MERIDIAN JUNIOR COLLEGE
Preliminary Examination
Higher 2

H2 Physics 9646/2

Paper 2 **18 September 2013**

1 hour 45 min

Class	Reg Number

Candidate Name _____

READ THESE INSTRUCTIONS FIRST

This booklet contains 7 questions.

Do not open this booklet until you are told to do so.

Answer **all** questions.

Write your answers on this question booklet in the blanks provided.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets [ ] at the end of each question or part question. Marks will be deducted if units are not stated where necessary or if answers are not quoted to the appropriate number of significant figures.

All working for numerical answers must be shown. You are reminded of the need for good English and clear presentation of your answers.

Examiner's Use	
Section A	
Q1	**/10**
Q2	**/10**
Q3	**/10**
Q4	**/ 9**
Q5	**/ 6**
Q6	**/15**
Q7	**/12**
Deductions	
Total	**/72**

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_o	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{Gm}{r}$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
		=	$\pm \omega\sqrt{x_o^2 - x^2}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
transmission coefficient	T	$\propto$	$exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	=	$x_o\, exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

Answer all the questions in the spaces provided.

1 (a) A student submerges fully a stone of mass 200 g that is suspended from a cord in a beaker of water as shown in **Fig. 1.1**.
(Density of water = 1000 kg m^{-3})

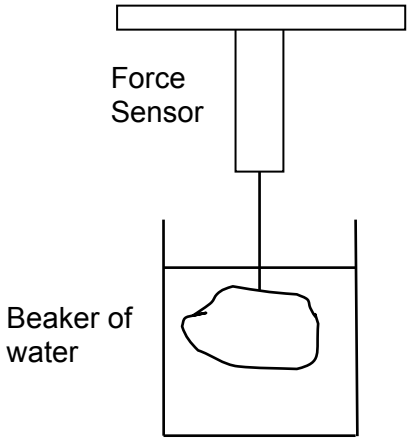

Fig. 1.1

(i) Given that the volume of stone is 50 cm^3, calculate the force sensor reading *F*.

F = ……..… N [2]

(ii) The student decides to now place the stone into a beaker of oil such that it is fully submerged.

Explain, with appropriate equation, how the reading on the force sensor will change.

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……

……

…….. [2]

(b) **(i)** State the two conditions that need to be met for an object to be at equilibrium.

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…….. [2]

(ii) A simple bridge consists of a rigid roadway supported at ends **A** and **B**. A car is in the position as shown in **Fig. 1.2**.

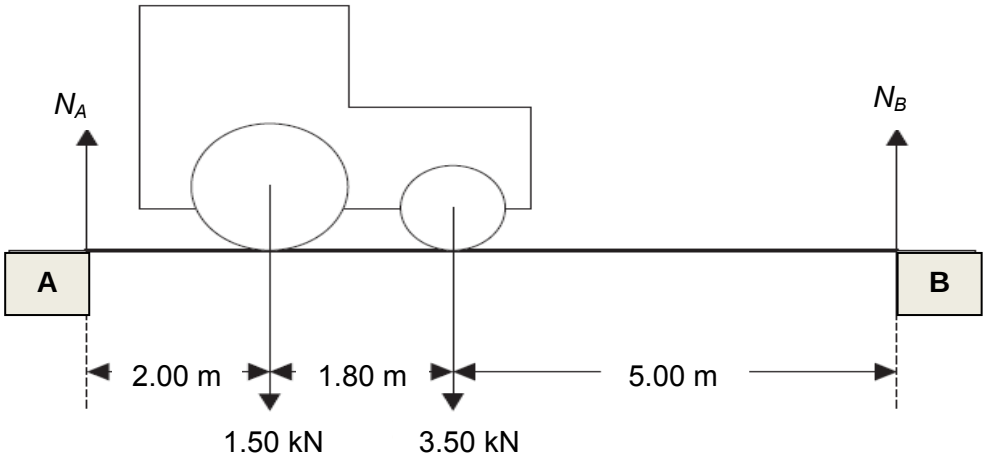

Fig. 1.2

The total load on the rear wheels of the car is 1.50 kN and on the front wheels is 3.50 kN.The distance between the front and rear wheels is 1.80 m. The rear wheels are 2.00 m from **A**, and the front wheels 5.00 m from **B**.

The vertical forces at the supports **A** and **B** of the bridge due to the car are N_A and N_B respectively. Determine the value of N_A and N_B.

N_A = …… N

N_B = …… N [2]

(c) Explain why acceleration-time graphs for cars can be almost vertical but its velocity-time graphs cannot.

……..

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…… [2]

2 (a) Define *gravitational field strength*.

……

…….. [1]

(b) Two stars of equal masses are in circular orbit about a common centre as shown in **Fig 2.1**.

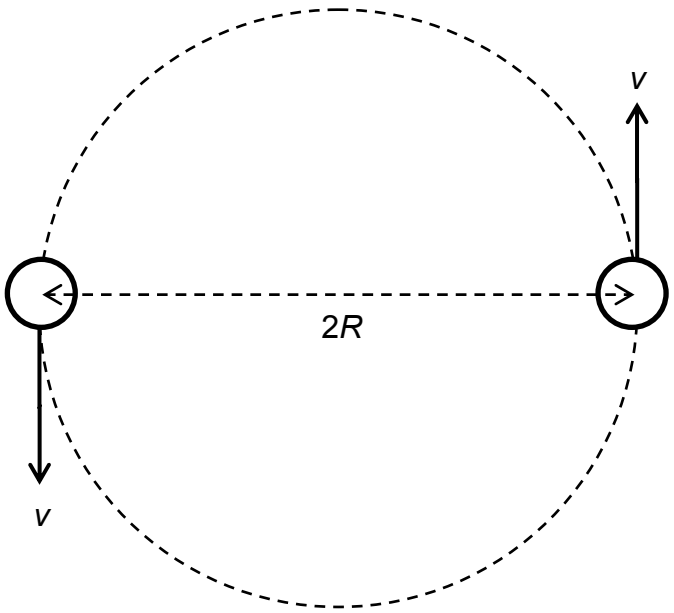

Fig 2.1

The mass of each star is M and their separation is $2R$. The speed of each star is v.

(i) Determine the speed of each star, v, in terms of G, M and R. [2]

(ii) Hence or otherwise, show that the period of revolution T of each star is given by the expression

$$T = \sqrt{\frac{16\pi^2 R^3}{GM}}$$

[2]

(b) The total energy E of the star system is given by the expression

$$E = -\frac{GM^2}{4R}$$

This particular star system is unstable and loses energy over time.

(i) Using conservation of energy, show that $E = -\frac{GM^2}{4R}$. [1]

(ii) Explain how the loss of energy implies that the orbital period of the stars will decrease.

……

……

…… [2]

(iii) For an unstable star system with $R = 6.5 \times 10^5$ km and $M = 3.0 \times 10^{30}$ kg, the rate of decrease of the period of star system is 7.0×10^{-5} s per year.

Estimate the time, in years, when the stars will crash into each other.

time = …… yrs [2]

3 (a) A rectangular coil is rotating about an axis between two magnets with uniform angular velocity ω. The uniform magnetic field *B* between the two magnets is 0.80 T. The coil is rotating at 50 revolutions per second. The number of turns *N* of the coil is 30. The cross-sectional area *A* of the coil is 2.5 m^2. A current is found going through the resistor *R* with resistance of 40 Ω. **Fig. 3.1** shows the instant when the plane of the coil is in a horizontal position.

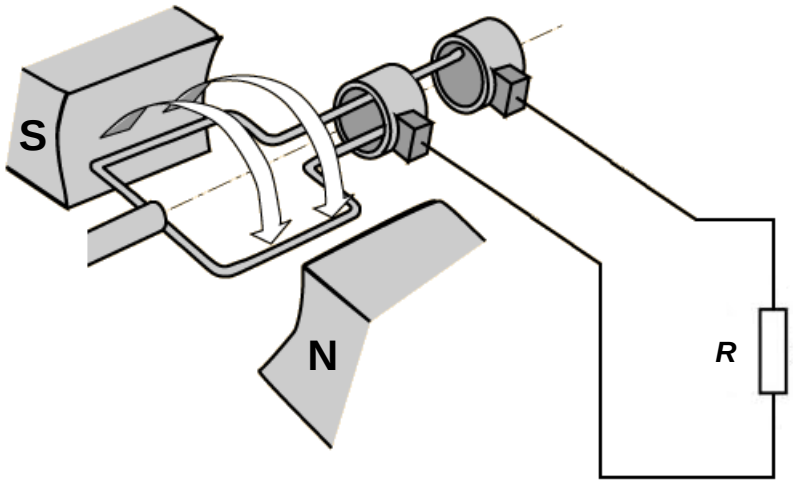

Fig. 3.1

(i) Explain how the current flowing through the resistor *R* is formed.

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…… [2]

(ii) Show that the variation of the current I through resistor *R* with time is given by the expression

$$I = -471\cos(100\pi t)$$

Take **Fig. 3.1** as the orientation of the coil at *t* = 0 s. You are required to show all your steps clearly. [2]

(iii) Diode, $\mathbf{D_1}$ is connected in series with resistor R = 40 Ω as shown in **Fig. 3.2**.

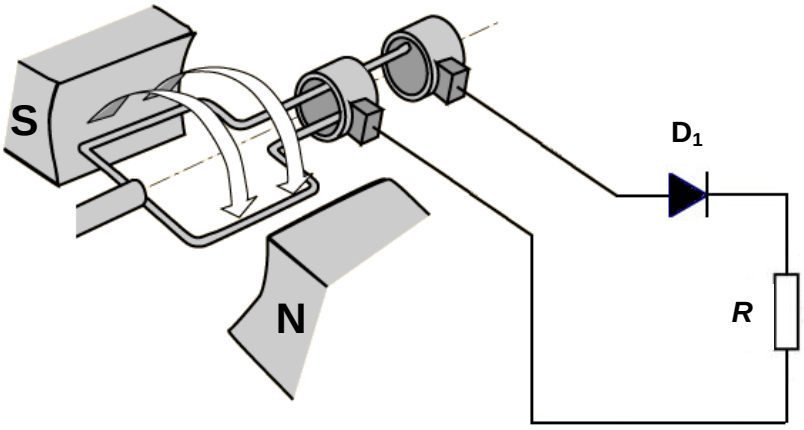

Fig. 3.2

Determine the mean power dissipated by resistor *R*.

mean power = ... kW [2]

(b) Electrodynamic bearings can be used to maintain the alignment of rotating conductors to high accuracy. **Fig. 3.3(a)** and **(b)** below show the essential components of such a system.

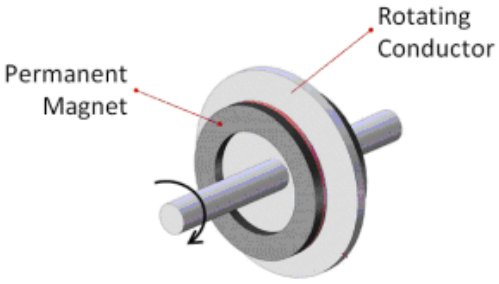

Fig. 3.3 (a)

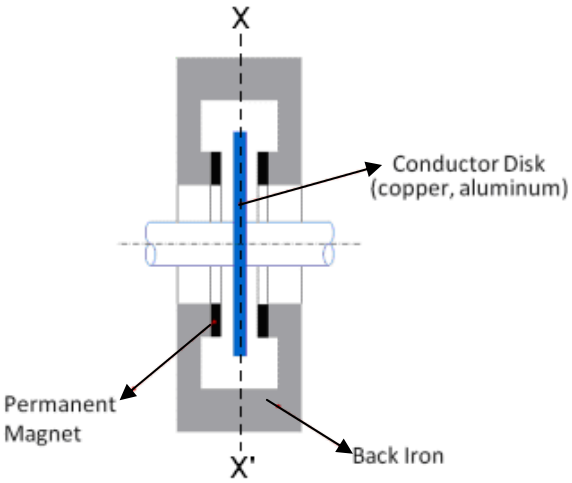

Fig. 3.3 (b)

The conductor disc remains aligned along central axis **XX'** when it is rotating at a high angular velocity.

(i) Using the laws of electromagnetic induction, explain how the alignment is achieved.

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…… [3]

(ii) Rotating parts in machines are commonly aligned using ball bearings. Precision ball bearings keep the distance between the rotating part and the static part fixed as shown in **Fig. 3.4** below.

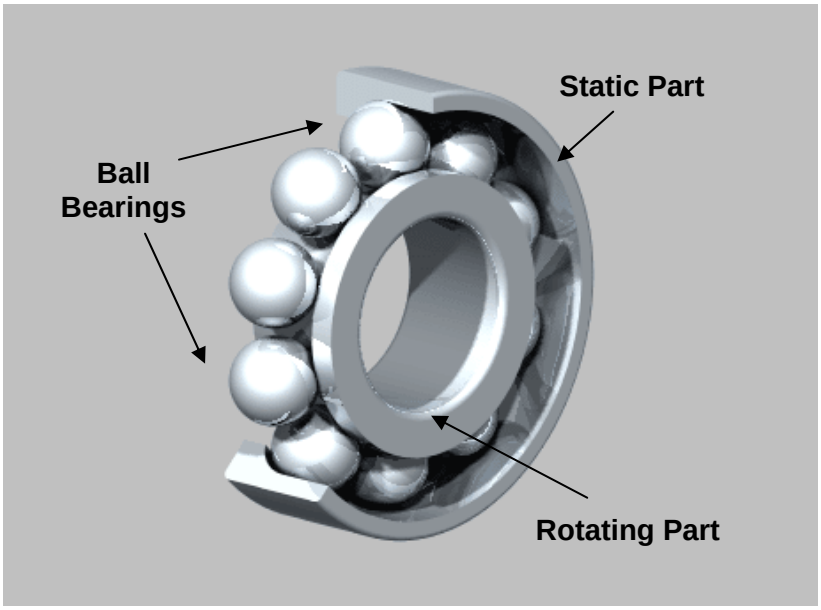

Fig. 3.4

State one advantage of electrodynamic bearings compared to ball bearings in the alignment of rotating parts in machinery.

……

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…… [1]

4 **Fig. 4.1** shows the graph shows the variation with wavelength λ of the relative intensity of an X-ray spectrum produced when the electrons strike a metal target.

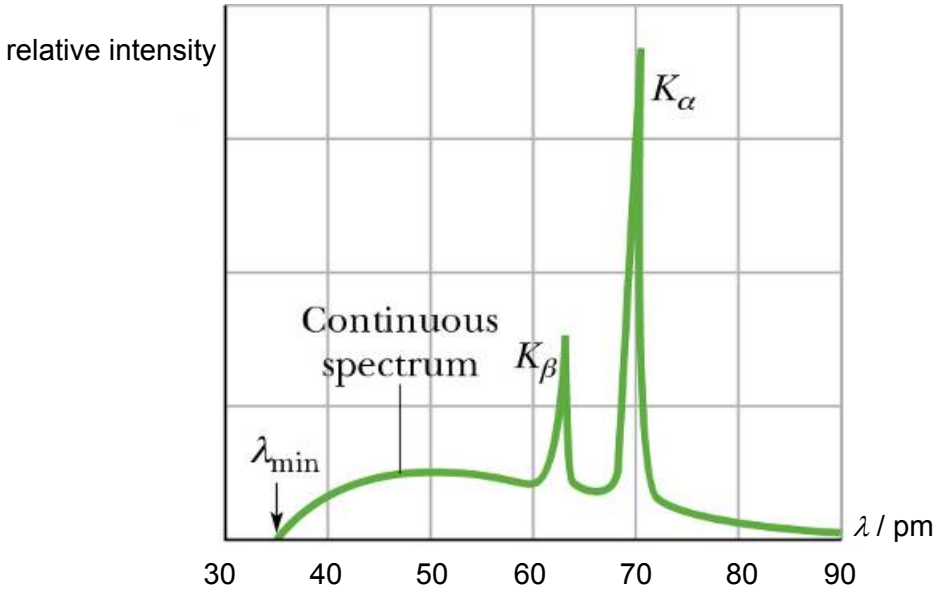

Fig. 4.1

The spectrum consists of a continuous spectrum and a characteristic line spectrum.

(a) **(i)** Estimate the maximum momentum of the incoming electrons striking the target.

maximum momentum of incoming electrons = …… N s [3]

(ii) State and explain how one can increase the relative intensity of the X-ray without causing a change in λ_{min}.

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..... [2]

(b) The metal target is now replaced by a new one. The X-ray spectrum produced is shown below in **Fig. 4.2**.

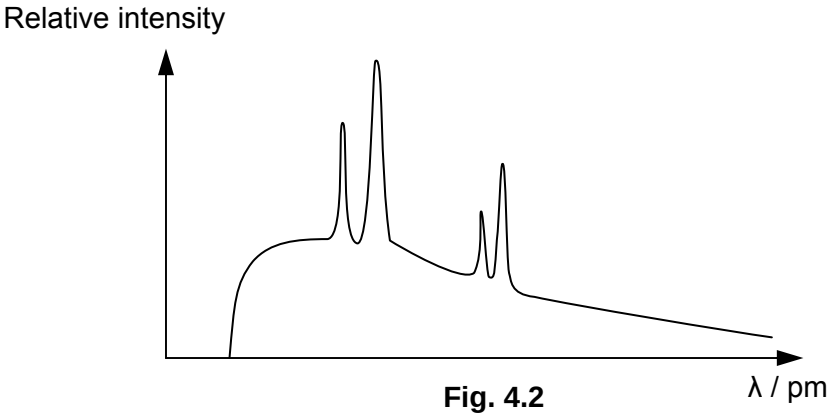

Fig. 4.2

(i) With reference to the presence of additional characteristic wavelengths, discuss whether the new metal target is made of atoms of a larger or smaller atomic mass than that of the old target.

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..... [3]

(ii) Suggest a reason why the characteristic wavelengths emitted have small variations, instead of being a well-defined value.

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..... [1]

5 **(a)** Stimulated emission and spontaneous emission are two processes in which photon emissions can take place.

Compare the main difference between how these processes can happen.

……..…….

……..…… [1]

(b) When a filament bulb is connected to a power supply, the filament in the bulb is heated up to produce a glow.

State the main type of photon emission process in a laser and a filament bulb.

Laser: ……..……

Filament bulb: ……..…… [1]

(c) Light from the laser is coherent whereas light from the filament bulb is not coherent.

Explain why.

……..…….

……..…….

……..…… [2]

(d) Light from the laser is directed through a diffraction grating onto a screen. It is then replaced with light from the filament bulb. Predict the observations.

……..…….

……..…… [1]

(e) State one other unique characteristic of light from laser.

……..…… [1]

6 **Fig 6.1** shows an electric storage cooker designed for use in a Nepalese village. During off-peak periods in electrical consumption a current is passed through an electric element thereby raising the temperature of the pebbles in a well-insulated container. The energy so stored is recovered when needed by using a fan to blow air over the hot pebbles. The heated air flows along a pipe to emerge at the cooking hob.

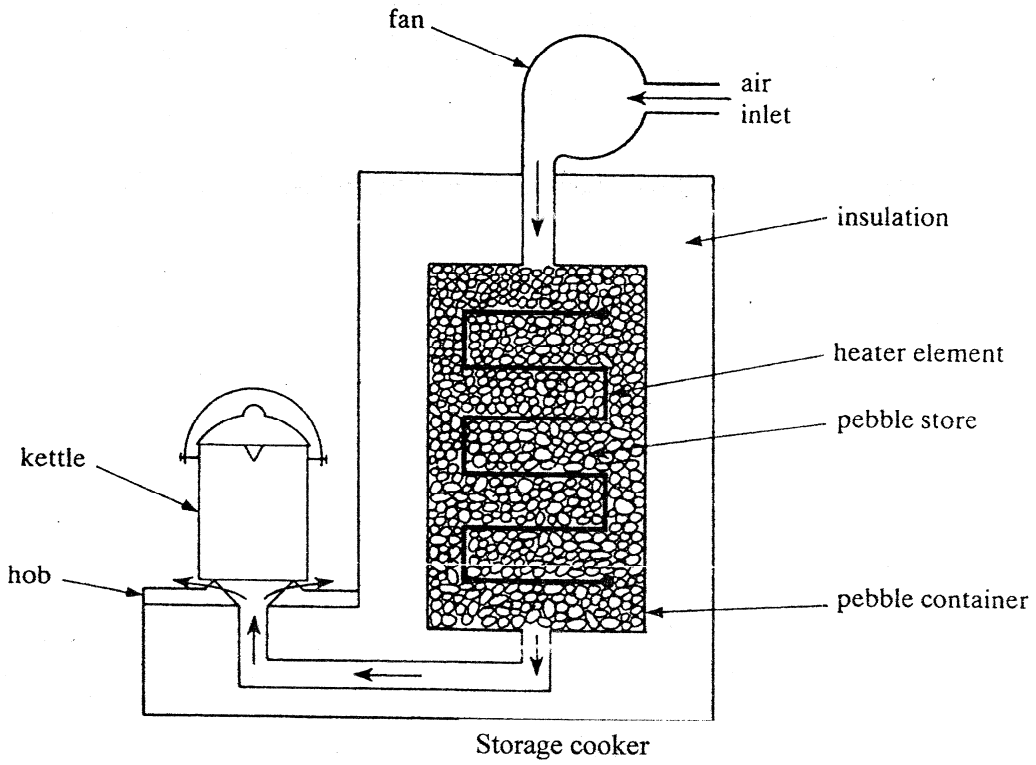


Fig. 6.1

Information on the storage cooker

Mass of the pebbles	20 kg
Initial temperature of the pebbles	20 °C
Final temperature of the pebbles	500 °C
Power of heater (heating element)	250 W
Time running the heater	8.0 h

Information of storage cooker when used to heat 1.2 kg of water in a kettle
(Assume that the kettle has negligible heat capacity.)

Mass of water	1.2 kg
Initial temperature of water	20 °C
Specific heat capacity of water	4.2 kJ kg^{-1} K^{-1}
Final temperature of water	100 °C
Time taken to heat water	12 min
Initial temperature of pebbles	500 °C
Final temperature of pebbles	460 °C
Specific heat capacity of air	990 J kg^{-1} K^{-1}
Density of air	1.3 kg m^{-3}
Temperature of air entering the system	20 °C
Volume flow rate of air	1.5 x 10^{-3} m^3 s^{-1}

(a) Assuming that the insulation is perfect and that energy losses from the storage cooker are negligible when the fan is switched off, determine the specific heat capacity of the pebbles, by considering the energy transferred to the pebbles during the 8.0 h period.

specific heat capacity of pebbles = ……. J kg^{-1} K^{-1} [3]

(b) By considering the energy transfer when the storage cooker is used to heat 1.2 kg of water in a kettle, determine the efficiency of the energy transfer between the pebbles and the water.

efficiency = …….. [4]

(c) Determine the average power output of the storage cooker (i.e. the average rate of energy loss of the pebbles) during this period.

average power output = ... W [1]

(d) Show that during the heating of water in the kettle, the average temperature of the air leaving the pebbles is 450 °C. [4]

(e) Estimate the power output of the storage cooker if the temperature of the air leaving the pebbles is 150°C (the minimum useful temperature to boil water in a kettle).

power output = ... W [2]

(f) Suggest one improvement to the design of the system such that it is possible to boil more kettles of water from each charging.

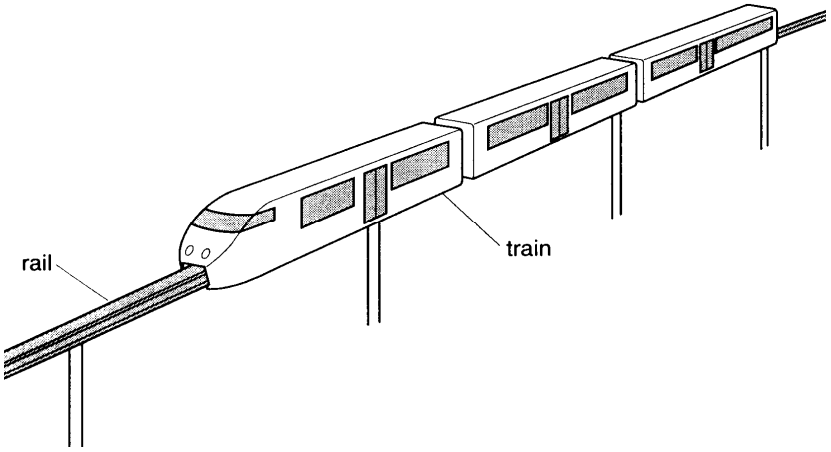
.....

..... [1]

Name: …… Class: ……...

*It is recommended that you spend about **30 minutes** on this question.*

7 Efforts are being made to increase the efficiency of railway networks. One way of doing this is to reduce the resistive forces experienced by trains. This can be achieved by levitating the train using very large electric currents which pass through superconducting materials to produce strong magnetic fields. It is important that the train remains at a fixed distance above the rail.



As a first-stage investigation of this effect, an electromagnet (consisting of a coil of copper wire at the base of an iron rod) is used to levitate an aluminium ring at a fixed height, based on principles of electromagnetic induction. When the coil is energized by passing a current through it, the ring rises to a stationary position above the coil.

Design an experiment to investigate how the coil current needed to raise the ring to a fixed distance above the coil varies with the load supported by the aluminium ring.

You may assume that the following apparatus are available, together with any other standard equipment which may be found in a college science laboratory.

Aluminium ring
Plasticine block
Cardboard
Iron rod
Roll of copper wire
D.C power supply
A.C power supply

In your answer, you should pay particular attention to

(a) the procedure to be followed,

(b) the control of variables,

(c) how would the iron rod be used to guide the aluminum ring,

(d) any safety precautions with reasons,

(e) any precautions that you would take to improve the accuracy of the experiment.

[Total marks for this question: 12]

Diagram:

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End of Paper