Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2018 Preliminary Examination

PHYSICS **9749/02**
Higher 2

13 September 2018
Paper 2 Structured Questions **2 hours**

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your index number, name and class in the spaces at the top of this page.
Write in dark blue or black pen in the spaces provided in this booklet.
You may use pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	/ 15
2	/ 10
3	/ 12
4	/ 11
5	/ 12
6	/ 20
Deduction	
Total	/ 80

This document consists of **20** printed pages and **1** blank page.

Data

speed of light in free space	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}
		=	$(1/(36\pi)) \times 10^{-9}$ 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	=	$-Gm/r$
temperature	T/K	=	$T/{}^\circ\text{C} + 273.15$
pressure of an ideal gas	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_0 \cos \omega t = \pm\omega\sqrt{x_0^2 - x^2}$
electric current	I	=	$Anvq$
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	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	B	=	$\mu_0 nI$
radioactive decay	x	=	$x_0 \exp(-\lambda t)$
decay constant	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** **(i)** State Newton's Second Law of Motion as applied to a *system of bodies*.

....

....

.... [2]

(ii) Explain the implication of Newton's Second Law for a *system of bodies* isolated from all external forces.

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.... [2]

(b) Two blocks A and B are held together with a light spring in between them as shown in Fig. 1.1. The spring has a force constant 80 N m^{-1} and is compressed by 0.060 m.

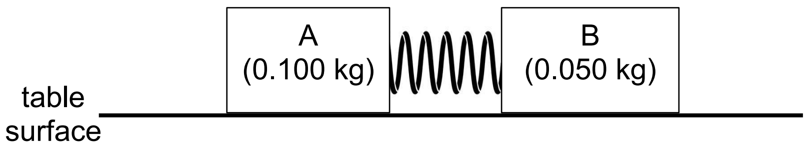

Fig. 1.1

The masses of blocks A and B are 0.100 kg and 0.050 kg respectively. Upon release, the two blocks move off in opposite directions on a smooth table surface and the spring falls off.

(i) On Fig. 1.2, sketch a graph to show the variation with time *t* of the force exerted by the spring on block B during which B is being pushed away from block A.

Fig. 1.2

[2]

(ii) Determine the final speeds of the two blocks.

speed of block A = ... m s^{-1}

speed of block B = ... m s^{-1} [4]

(c) As block B slides forward, it topples over at the edge of the table and lands on a horizontal uniform plank hinged to a wall at O. The centre of block B is at a horizontal distance of 0.15 m from the free end of the plank. The plank is supported by a rope attached to the wall as shown in Fig. 1.3.

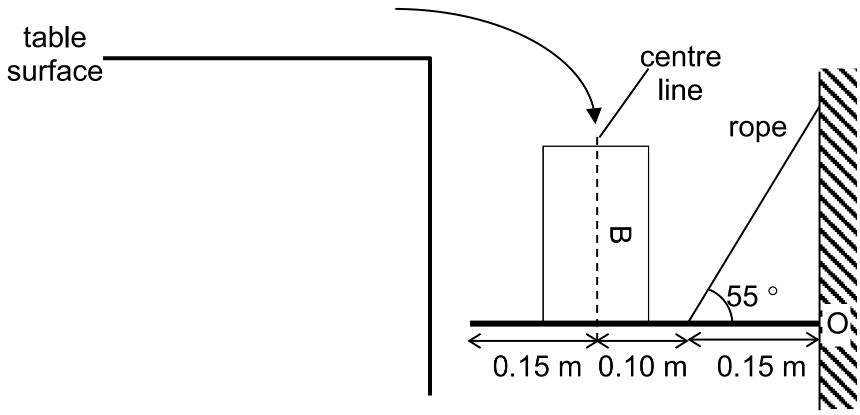

Fig. 1.3

Given that the weight of the plank is 4.0 N, calculate

(i) the tension in the rope after B is at rest on the plank,

tension = ... N [2]

(ii) the magnitude of the horizontal and vertical components of the force exerted by the hinge on the plank,

magnitude of horizontal component = ... N

magnitude of vertical component = ... N [2]

(iii) the angle θ that the force by the hinge on the plank makes with the horizontal. On Fig. 1.3, draw and label the force *F* by the hinge and indicate the angle θ.

θ = ... ° [1]

2 **(a)** A speaker emits sound waves uniformly in all directions. Fig. 2.1 shows the variation with time t of the displacement x of an air molecule at a point Q that is 120 cm from the speaker.

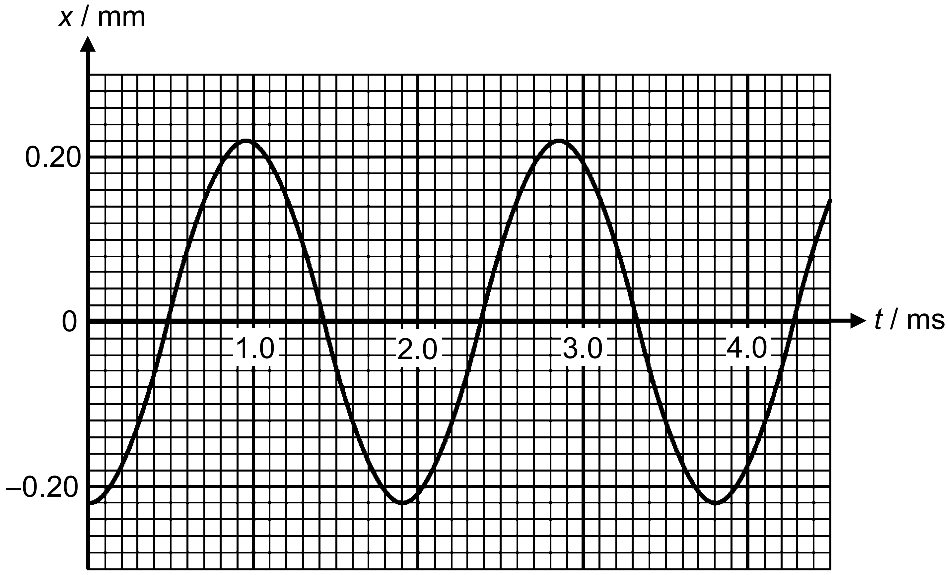

Fig. 2.1

(i) Use Fig. 2.1 to determine the

1. frequency f of the sound waves,

f = ... Hz [1]

2. uncertainty in f calculated in **(a)(i)1.** caused by reading the scale of the graph.

uncertainty in f = ... Hz [3]

(ii) Determine the next earliest time after 1.5 ms when the motion of the air molecule at Q has a phase difference of $\frac{4}{5}\pi$ compared to its phase at 1.5 ms.

time = ... ms [2]

(iii) If the power of the source is reduced to 0.25 of its initial value, calculate the distance from the speaker that will have the same intensity as that at point Q.

distance = ... cm [2]

(b) The wave arriving at point Q is progressive in nature. A stationary wave may be formed when two identical waves travelling in opposite directions superpose.

State the differences between the particles of a progressive wave and particles of a stationary wave in the following aspects:

(i) amplitude,

....

....

.... [1]

(ii) phase difference.

....

....

.... [1]

3 **(a)** Fig. 3.1 shows two chambers, X and Y, connected by a small pipe which is fitted with a valve. Both chambers are filled with ideal gas and the valve was initially closed. The volume of chambers X and Y are 2.5 m^3 and 4.0 m^3 respectively. Chambers X and Y are held at temperatures of 450 K and 300 K respectively.

The valve is then opened and a state of equilibrium is reached with the temperatures in each chamber remaining unchanged.

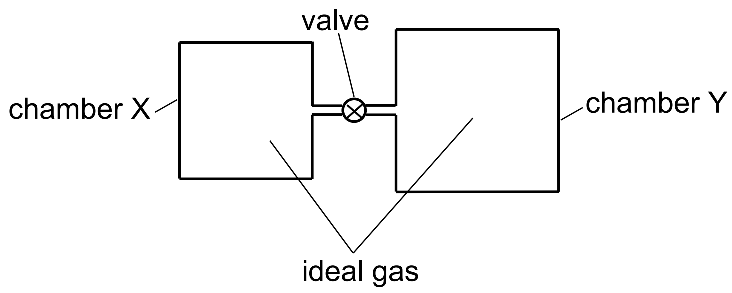

Fig. 3.1

(i) Determine the number of moles of ideal gas in chamber X, given that the number of moles of ideal gas in chamber Y is 1.2 after equilibrium has been reached.

number of moles of ideal gas in X = ... [2]

(ii) Calculate the pressure in both chambers after equilibrium has been reached.

pressure = ... Pa [1]

(iii) The valve is now closed and a pump is used to remove some ideal gas from chamber Y.

State and explain, using the kinetic theory of gas, why the pressure in chamber Y decreases, assuming no change in its temperature.

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.... [1]

(b) A system of a fixed mass of ideal gas undergoes a cycle of changes. Fig. 3.2 shows the variation with volume V of the pressure p of the ideal gas as it undergoes the cycle ABCA.

Process A to B is isothermal, process B to C is isovolumetric and process C to A is adiabatic where there is no heat transfer into or out of the system of ideal gas.

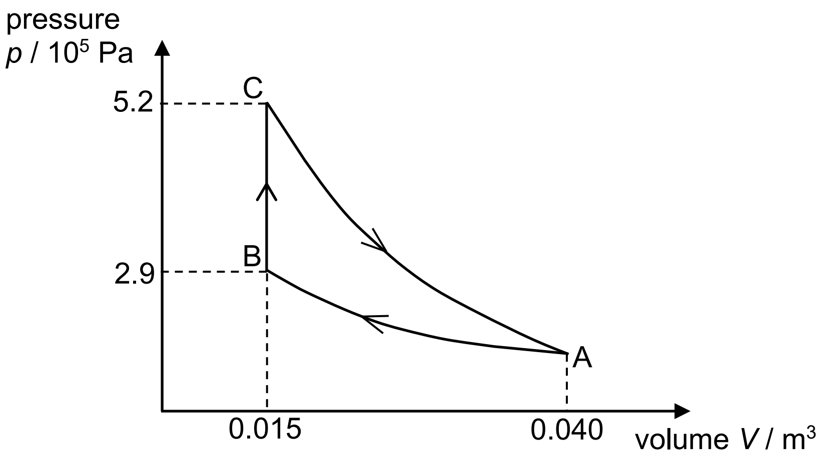

Fig. 3.2

Given that the mass of the ideal gas is 0.060 kg, calculate

(i) the pressure of the ideal gas in state A,

pressure = ... Pa [2]

(ii) the root-mean-square (r.m.s.) speed of the ideal gas molecules in state A,

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

(iii) the thermal energy absorbed by the system of ideal gas from B to C.

thermal energy = ... J [3]

(iv) Suggest one other way in which the adiabatic process C to A could be achieved in practice, other than by thermally insulating the system of gas.

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.... [1]

4 **(a)** State, in words, the relation between the electric field strength E and potential V at a point.

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.... [1]

(b) Two positively charged metal spheres, P and Q, of diameters 32 cm and 16 cm respectively, each carrying a charge of +7.2 nC, are isolated in space, as shown in Fig. 4.1.

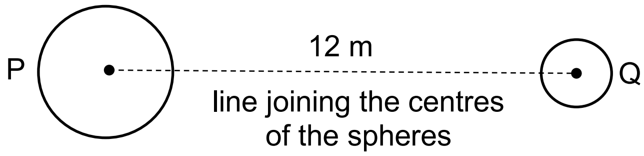

Fig. 4.1

The centres of the spheres are separated by a distance of 12 m. The distance x is measured from the centre of sphere P along the line joining the centres of the two spheres. Assume charges remain uniformly distributed on the surfaces of the spheres.

(i) State the value of x for which a stationary charged particle remains stationary when placed at this distance from the centre of sphere P.

x = ... m [1]

(ii) Calculate the electric potential at the point where the stationary charged particle remains stationary as stated in **(b)(i)**.

electric potential = ... V [1]

(iii) Sketch on Fig. 4.2, the variation with distance x of the electric potential V along the line joining the centres of the two spheres. Indicate on the horizontal axis your value of x in **(b)(i)**.

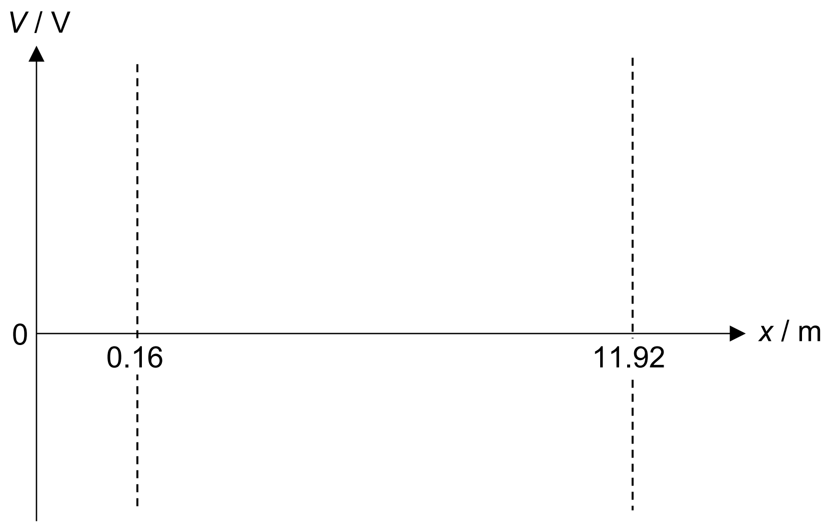

Fig. 4.2 (not to scale)

[3]

(iv) A positively charged particle is released at x = 0.16 m (surface of P).

With reference to your graph in **(b)(iii)**,

1. state and explain whether it will reach x = 11.92 m (surface of Q),

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.... [2]

2. describe and explain the entire motion of this particle, using energy considerations or otherwise.

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.... [3]

5 **(a)** **(i)** Distinguish between electrical resistance and resistivity.

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.... [1]

(ii) A metal wire XY of resistance 2.0 Ω has a diameter of 1.0 mm and a resistivity of 1.5×10^{-6} Ω m.

Calculate the length of the wire.

length = ... m [1]

(b) A battery of e.m.f. 6.0 V with negligible internal resistance is connected to the metal wire XY and a light bulb of resistance 4.0 Ω as shown in Fig 5.1. The length of the connecting wire joining the negative terminal of the battery to the lamp is 0.20 m.

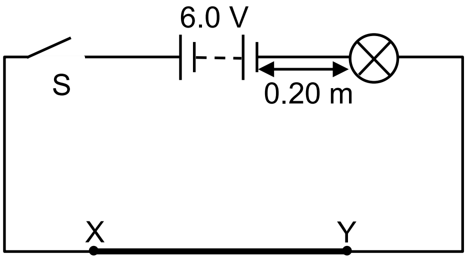

Fig. 5.1

(i) Switch S is closed. Calculate the current in the circuit.

current = ... A [1]

(ii) The connecting wires of diameter 1.0 mm are made of copper.

Given that the density and molar mass of copper are 8.96×10^3 kg m^{-3} and 64.0 g respectively, calculate the average drift velocity in the copper wires.

Assume that the number of conduction electrons is equal to the number of copper atoms in the wire.

drift velocity = ... m s^{-1} [3]

(iii) Calculate the time it would take for an electron to move from the negative terminal of the battery to the light bulb.

time = ... s [1]

(iv) The light bulb lights up in a time much lesser than the time calculated in **(b)(iii)**. Explain this observation.

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.... [2]

(c) The light bulb is removed from the circuit in Fig. 5.1.

A cell with e.m.f. 3.0 V and internal resistance 0.50 Ω and a galvanometer are now connected to the circuit as shown in Fig. 5.2.

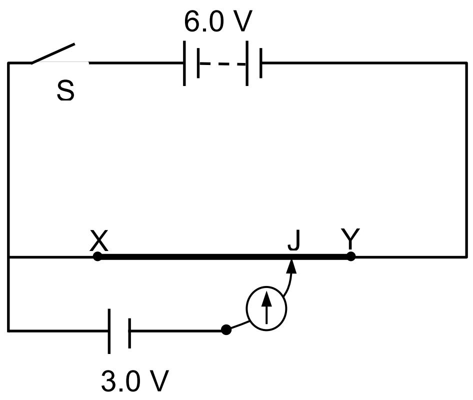

Fig. 5.2

(i) Calculate the length XJ when the galvanometer reads zero.

length XJ = ... m [1]

(ii) A 1.0 Ω resistor is now connected across the 3.0 V cell.

Calculate the new length XJ when the galvanometer reads zero.

length XJ = ... m [2]

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6 The electrical generator in a power station is driven by a steam turbine. The turbine absorbs thermal energy from a boiler and produces useful work. However, thermal energy must also be removed from the turbine by a cooling system as shown in Fig. 6.1.

The operating efficiency e of the turbine is defined by

$$e = \frac{\text{useful work output}}{\text{thermal energy input}}$$

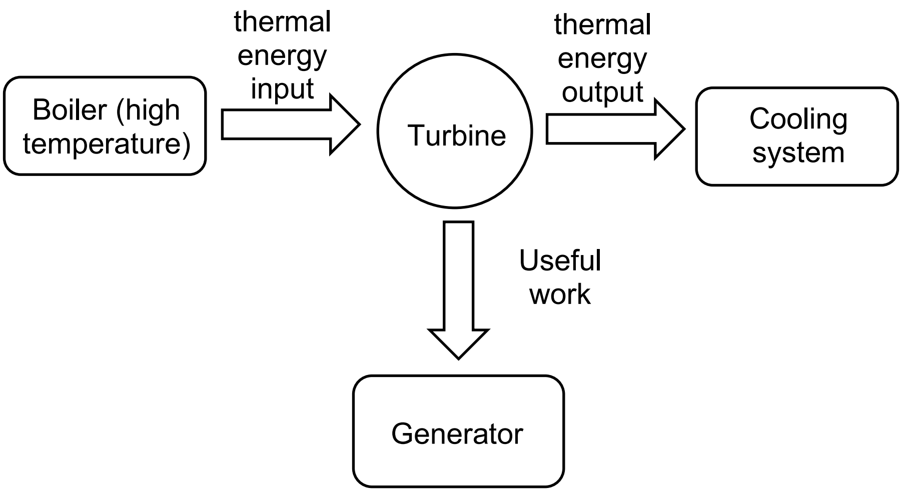

Fig. 6.1

The efficiency of heat engines, of which the turbine is an example, can never exceed a certain value which is fixed by temperatures of the boiler and the cooling system. This ideal efficiency e_{max} is given by the equation

$$e_{max} = \frac{T_2 - T_1}{T_2}$$

where T_2 is the thermodynamic temperature of the boiler and T_1 is the thermodynamic temperature of the cooling system.

Further data for a particular power station situated in Newtown, United Kingdom, are given in Fig. 6.2 below.

Electrical power output	200 MW
Efficiency of electrical generator	100%
Operating efficiency of turbine	31%
Ideal efficiency of turbine	52%
Effective temperature of cooling system (The cooling system uses water which enters at a temperature of 283 K and leaves at 291 K.)	330 K
Specific heat capacity of water in cooling system	4200 J kg^{-1} K^{-1}

Fig. 6.2

(a) Calculate the ideal efficiency e_{max} if the boiler temperature is 100 °C and the cooling system is at 27 °C.

e_{max} = ... [2]

(b) **(i)** Fig. 6.3 shows values of T_2 and e_{max} for a particular value of T_1.

T_2 / K	e_{max}
333	0.048
373	0.15
450	0.30
600	0.47
750	0.58

Fig. 6.3

Plot the variation with T_2 of e_{max} on the axes in Fig. 6.4.

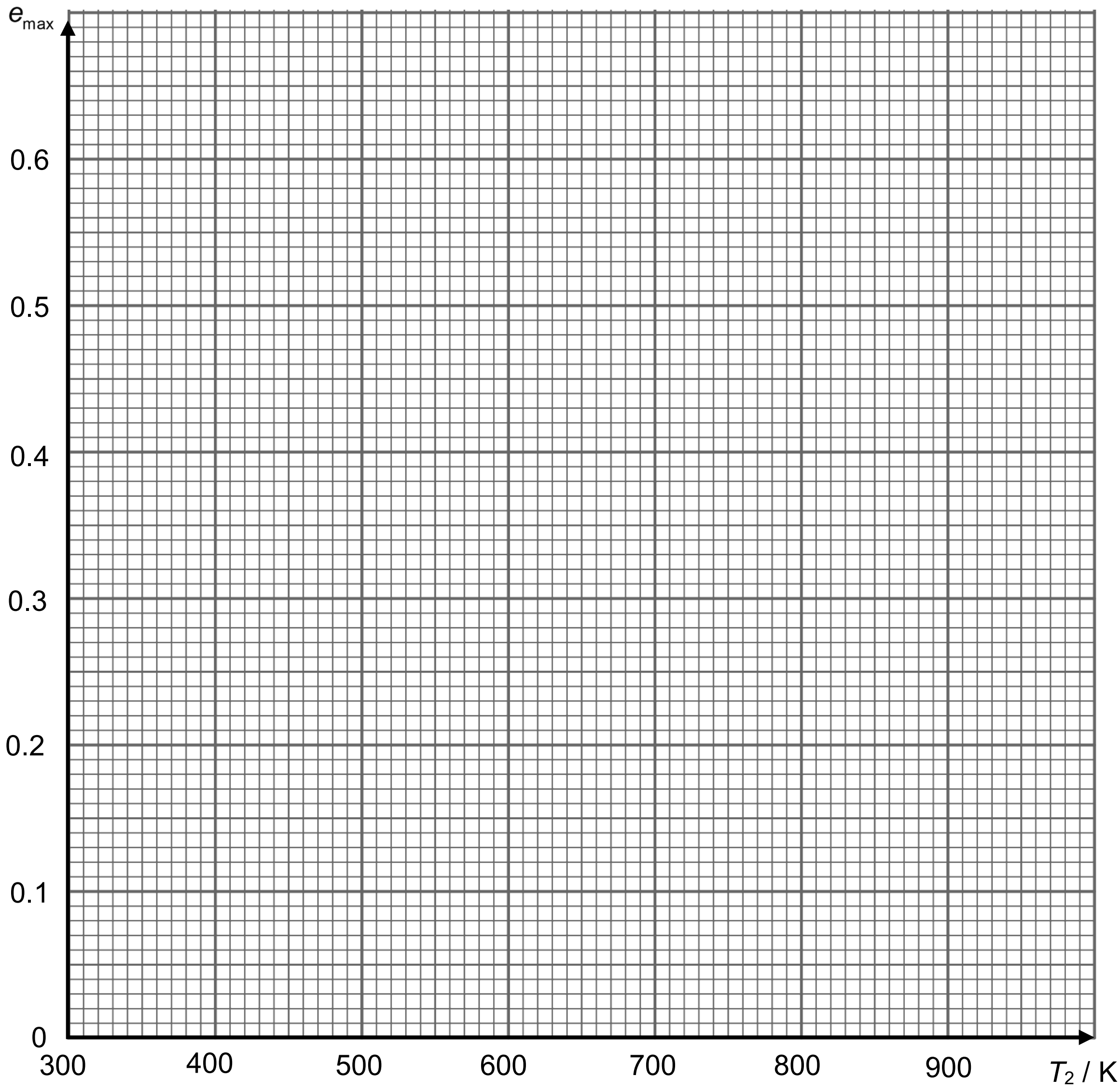

Fig. 6.4

[3]

(ii) From the graph, deduce the value of T_2 for which $e_{max} = 0$.

T_2 = ... K [1]

(iii) Hence, deduce the value of T_1.

T_1 = ... K [1]

(iv) Explain why it is not practical to attain an efficiency of 1.

....

....

....

.... [2]

(c) For the power station in Newtown, calculate

(i) the effective boiler temperature,

effective boiler temperature = ... K [1]

(ii) the rate of input of thermal energy to the turbine,

rate of input of thermal energy = ... W [1]

(iii) the rate at which thermal energy is removed from the turbine,

rate at which thermal energy is removed = ... W [1]

(iv) the required rate of flow of water through the cooling system.

rate of flow of water = ... kg s^{-1} [2]

(d) Suggest a reason for the discrepancy between the ideal efficiency of the turbine and its operating efficiency.

....

.... [1]

(e) A significant fraction of the electrical power produced in the UK by burning fossil fuels is used for domestic heating. Two suggestions for improvement are as follows:

(i) Burn the fossil fuel in the home instead of at the power station.

(ii) Cogeneration or combined heat and power (CHP) mechanisms which use the thermal energy output from the turbine for domestic heating.

Comment critically on these suggestions.

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.... [2]

(f) Approximately 95% of Singapore's electricity is produced from fossil fuels (natural gas, coal, petroleum). Due to the lack of natural resources, most of the fossil fuels are imported from neighbouring countries. To enhance the nation's energy security and reduce our carbon footprint, the government has been exploring alternative energy sources.

(i) Suggest, with a reason, the renewable energy source that is the most viable option for Singapore.

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.... [2]

(ii) State and explain a limitation in the deployment of the renewable energy source suggested in **(f)(i)** on a large scale to generate electricity reliably in Singapore.

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.... [1]

End of Paper 2