THIS IS A LEGACY SPECIFICATION

ADVANCED GCE
PHYSICS A
Materials

2825/03

Candidates answer on the Question Paper

OCR Supplied Materials:
None

Other Materials Required:
- Electronic calculator

Tuesday 29 June 2010
Afternoon

Duration: 1 hour 30 minutes

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

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 seven questions concern Materials. The last question concerns general physics.
- This document consists of **20** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**13**	
2	**8**	
3	**10**	
4	**7**	
5	**4**	
6	**15**	
7	**13**	
8	**20**	
TOTAL	**90**	

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,	$\mathrm{u} = 1.66 \times 10^{-27}\ \mathrm{kg}$
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, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

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, $= \surd\,(1 - \frac{v^2}{c^2})$

current, $I = nAve$

nuclear radius, $r = r_0 A^{1/3}$

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

Answer **all** the questions.

1 (a) (i) Distinguish between the molecular structures of *polycrystalline* and *amorphous* solids.

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.... **[3]**

(ii) State an example of

1 a polycrystalline solid ....

2 an amorphous solid. .... **[2]**

(b) The graph in Fig. 1.1 shows the variation with separation r of the resultant force F between a pair of atoms in a metal wire.

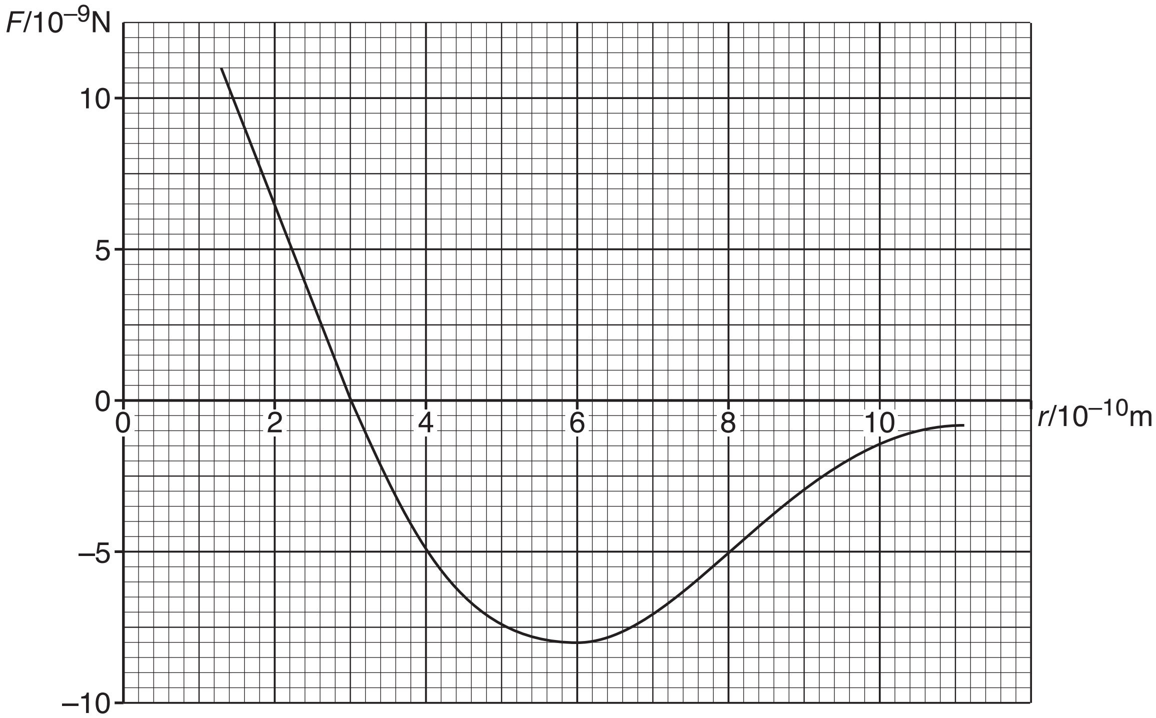

Fig. 1.1

State

(i) the equilibrium separation d of the atoms

separation = ... m **[1]**

(ii) the separation of two atoms when the repulsive force between them is 5.0×10^{-9} N

separation = ... m **[1]**

(iii) the force F_s needed to separate these atoms.

F_s = ...N **[1]**

(c) The wire in **(b)** has cross-sectional area A. The atoms in the wire have mean separation d. The force required to separate a pair of atoms in the wire is F_s.

(i) State, in terms of A, F_s and d

1 the number of atoms in a cross-section of the wire .... **[1]**

2 the force required to break the wire .... **[1]**

3 the breaking stress of the wire. .... **[2]**

(ii) Calculate the breaking stress of the wire.

breaking stress = ... Pa **[1]**

[Total: 13]

2 **(a)** State **two** types of close-packed crystal structures.

1. .... 2. .... **[2]**

(b) Describe, with sketches, how these **two** types of close-packed crystal structure can be modelled using spheres of equal size to represent **three** layers of atoms. Refer to the bottom layer as X, the middle layer as Y and the top layer as Z. Identify the two types of structure.

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.... **[6]**

[Total: 8]

3 **(a)** The superconducting transition temperature of the alloy niobium-titanium (Nb-Ti) is 10 K. A specimen of this alloy is to be cooled from 20 K to 5 K.

(i) The temperature of the specimen is firstly reduced from 20 K to just above 10 K. Discuss how this affects the drift velocity of the free electrons and hence explain the change in resistivity of Nb-Ti.

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.... **[4]**

(ii) State what happens to the resistivity of Nb-Ti when the temperature is then gradually reduced from just above 10 K to 5 K.

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.... **[2]**

(b) An electromagnet in a nuclear research machine generates a very strong magnetic field. The cables of the electromagnet are made of many fine Nb-Ti wires embedded in copper. The total cross-sectional area of all the Nb-Ti wires is half that of the copper. In normal operation the electromagnet operates at about 5 K and carries a current of about 20 000 A. Between 20 K and 5 K the resistivity of copper is about $1 \times 10^{-9}\ \Omega\,m$.

(i) Explain why in normal operation the current in the cables is carried by the Nb-Ti wires and the copper acts as an insulator.

.... **[1]**

(ii) A fault develops and the temperature of the cable rises to 20 K. At 20 K the resistivity of Nb-Ti is about $4 \times 10^{-8}\ \Omega\,m$. Explain why the current now carried by the copper is much greater than the current in the Nb-Ti wires.

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.... **[3]**

[Total: 10]

4 The approximate resistivities of copper and the semiconductor silicon, at various temperatures, are listed below.

material	temperature / °C	resistivity / Ω m
copper	20	2×10^{-8}
silicon	20	4000
silicon	40	200
silicon	60	10

Outline the principles of band theory and explain

- the large difference in the resistivities of copper and silicon at 20 °C
- the large variation with temperature of the resistivity of silicon.

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.... [7]

[Total: 7]

5 Fig. 5.1 shows a horizontal circular tube of internal diameter 0.065 m. The tube is placed in a vertical magnetic field of flux density 0.24 T. A liquid containing positive ions in solution flows through the tube. Electrodes **X** and **Y** are fixed in the wall of the tube at opposite ends of a horizontal diameter. A voltmeter connected between **X** and **Y** reads 0.28 mV.

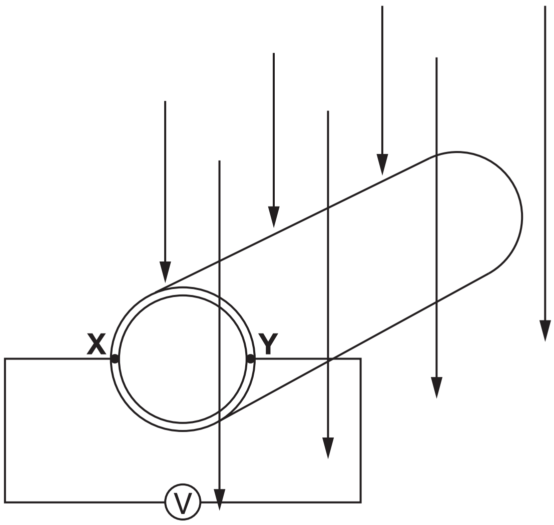

Fig. 5.1

(a) Show that the mean speed at which the liquid flows through the tube is about 0.02 m s^{-1}.

[2]

(b) Calculate the volume rate of flow of the liquid.

volume rate of flow = ... m^3 s^{-1} **[2]**

[Total: 4]

6 **(a)** When an iron bar is magnetised to saturation, **two** processes occur within the iron.

(i) Describe the two processes in terms of domain theory.

1. ....

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2. ....

.... **[3]**

(ii) Explain what is meant by *saturation*.

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.... **[2]**

(b) Fig. 6.1 shows the hysteresis loop of an iron specimen inside a current-carrying coil. The current in the coil is I. The flux density of the magnetic field in the iron is B.

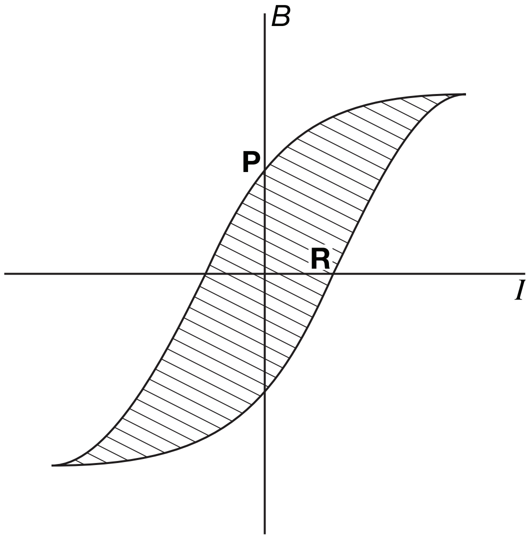

Fig. 6.1

(i) State the significance in Fig. 6.1 of

1 the value of B at **P** when $I = 0$

....

.... **[1]**

2 the value of I at **R** when $B = 0$.

....

.... **[1]**

(ii) State the significance of the shaded area.

....

....

.... **[2]**

(c) Explain

(i) the process by which eddy currents are produced in the core of a transformer and lead to power loss

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.... **[4]**

(ii) how eddy currents can be minimised.

....

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.... **[2]**

[Total: 15]

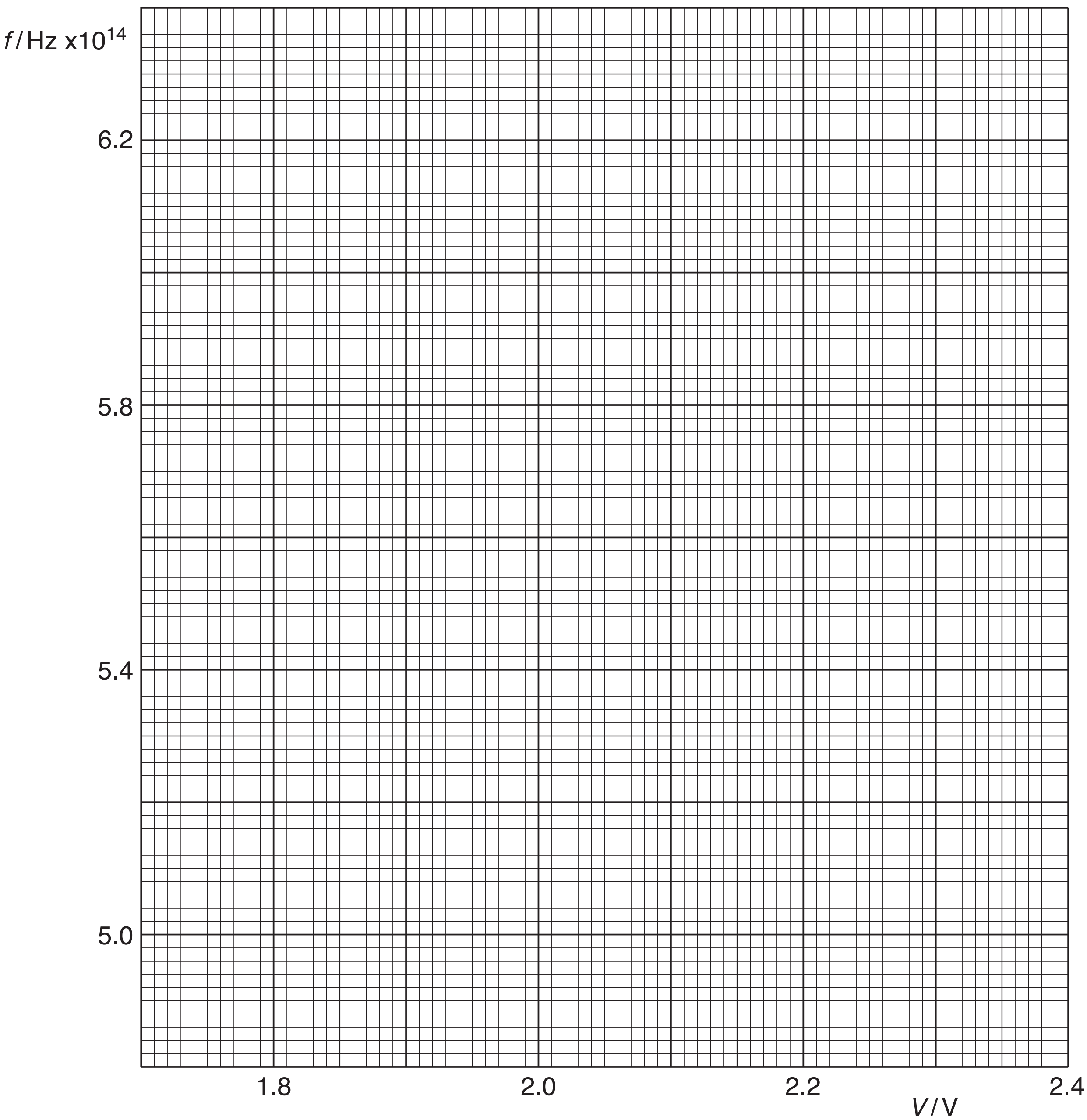
7 **(a)** Light-emitting diodes (LEDs) of various colours are used in an experiment to measure the Planck constant h. When the voltage across an LED is gradually increased, light of frequency f is just emitted when the voltage reaches the value V. The relationship between V and f is given by the expression

$$hf = eV + k \qquad \text{where } k \text{ is a constant.}$$

The table shows values of V and f for four LEDs.

colour of LED	V / V	f / Hz x 10^{14}
red	1.72	4.8
yellow	1.82	5.1
green	1.94	5.3
blue	2.40	6.4

(i) Plot a graph of f (y-axis) against V (x-axis).



[2]

(ii) Determine the gradient of the graph.

gradient = ... **[3]**

(iii) Calculate h.

h = ... J s **[2]**

(b) A particular type of red LED is fully lit when carrying a current of 25 mA. The voltage across the LED is then 1.8 V.

(i) Calculate

1 the maximum number of these LEDs that can be fully lit if connected in **series** with a resistor to a 12 V battery of negligible internal resistance so as not to exceed 25 mA

number of LEDs = ... **[1]**

2 the value of this resistor.

resistance = ...Ω **[1]**

(ii) A brake light of a car incorporates 60 of these LEDs. The supply to the light is 12 V. Suggest how these LEDs are connected to the supply. A circuit diagram is **not** required.

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.... **[2]**

(iii) State and explain an advantage of using large numbers of red LEDs rather than a single filament bulb in a rear light of a car.

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.... **[2]**

[Total: 13]

8 This question is about a cliff railway that is entirely powered by water. The rail line links a town at the top of a hill with another town at the bottom of the hill. The railway has two carriages running on parallel tracks. They are connected by a continuous cable running around two pulley wheels mounted at the top and bottom of the track bed (see Fig. 8.1). Brakes can be applied to the lower pulley wheel to control the speed of the carriages.

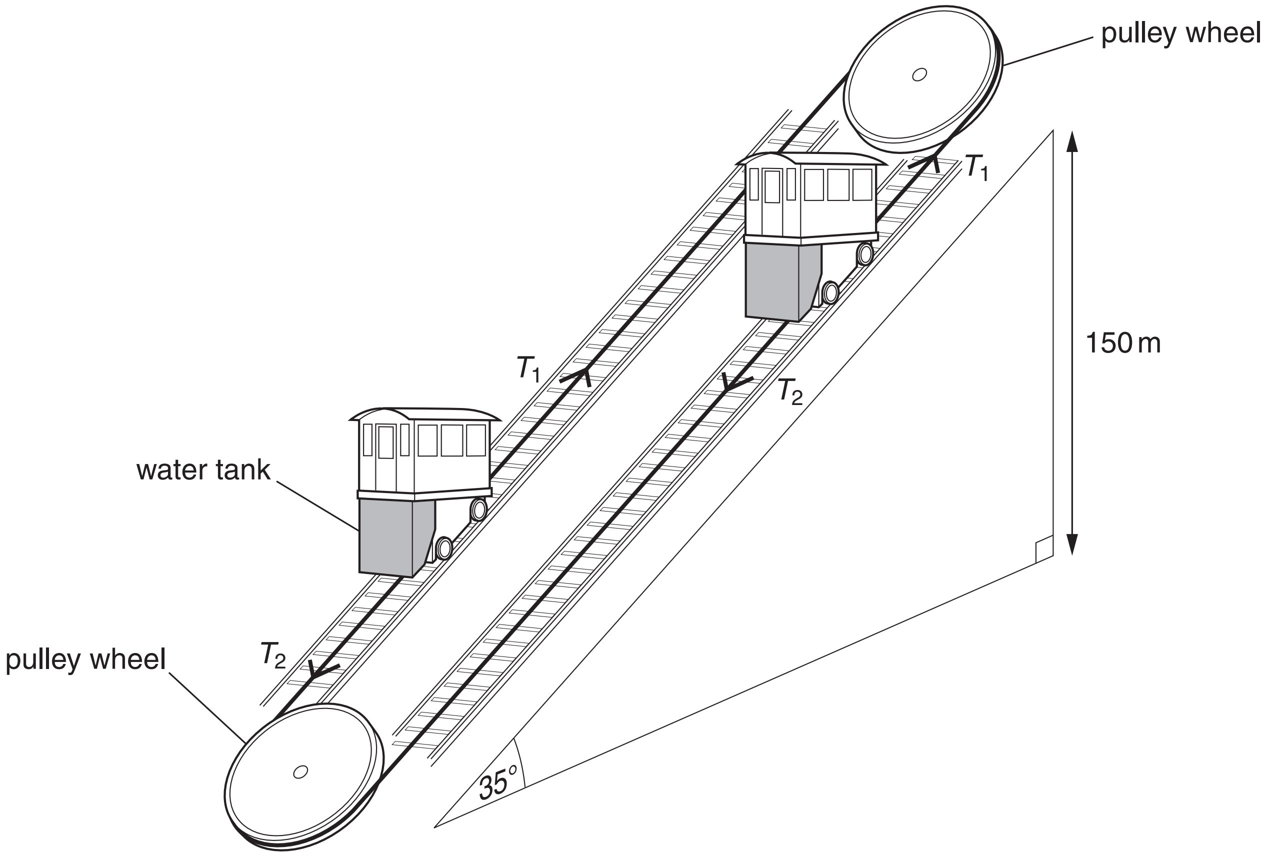

Fig. 8.1

Each carriage has a tank beneath the passenger compartment which can hold 5.0 m^3 of water. Before the start of each journey both tanks are full of water. When the passengers are aboard, water is released from the lower carriage until the weight of the lower carriage is less than that of the upper carriage. The brakes on the pulley wheel are released and the carriages accelerate toward the other station. When the speed of the carriages reaches 6.6 m s^{-1}, the brakes are partially applied to maintain a constant speed.

When the carriages reach the stations the brakes are fully applied and the carriages slow down and stop. While the passengers leave, the water tank beneath the carriage at the top station is refilled with water from a river. Passengers board both lower and upper carriages and the whole process is repeated.

Data: mass of each carriage fully loaded (including a full tank of water) = 10 000 kg
volume of water tank = 5.0 m^3
length of rails = 260 m
vertical height from lower station to the top station = 150 m
angle of inclination of rails = 35°
density of water = 1000 kg m^{-3}
mass of each brake block = 25 kg

(a) Describe the energy changes that occur when the lower carriage is lifted to the upper station while the upper carriage moves to the lower station.

....

....

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.... **[3]**

(b) Just before the water tank in the lower carriage begins to drain, both carriages are carrying their full load and the tension T_2 in the lower cable is small enough to be ignored.

Show that the tension T_1 in the upper cable is about 5.5×10^4 N when both carriages are fully loaded.

[2]

(c) When the brakes are released, the acceleration of both cars is $1.5\,\mathrm{m\,s^{-2}}$ and there is a resultant force of 8.7×10^3 N parallel to the track acting on the lower carriage.

(i) Calculate the volume of water which has been released from the lower carriage.

volume = ... $\mathrm{m^3}$ **[4]**

(ii) Calculate the time taken from the moment the lower carriage leaves the station to the point when it reaches its maximum speed of 6.6 m s^{-1}. Assume the acceleration remains constant.

time = ... s **[2]**

(iii) Calculate the distance travelled during this time.

distance = ... m **[2]**

(d) At the start of one particular journey both carriages are fully loaded. 3800 kg of water is released from the lower carriage.

(i) Show that the net change in potential energy of the system is about 5.5 MJ.

[2]

Six iron brake blocks, each of mass 25 kg, apply a force against the lower pulley wheel. This maintains the constant speed during the journey and then, following an increase in this force, brings the carriages to a halt.

(ii) Calculate the rise in temperature of the brake blocks in this journey if the brake blocks absorb all of the potential energy change calculated in **(i)**.

The specific heat capacity of iron is $4.7 \times 10^2\,J\,kg^{-1}\,K^{-1}$.

rise in temperature = ... K **[3]**

(iii) In practice the rise in temperature of the brake blocks is much less than the value calculated in **(ii)**. Discuss reasons why.

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.... **[2]**

[Total: 20]

END OF QUESTION PAPER

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