OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS A **2825/03**

Materials

Monday **28 JUNE 2004** 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.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The first seven questions concern Materials. The last question concerns general physics.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	11	
2	7	
3	9	
4	8	
5	13	
6	12	
7	10	
8	20	
TOTAL	90	

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

[Turn over

For Examiner's Use

Answer **all** the questions.

1 A metal wire 1.5 m long has a cross-sectional area of $1.6 \times 10^{-7}\,m^2$. The equilibrium separation of atoms in the wire is 3.0×10^{-10} m.

(a) Show that the number of atoms

(i) along any line parallel to the axis of the wire is about 5×10^9

[1]

(ii) in any plane perpendicular to the length of the wire is about 2×10^{12}.

[2]

(b) Suggest **two** reasons why the number of atoms found in **(a)(ii)** is an approximation.

1. ....

....

2. ....

....

[2]

(c) The material of the wire has a Young modulus of 1.9×10^{11} Pa. The wire is stretched elastically by 2.8×10^{-3} m.

(i) Show that the strain in the wire is about 2×10^{-3}.

[1]

(ii) Calculate the stress in the wire.

stress = ... Pa [2]

(iii) Calculate the tension in the wire.

tension = ... N [1]

(d) Estimate, for a pair of adjacent atoms on the axis of the wire,

(i) the increase in their separation when the wire is stretched as in **(c)**

increase in separation = ... m [1]

(ii) the force causing the increased separation.

force = ... N [1]

[Total: 11]

For Examiner's Use

2 The graphs in Fig. 2.1 show the variation with absolute temperature *T* of the conductivity σ of specimens of copper and lead. Lg σ is plotted against *T*.

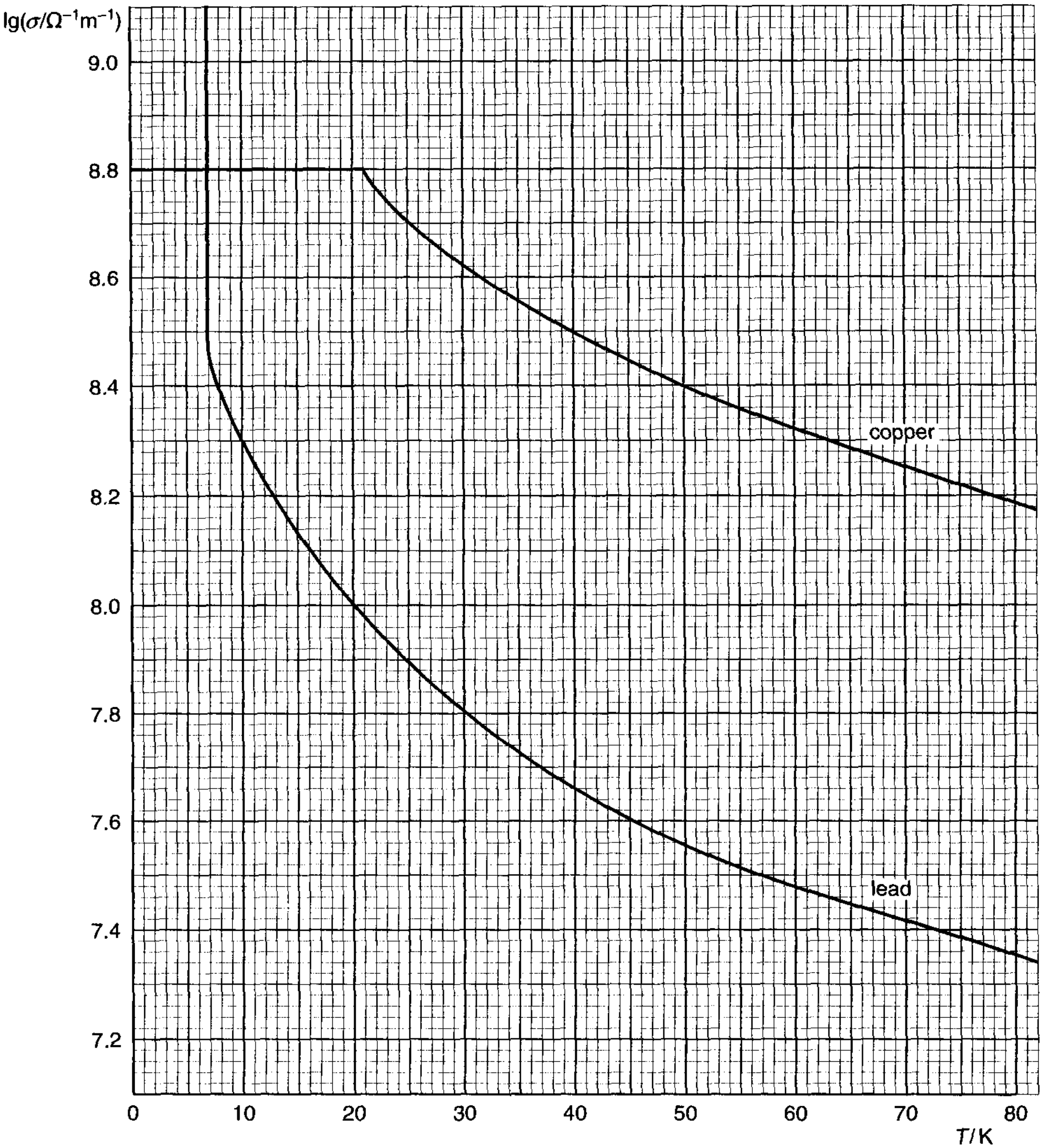

Fig. 2.1

For Examiner's Use

Use information from the graphs in Fig. 2.1, where appropriate, to determine

(a) **(i)** the temperature at which lead has a conductivity of $8.0 \times 10^{7}\,\Omega^{-1}\,m^{-1}$

temperature = ... K [2]

(ii) the superconducting transition temperature of lead

transition temperature = ... K [1]

(b) **(i)** the maximum conductivity of copper

conductivity = ... $\Omega^{-1}\,m^{-1}$ [2]

(ii) the minimum resistivity of copper, stating the unit of your answer.

resistivity = ... unit .... [2]

[Total: 7]

3 **(a)** Using circles of equal size to represent atoms, sketch the arrangement of atoms in a layer of a hexagonal close-packed crystal structure.

[1]

(b) **(i)** Glass is amorphous. Quartz occurs as single crystals.
Distinguish between the microstructures of these materials.

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[2]

(ii) State an example of the use of a single-crystal material in a technological application.

....[1]

(c) Some transformers have cores made of metallic glass.

- Suggest why the term *metallic glass* is appropriate to describe this material.
- Explain why metallic glass is suitable for use in transformer cores.

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....[5]

[Total: 9]

For Examiner's Use

4 (a) Explain, in terms of band theory, why

(i) a thin sheet of metal is opaque to visible light

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....[2]

(ii) a thin sheet of glass is transparent to visible light.

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....[2]

(b) An insulator has an energy gap of 1.95 eV.

(i) Show that the maximum wavelength of electromagnetic radiation for which this insulator is transparent is about 640 nm.

[3]

(ii) A bulb emitting white light is viewed through a thin slab of this insulator. Suggest why the bulb appears to be emitting red light.

....

....[1]

[Total: 8]

5 (a) Fig. 5.1 shows a bar of semiconductor of cross-section 2.4 mm × 2.4 mm, carrying a current I of 43 mA in the direction shown. Assume that this semiconductor conducts only through the movement of free electrons. At room temperature the number of free electrons per unit volume in the semiconductor is $7.5 \times 10^{20}\,m^{-3}$.

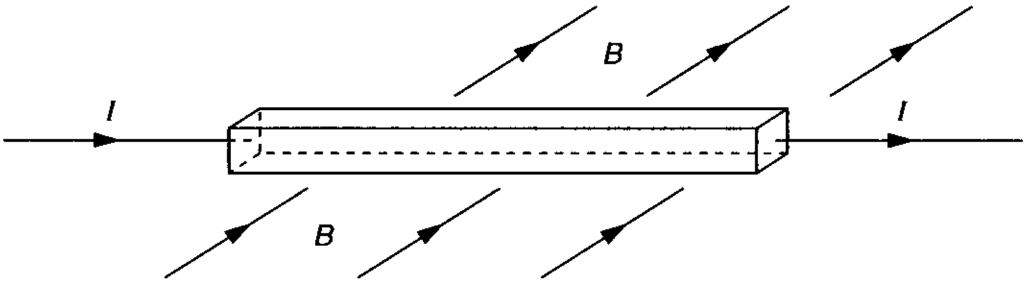

Fig. 5.1

(i) Show that, at room temperature, the drift velocity of free electrons in the bar is about $60\,m\,s^{-1}$.

[2]

(ii) The bar is placed in a magnetic field of flux density $B = 0.35$ T in the direction shown in Fig. 5.1. Calculate the Hall voltage produced across the bar.

Hall voltage = ...V [2]

(iii) On Fig. 5.1, mark with an **X** the face of the bar with the positive Hall voltage. [1]

(iv) The temperature of the bar increases, and the current remains constant. State and explain the effect on the Hall voltage.

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....[3]

(b) (i) Describe an experiment, using a calibrated Hall probe, to investigate how the magnetic field changes along the axis of a current-carrying solenoid.

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....[4]

(ii) The direct current in the solenoid is changed to alternating current. Suggest how you would display the variation with time of the magnetic field at the centre of the solenoid.

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....[1]

[Total: 13]

6 A solenoid with many turns of wire is wound round an iron bar, initially unmagnetised. The graph in Fig. 6.1 shows the variation of B, the magnetic flux density in the iron bar, as the current I through the solenoid is increased.

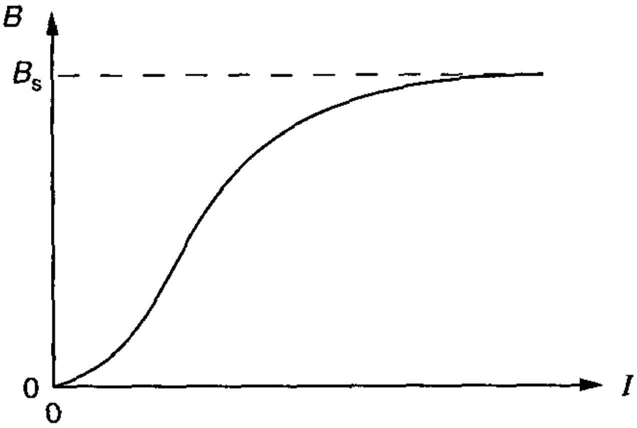

Fig. 6.1

(a) Describe the arrangment of magnetic domains in the iron bar when

(i) B = zero

....[1]

(ii) $B = B_s$, the saturation flux density.

....[1]

(b) **(i)** Describe **two** changes, involving domains, which take place in the iron as B increases from zero to B_s.

1. ....

....

2. ....

....

[2]

(ii) Explain why the gradient of the graph in Fig. 6.1 decreases as B_s is approached.

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....[2]

For Examiner's Use

(iii) State and explain, in terms of domain theory, what happens when the iron is raised to the Curie temperature.

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....[2]

(c) The core of a certain transformer is made of soft iron.

Explain

(i) why a soft magnetic material is used

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....[2]

(ii) why the core has a laminated structure.

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....[2]

[Total: 12]

For Examiner's Use

7 **(a)** On the axes of Fig. 7.1, sketch a graph of the variation with wavelength of the percentage of visible and infra-red radiation transmitted per kilometre of optic fibre. Assume that for a wavelength of 0.5 μm the percentage transmission is 20%. [3]

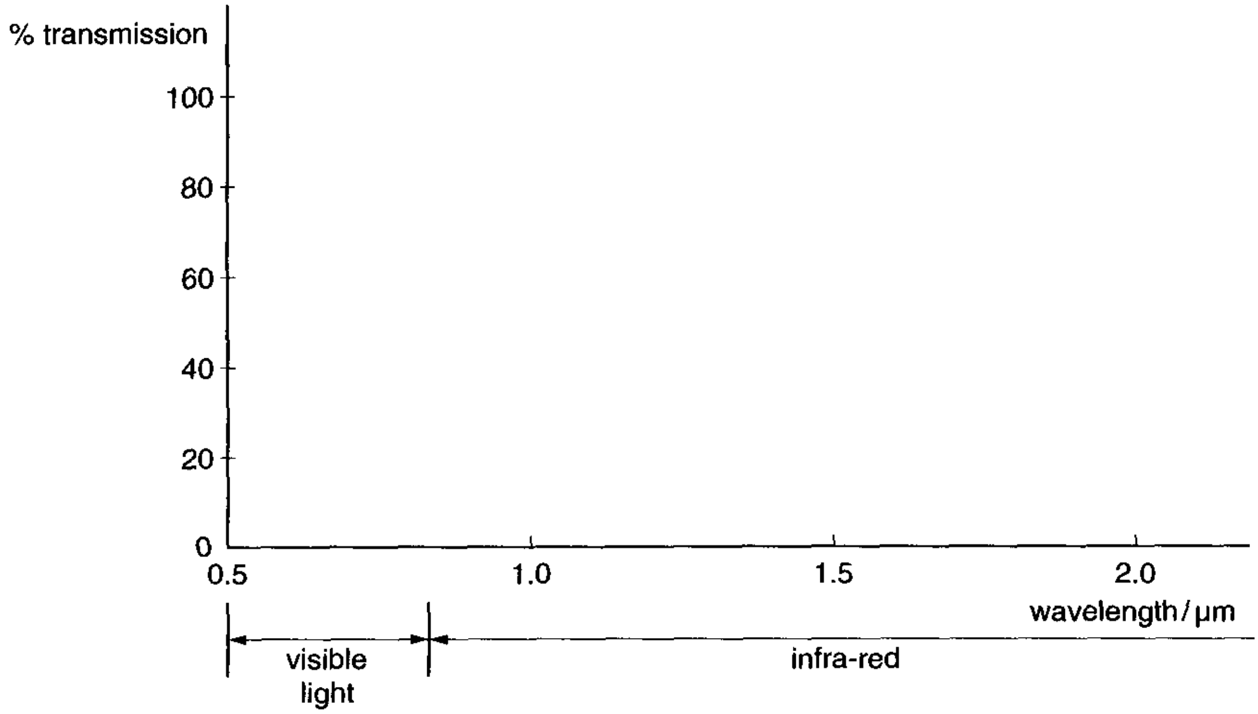

Fig. 7.1

(b) Discuss the processes which cause the percentage of light transmitted through the fibre in **(a)** to vary with wavelength, relating each process to different sections of your graph.

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....[7]

[Total: 10]

8 A student is concerned to keep fit and equally concerned to minimise the use of electricity from the national grid. The student decides to combine the two issues and designs the system shown in Fig. 8.1. The chain on the exercise bicycle turns a d.c. generator which passes a current through a heating coil immersed in a hot water tank. The idea is that the student exercises for a certain length of time and instead of simply "wasting" energy in pedalling, the energy is used to heat the water necessary for a shower when finished.

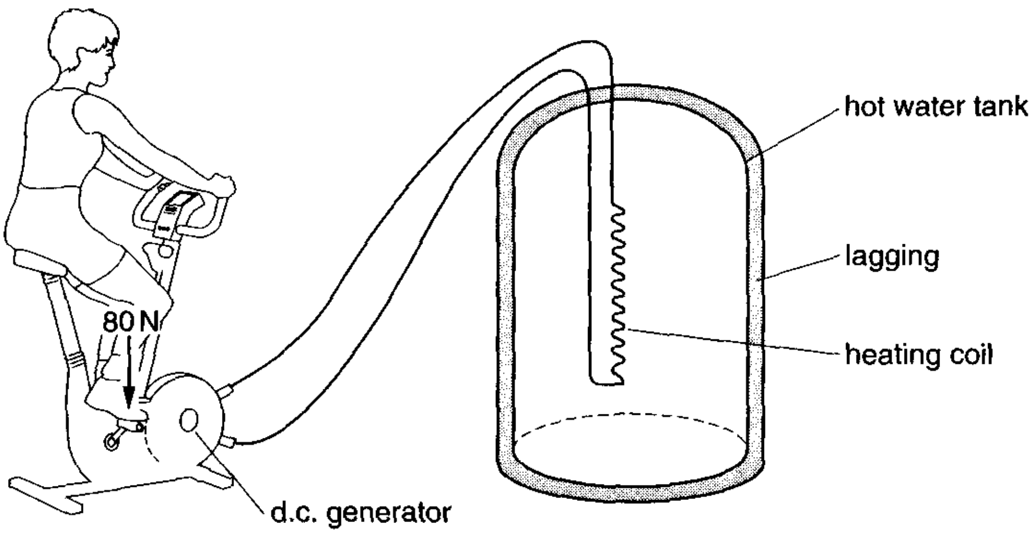

Fig. 8.1

The specific heat capacity of water = 4200 J kg^{-1} K^{-1}

(a) The water enters the hot water tank at a temperature of 8 °C and is required to be heated to 38° C for an acceptable shower. The shower lasts for 5 minutes during which time the water flows at a rate of 0.15 kg s^{-1}. Calculate

(i) the mass of water used during the shower

mass of water = ... kg [2]

(ii) the energy required to heat the water for the shower.

energy = ... J [2]

For Examiner's Use

(b) When pedalling on the exercise bicycle, each foot spends half the cycle doing work and the other half relaxing. While doing work, an average tangential force of 80 N is applied to each pedal. The pedal is positioned at a radius of 20 cm from the axle and the student maintains 1.3 revolutions per second.

(i) Show that the work done by the student during one revolution of the pedals is about 100 J.

[2]

(ii) Calculate the power produced by the student while pedalling.

power = ... W [1]

(iii) Calculate the total number of revolutions of the pedals required before the energy expended by the student equals that required to heat the water.

number of revolutions = ... [1]

(iv) Calculate the time for which the student must pedal in order to deliver the heat energy required.

time = ... hour [2]

For Examiner's Use

(c) The d.c. generator being driven by the exercise bicycle has an internal resistance of 1.2 Ω and produces an e.m.f. of 24 V while delivering a current of 5A.

(i) Show that the resistance of the heater element in the hot water tank is 3.6 Ω.

[3]

(ii) Calculate the length of heater wire required if the element is made from resistance wire of resistivity $1.5 \times 10^{-7}\,\Omega\,m$ and cross-sectional area $0.32\,mm^2$.

length .... m [3]

(d) In practice, the student would have to pedal for an even longer time than your answer to **(b)(iv)**. By considering energy losses, give reasons for this. Include some calculations in your answer.

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....[4]

[Total: 20]

END OF QUESTION PAPER

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