unit 10 The Synoptic Unit

Thursday 21 June 2007 1.30 pm to 3.30 pm

For this paper you must have:
- a calculator
- a pencil and a ruler.

Time allowed: 2 hours

Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Answer the questions in the spaces provided.
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The maximum mark for this paper is 80.
- Two of these marks will be awarded for using good English, organising information clearly and using specialist vocabulary where appropriate.
- The marks for questions are shown in brackets.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination
- You are expected to use a calculator where appropriate.
- Question 4(b) and 5(a) should be answered in continuous prose. In these questions you will be marked on your ability to use good English, to organise information clearly and to use specialist vocabulary where appropriate.

For Examiner's Use			
Question	Mark	Question	Mark
1			
2			
3			
4			
5			
6			
7			
8			
Total (Column 1) →			
Total (Column 2) →			
Quality of Written Communication			
TOTAL			
Examiner's Initials			

Data Sheet

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

Fundamental constants and values

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^{8}	$m\ s^{-1}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$H\ m^{-1}$
permittivity of free space	ε_0	8.85×10^{-12}	$F\ m^{-1}$
charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$N\ m^{2}\ kg^{-2}$
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	$J\ K^{-1}\ mol^{-1}$
the Boltzmann constant	k	1.38×10^{-23}	$J\ K^{-1}$
the Stefan constant	σ	5.67×10^{-8}	$W\ m^{-2}\ K^{-4}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4}u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	e/m_e	1.76×10^{11}	$C\ kg^{-1}$
proton rest mass (equivalent to 1.00728u)	m_p	1.67×10^{-27}	kg
proton charge/mass ratio	e/m_p	9.58×10^{7}	$C\ kg^{-1}$
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-27}	kg
gravitational field strength	g	9.81	$N\ kg^{-1}$
acceleration due to gravity	g	9.81	$m\ s^{-2}$
atomic mass unit (1u is equivalent to 931.3 MeV)	u	1.661×10^{-27}	kg

Fundamental particles

Class	Name	Symbol	Rest energy /MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^{\pm}$	0.510999
	muon	$\mu^{\pm}$	105.659
mesons	pion	$\pi^{\pm}$	139.576
		π^{0}	134.972
	kaon	$K^{\pm}$	493.821
		K^{0}	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

Type	Charge	Baryon number	Strangeness
u	$+\frac{2}{3}$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}$	$+\frac{1}{3}$	–1

Geometrical equations

arc length $= r\theta$

circumference of circle $= 2\pi r$

area of circle $= \pi r^2$

area of cylinder $= 2\pi rh$

volume of cylinder $= \pi r^2 h$

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

volume of sphere $= \frac{4}{3}\pi r^3$

Mechanics and Applied Physics

$v = u + at$

$s = \left(\frac{u + v}{2}\right) t$

$s = ut + \frac{at^2}{2}$

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

$F = \frac{\Delta(mv)}{\Delta t}$

$P = Fv$

efficiency $= \frac{\textit{power output}}{\textit{power input}}$

$\omega = \frac{v}{r} = 2\pi f$

$a = \frac{v^2}{r} = r\omega^2$

$I = \sum mr^2$

$E_k = \frac{1}{2} I\omega^2$

$\omega_2 = \omega_1 + \alpha t$

$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$

$\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$

$T = I\alpha$

angular momentum $= I\omega$

$W = T\theta$

$P = T\omega$

angular impulse = change of angular momentum $= Tt$

$\Delta Q = \Delta U + \Delta W$

$\Delta W = p\Delta V$

pV^{γ} = constant

work done per cycle = area of loop

input power = calorific value × fuel flow rate

indicated power as (area of p – V loop) × (no. of cycles/s) × (no. of cylinders)

friction power = indicated power – brake power

efficiency $= \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$

maximum possible efficiency $= \frac{T_H - T_C}{T_H}$

Fields, Waves, Quantum Phenomena

$g = \frac{F}{m}$

$g = -\frac{GM}{r^2}$

$g = -\frac{\Delta V}{\Delta x}$

$V = -\frac{GM}{r}$

$a = -(2\pi f)^2 x$

$v = \pm 2\pi f\sqrt{A^2 - x^2}$

$x = A\cos 2\pi ft$

$T = 2\pi\sqrt{\frac{m}{k}}$

$T = 2\pi\sqrt{\frac{l}{g}}$

$\lambda = \frac{\omega s}{D}$

$d\sin\theta = n\lambda$

$\theta \approx \frac{\lambda}{D}$

${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$

${}_1n_2 = \frac{n_2}{n_1}$

$\sin\theta_c = \frac{1}{n}$

$E = hf$

$hf = \phi + E_k$

$hf = E_1 - E_2$

$\lambda = \frac{h}{p} = \frac{h}{mv}$

$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

Electricity

$\epsilon = \frac{E}{Q}$

$\epsilon = I(R + r)$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

$R_T = R_1 + R_2 + R_3 + \cdots$

$P = I^2R$

$E = \frac{F}{Q} = \frac{V}{d}$

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

$E = \frac{1}{2}QV$

$F = BIl$

$F = BQv$

$Q = Q_0 e^{-t/RC}$

$\Phi = BA$

Turn over ▶

magnitude of induced emf $= N \frac{\Delta \Phi}{\Delta t}$

$I_{rms} = \frac{I_0}{\sqrt{2}}$

$V_{rms} = \frac{V_0}{\sqrt{2}}$

Mechanical and Thermal Properties

the Young modulus $= \frac{\textit{tensile stress}}{\textit{tensile strain}} = \frac{F}{A}\frac{l}{e}$

energy stored $= \frac{1}{2} Fe$

$\Delta Q = mc\,\Delta\theta$

$\Delta Q = ml$

$pV = \frac{1}{3} Nm\overline{c^2}$

$\frac{1}{2} m\overline{c^2} = \frac{3}{2} kT = \frac{3RT}{2N_A}$

Nuclear Physics and Turning Points in Physics

force $= \frac{eV_p}{d}$

force $= Bev$

radius of curvature $= \frac{mv}{Be}$

$\frac{eV}{d} = mg$

work done $= eV$

$F = 6\pi\eta rv$

$I = k\frac{I_0}{x^2}$

$\frac{\Delta N}{\Delta t} = -\lambda N$

$\lambda = \frac{h}{\sqrt{2meV}}$

$N = N_0 e^{-\lambda t}$

$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

$R = r_0 A^{\frac{1}{3}}$

$E = mc^2 = \frac{m_0 c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

$l = l_0 \left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$

$t = \frac{t_0}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

Astrophysics and Medical Physics

Body	*Mass*/kg	*Mean radius*/m
Sun	2.00×10^{30}	7.00×10^{8}
Earth	6.00×10^{24}	6.40×10^{6}

1 astronomical unit = 1.50×10^{11} m

1 parsec = 206265 AU = 3.08×10^{16} m = 3.26 ly

1 light year = 9.45×10^{15} m

Hubble constant (H) = 65 km s^{-1} Mpc^{-1}

$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$

$M = \frac{f_o}{f_e}$

$m - M = 5 \log \frac{d}{10}$

$\lambda_{max} T = \text{constant} = 0.0029 \text{ m K}$

$v = Hd$

$P = \sigma A T^4$

$\frac{\Delta f}{f} = \frac{v}{c}$

$\frac{\Delta \lambda}{\lambda} = -\frac{v}{c}$

$R_s \approx \frac{2GM}{c^2}$

Medical Physics

power $= \frac{1}{f}$

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ and $m = \frac{v}{u}$

intensity level $= 10 \log \frac{I}{I_0}$

$I = I_0 e^{-\mu x}$

$\mu_m = \frac{\mu}{\rho}$

Electronics

Resistors

Preferred values for resistors (E24) Series: 1.0 1.1 1.2 1.3 1.5 1.6 1.8 2.0 2.2 2.4 2.7 3.0 3.3 3.6 3.9 4.3 4.7 5.1 5.6 6.2 6.8 7.5 8.2 9.1 ohms
and multiples that are ten times greater

$Z = \frac{V_{rms}}{I_{rms}}$

$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$

$C_T = C_1 + C_2 + C_3 + \cdots$

$X_C = \frac{1}{2\pi fC}$

Alternating Currents

$f = \frac{1}{T}$

Operational amplifier

$G = \frac{V_{out}}{V_{in}}$ voltage gain

$G = -\frac{R_f}{R_1}$ inverting

$G = 1 + \frac{R_f}{R_1}$ non-inverting

$V_{out} = -R_f \left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$ summing

Turn over for the first question

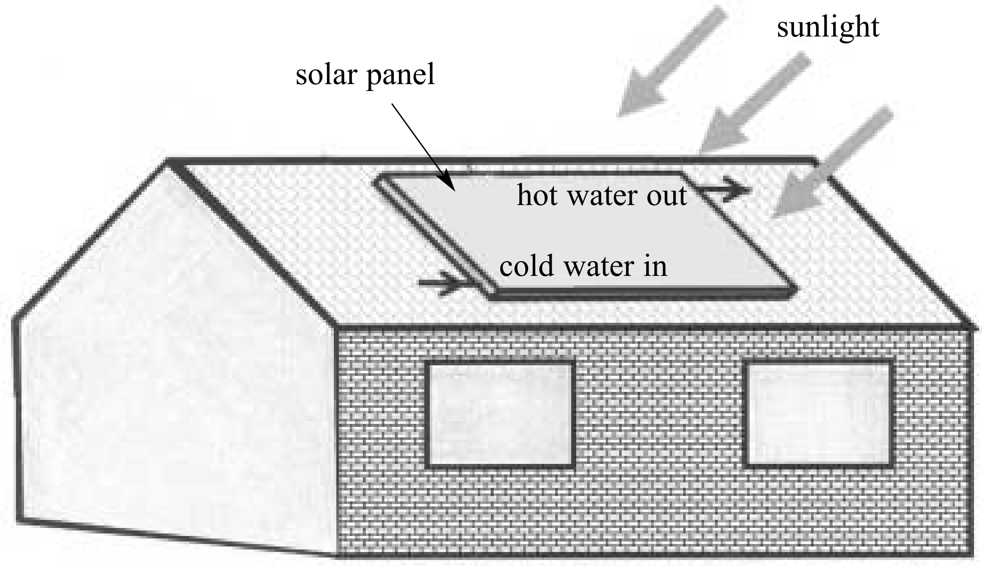
LEAVE MARGIN BLANK

Answer **all** questions in the spaces provided.

1 (a) Water flowing through a solar heating panel, as in **Figure 1**, is heated from 15 °C to 45 °C when the flow rate is $3.2 \times 10^{-6}\,\text{m}^3\,\text{s}^{-1}$. Show that the water gains energy at a rate of $400\,\text{J}\,\text{s}^{-1}$.

specific heat capacity of water = $4200\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$
density of water = $1000\,\text{kg}\,\text{m}^{-3}$

Figure 1



....

....

....

....

....

(3 marks)

LEAVE MARGIN BLANK

(b) A solar cell produces electrical power when sunlight is incident on it. The data sheet on a panel of solar cells states that the panel is capable of delivering a current of 100 mA at a potential difference of 6.0 V.

(i) With the aid of a circuit diagram, describe how you could check these data by making appropriate measurements.

....

....

....

....

....

....

....

....

(ii) The solar cell panel described in part (b)(i) is 150 mm long and 100 mm wide. The solar heating panel in part (a) is 1.60 m long and 1.25 m wide.

Calculate the ratio $\dfrac{\text{output power per unit area of the solar heating panel}}{\text{output power per unit area of the solar cell panel}}$.

....

....

....

....

(7 marks)

10

2 (a) (i) State **three** assumptions concerning the motion of the molecules in an ideal gas.

....

....

....

....

....

....

(ii) For an ideal gas at a temperature of 300 K, show that the mean kinetic energy of a molecule is 6.2×10^{-21} J.

....

....

....

(4 marks)

LEAVE
MARGIN
BLANK

(b) (i) When no current passes along a metal wire, conduction electrons move about in the wire like molecules in an ideal gas.

Calculate the speed of an electron which has 6.2×10^{-21} J of kinetic energy.

....

....

....

(ii) Describe the motion of conduction electrons in a wire when a pd is applied across the ends of the wire.

....

....

....

....

....

....

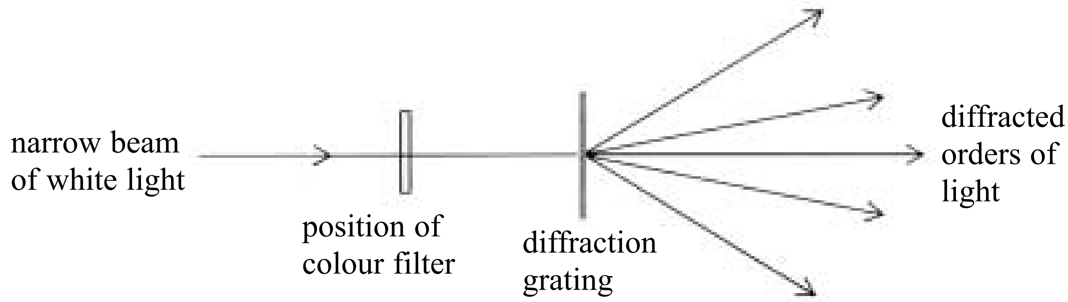
(4 marks)

8

Turn over for the next question

3 A narrow beam of white light is incident normally on a diffraction grating. Different colour filters are placed in the path of the beam, one at a time, as shown in **Figure 2**.

Figure 2



(a) (i) With a red filter, which transmits light of wavelength 630 nm, the angle of diffraction of the second order beam is 49.1°. Show that the grating spacing is 1.67×10^{-6} m.

....

....

....

....

(ii) When the red filter is replaced by a blue filter, the angle of diffraction of the second order beam is 33.5°. Calculate the wavelength of light transmitted by the blue filter.

....

....

....

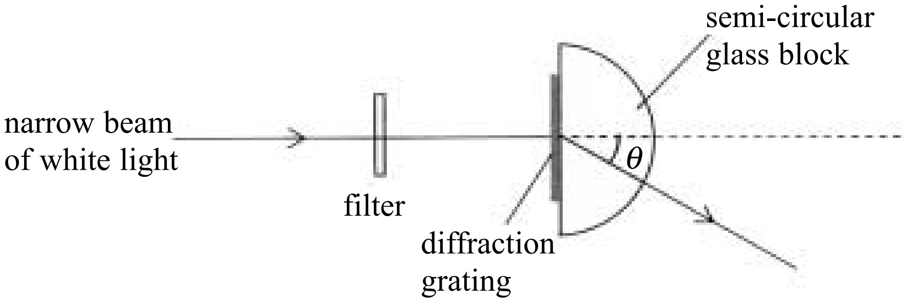
....

(3 marks)

LEAVE MARGIN BLANK

(b) A semi-circular glass block is placed with its flat side in contact with the diffraction grating, as shown in **Figure 3**. The glass block is positioned so that the centre of its flat side is in the path of the incident beam.

Figure 3



(i) When the red filter is used in this arrangement, the angle θ of the second order diffracted beam is 29.8°. Calculate the refractive index of the glass block for red light.

....

....

....

....

....

....

(ii) Describe how the arrangement could be used to determine the ratio

$$\frac{\text{speed of red light in the glass block}}{\text{speed of blue light in the glass block}}.$$

....

....

....

....

....

(4 marks)

7

Turn over ▸

LEAVE MARGIN BLANK

4 (a) (i) Show that the gravitational field strength of the Earth at height h above the surface is given by

$$g = g_s \left(\frac{R}{R + h} \right)^2,$$

where g_s is the gravitational field strength at the surface and R is the radius of the Earth.

....

....

....

....

....

....

(ii) Calculate the gravitational field strength of the Earth at a height of 200 km above its surface.

....

....

....

....

(5 marks)

(b) An astronaut floats in a spacecraft which is in a circular orbit around the Earth. Discuss whether or not the astronaut is weightless in this situation.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

....

....

....

....

....

....

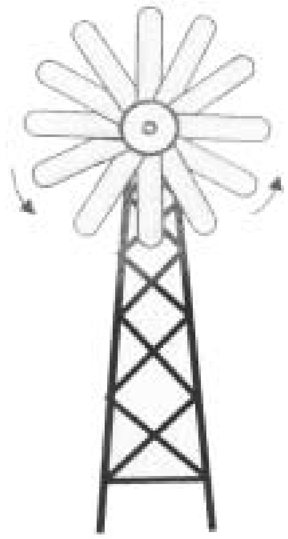
(3 marks)

8

LEAVE MARGIN BLANK

5 (a) The low-speed wind turbine in **Figure 4** is used to generate electricity. The turbine is designed so that it faces the wind. Because the rotor blades are set at an angle to the plane in which they rotate, they deflect the wind.

Figure 4



Explain why the rotor blades are forced to rotate when subjected to the wind.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

....

....

....

....

....

....

....

(3 marks)

Question 5 continues on the next page

Turn over ▸

LEAVE MARGIN BLANK

(b) The table shows how the output power, P, from a wind turbine varies with the speed, v, of the wind.

wind speed v / m s^{-1}	**output power** P/W	**ln (v / m s^{-1})**	**ln (P / W)**
1.5	20		
2.0	50		
2.7	120		
3.5	260		
4.2	440		
4.9	710		
5.5	990		

The variation of output power with wind speed is

$$P = k v^n,$$

where k and n are constants.

(i) Complete the table.
(ii) Plot a graph of ln (P/W) against ln (v/m s^{-1}).
(iii) Show that your graph confirms the above equation.

....

....

....

....

(iv) Use your graph to determine the values of n and k.

....

....

....

....

(11 marks)

Question 5 continues on page 16

(c) The initial kinetic energy per second of the air that passes through the wind turbine is given by $\frac{1}{2}\rho A v^3$, where ρ is the density of air and A is the area swept out by the rotor blades in each rotation.

The data in part (b) is for a wind turbine with a rotor of diameter 6.4 m. Calculate the efficiency of the turbine at a wind speed of $2.0\,\mathrm{m\,s^{-1}}$.

density of air = $1.2\,\mathrm{kg\,m^{-3}}$

....

....

....

(2 marks)

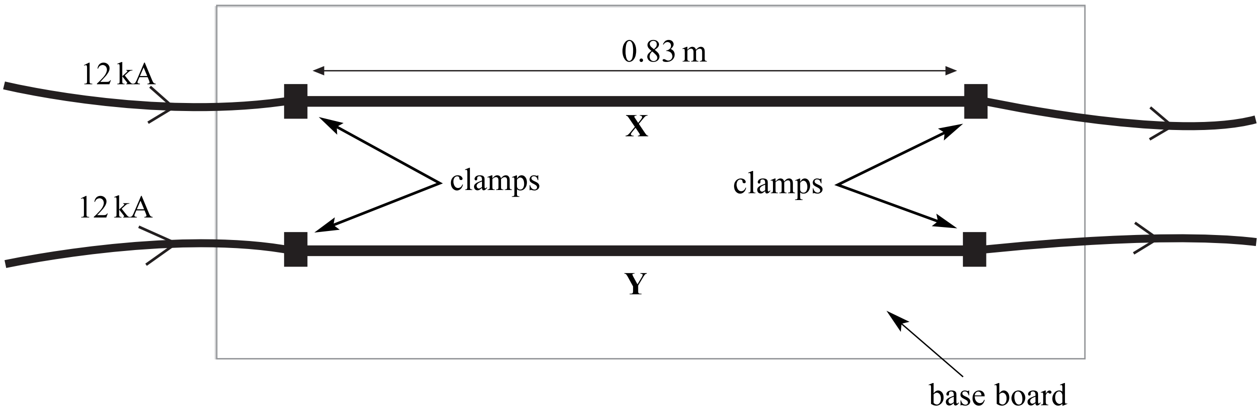
16

Turn over for the next question

LEAVE MARGIN BLANK

6 A 'bus bar' is a metal bar which can be used to conduct a large electric current. In a test, two bus bars, **X** and **Y**, of length 0.83 m are clamped at either end parallel to each other, as shown in **Figure 5**.

Figure 5



(a) When a constant current of 12 kA is carried by each bus bar, they exert a force of 180 N on each other. This force is due to the magnetic field created by the current carried by each bus bar.

(i) Calculate the magnetic flux density due to the current in one bus bar at the position of the other bus bar.

....

....

....

(ii) The magnetic flux density at any given distance from a straight conductor is proportional to the current through the conductor. Calculate the force on each bus bar if **X** carried a current of 6 kA and **Y** carried a current of 12 kA in the same direction.

....

....

....

....

....

....

....

(6 marks)

LEAVE MARGIN BLANK

(b) When the same alternating current is passed through the two bus bars, both vibrate strongly.

(i) Explain why the bars vibrate.

....

....

....

....

....

....

(ii) State **one** way the amplitude of the vibrations could be reduced without reducing the current.

....

....

....

(4 marks)

10

Turn over for the next question

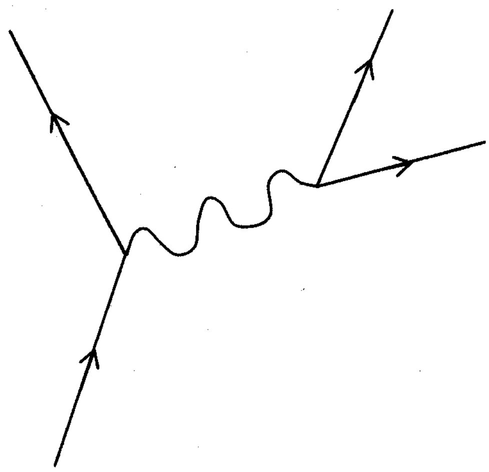
7 The fluorine isotope ${}^{18}_{9}F$ is a positron emitter which decays to form a stable isotope of oxygen.

(a) (i) Complete the equation below for the decay of ${}^{18}_{9}F$

$${}^{18}_{9}F \longrightarrow {}^{\cdots\cdots}_{\cdots\cdots}O \quad + \quad {}^{\cdots\cdots}_{\cdots\cdots}e \quad + \quad \cdots\cdots$$

(ii) Complete the Feynman diagram in **Figure 6** to represent the decay.

Figure 6



(5 marks)

(b) The ${}^{18}_{9}F$ isotope is used to obtain medical images in a PET (positron emission tomography) scanner. A solution containing the isotope is injected into the patient. When a ${}^{18}_{9}F$ nucleus in the body decays, the positron emitted travels no further than a millimetre before it loses its kinetic energy and is annihilated by an electron. As a result, two γ photons of the same energy are emitted in opposite directions.

$$e^{+} \quad + \quad e^{-} \longrightarrow 2\gamma$$

A ring of detectors surrounding the patient is used to detect the photons.

(i) Show that the energy of each photon is 0.51 MeV.

....

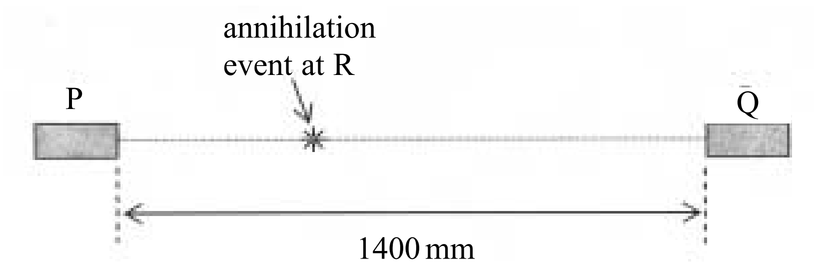
....

....

LEAVE MARGIN BLANK

(ii) A detector P was triggered by a γ photon from such an annihilation event at R, as shown in **Figure 7**. A second detector Q at a distance of 1400 mm from P was triggered 0.40 ns later by the other photon from this event.

Figure 7



Calculate the distance PR.

....

....

....

....

....

....

....

(4 marks)

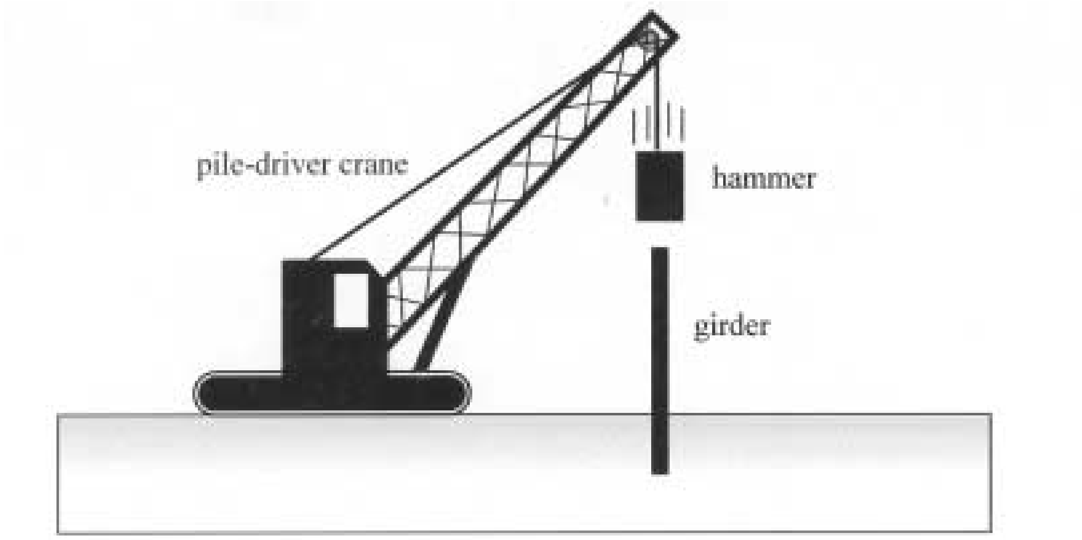
9

Turn over for the next question

LEAVE MARGIN BLANK

8 The pile-driver crane in **Figure 8** is used on a construction site to drive a steel girder vertically into the ground. The hammer of the pile-driver is raised and dropped repeatedly onto the upper end of the girder.

Figure 8



(a) The hammer is a steel cylinder of length 1.50 m and diameter 0.60 m.

(i) Calculate the mass of the cylinder.

density of steel = 7800 kg m^{-3}

....

....

....

(ii) The hammer is released from a height of 0.80 m above the top end of the girder. Calculate the velocity of the hammer just before it hits the girder.

....

....

....

....

....

....

(4 marks)

(b) (i) The girder has a mass of 1600 kg. Calculate its velocity immediately after the impact, assuming the hammer does not rebound after the impact.

....

....

....

....

....

(ii) The impact causes the girder to penetrate 25 mm into the ground. Estimate the average force of friction on the girder during this movement.

....

....

....

....

....

(6 marks)

10

Quality of Written Communication *(2 marks)*

2

END OF QUESTIONS

There are no questions printed on this page

Copyright © 2007 AQA and its licensors. All rights reserved.