Centre Number	Index Number	Name	Class
S3016			

RAFFLES INSTITUTION
2019 Preliminary Examination

PHYSICS
Higher 2

9749/03

Paper 3 Longer Structured Questions

27 September 2019
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 a 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.

Section A
Answer **all** questions.

Section B
Answer **one** question only and **circle the question number** on the cover page.

You are advised to spend one and half hours on Section A and half an hour on Section B.

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

* **This booklet only contains Section A.**

For Examiner's Use		
Section A	1	/ 7
	2	/ 10
	3	/ 7
	4	/ 10
	5	/ 10
	6	/ 9
	7	/ 7
Section B (circle 1 question)	8	/ 20
	9	/ 20
Deduction		
Total		/ 80

This document consists of **16** printed pages.

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 / °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	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** Define *moment* of a force about a point.

....

.... [2]

(b) Fig. 1.1 shows a force diagram that represents a load that is being lifted by the boom of a mobile crane.

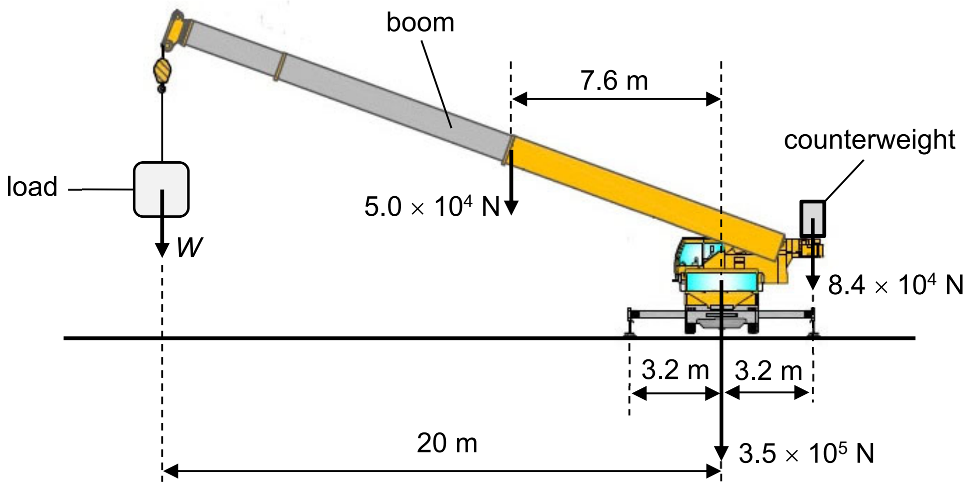

Fig. 1.1

The weight of the mobile crane is 3.5×10^5 N, the weight of the boom is 5.0×10^4 N and the weight of the load is W. A counterweight of 8.4×10^4 N is placed onto the crane to allow heavier loads to be lifted.

(i) The mobile crane will pivot about a point if the load is too heavy. On Fig. 1.1, mark this point and label it P.

[1]

(ii) Explain why the addition of a counterweight enables the crane to lift heavier loads.

....

....

.... [2]

(iii) Use the principle of moments to determine the maximum weight of the load that can be lifted by the crane at a constant speed.

W = ... N [2]

2 Fig 2.1 shows the variation with the distance d from the centre of the Moon of the gravitational potential ϕ between the surface of the Moon and the surface of the Earth.

Point P is on the surface of the Moon. Point Q, at a distance x from the center of the Earth, is where the gravitational potential due to the Earth and the Moon is the highest.

mass of Moon = 7.4×10^{22} kg
mass of Earth = 6.0×10^{24} kg
Earth-Moon distance = 3.8×10^{8} m

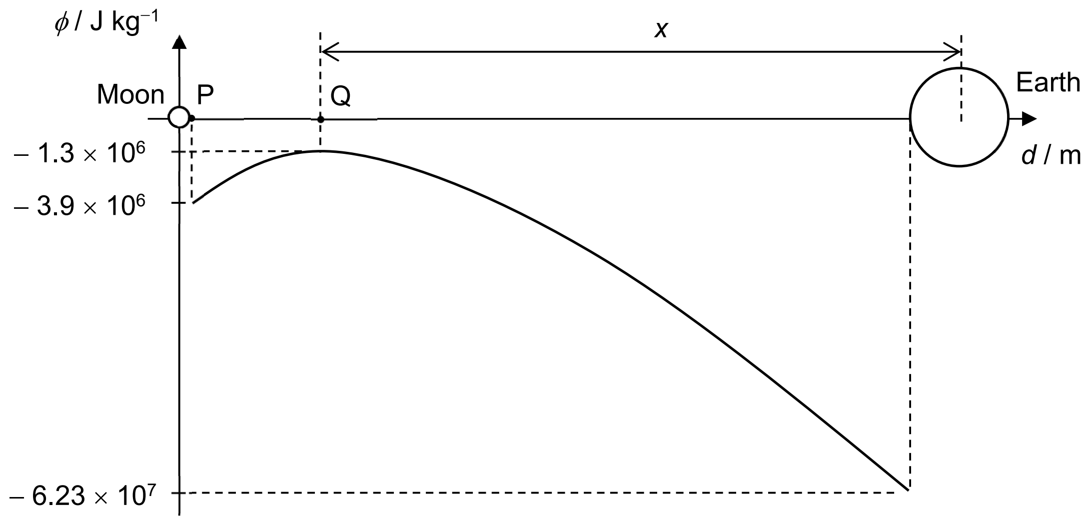

Fig. 2.1 (not drawn to scale)

(a) State what is meant by *gravitational potential* at a point.

....

.... [2]

(b) Show that x is approximately 3.4×10^{8} m.

x = ... m [2]

(c) A research company plans to launch a satellite of 520 kg that orbits around the Earth to observe the Moon.

In order to observe the Moon continuously, the satellite has an orbital period of 27 days such that it is always in between the Earth and the Moon as shown in Fig. 2.2.

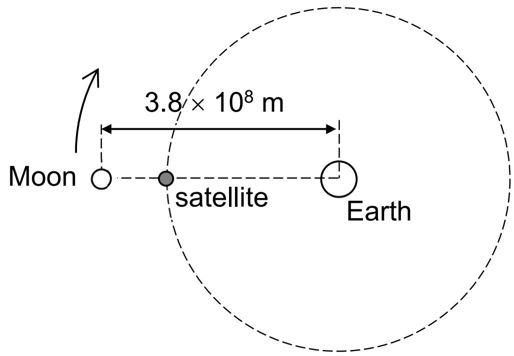

Fig. 2.2 (not drawn to scale)

(i) When the satellite is in orbit, the resultant force acting on the satellite due to the Moon and the Earth is 1.22 N.

Show that the distance of the satellite from the Earth is approximately 3.2×10^8 m.

[2]

(ii) Hence, determine the gravitational potential at the location of the satellite due to the Earth and the Moon.

gravitational potential = ... J kg^{-1} [3]

(d) An instrument is to be launched from the satellite to the Moon while it is in orbit.

A student claims that the minimum energy required to send the instrument to the Moon is the product of the mass of the instrument and the difference in gravitational potential on the surface of the Moon and at the position of the satellite.

Comment on the statement.

....

....

.... [1]

3 **(a)** State the first law of thermodynamics.

....

....

.... [2]

(b) A fixed mass of an ideal gas undergoes a cycle of changes ABCA, as shown in Fig. 3.1.

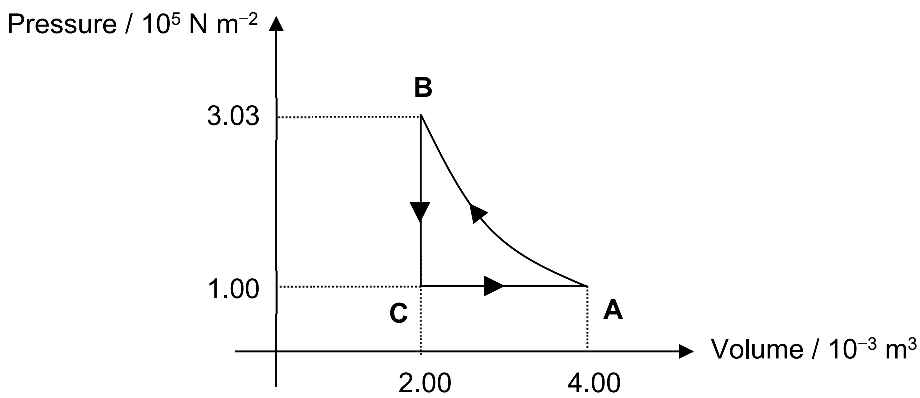

Fig. 3.1

(i) Calculate the work done by the gas during the change C to A.

work done by the gas = ... J [2]

(ii) Some energy changes during one cycle ABCA are shown in Fig. 3.2.

change	work done on gas / J	heat supplied to gas / J	increase in internal energy / J
A to B	310	0	
B to C		– 610	
C to A			

Fig. 3.2

Use your answer in **(i)** to complete Fig. 3.2. [3]

4 **(a)** **(i)** State the conditions required for the formation of a stationary wave.

....

....

....

.... [2]

(b) Fig. 4.1 shows two small and identical microwave emitters S_1 and S_2 placed 0.12 m apart in a wide open space. The emitters are in phase and emit microwaves of wavelength 0.040 m uniformly in all directions.

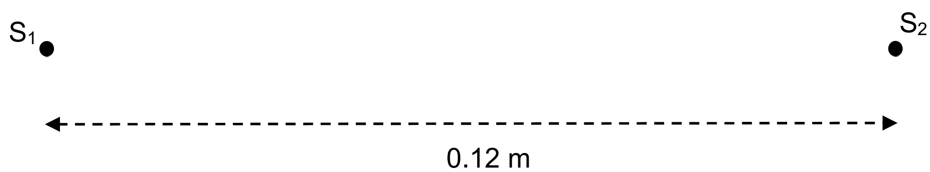

Fig. 4.1

(i) On Fig. 4.1, sketch the stationary wave pattern formed in the space between S_1 and S_2. Mark all the positions of the displacement nodes (use the letter N) and the displacement antinodes (use the letter A).

[2]

(ii) A microwave receiver is now placed at the point M, 0.18 m to the right of S_2, and along the line S_1S_2 as shown in Fig. 4.2.

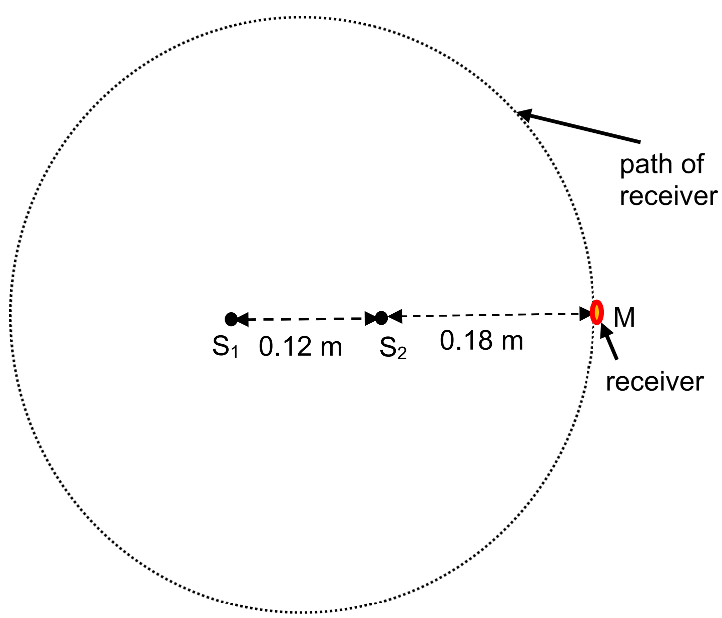

Fig. 4.2 (not drawn to scale)

1. State and explain whether the intensity of the signal detected by the receiver at M is a maximum or a minimum.

....

....

.... [2]

2. The receiver is now moved in a circular path for one complete round around the two emitters. Determine the number of intensity maxima it detects.

number of intensity maxima = ... [1]

(c) A parallel beam of monochromatic light of wavelength 550 nm falls normally on a narrow slit of width *d*, as shown in Fig. 4.3. The diffraction pattern is observed on a screen placed 1.2 m away, where it is found that the distance between the first dark fringes on both sides of the central maximum O is 2.3 mm.

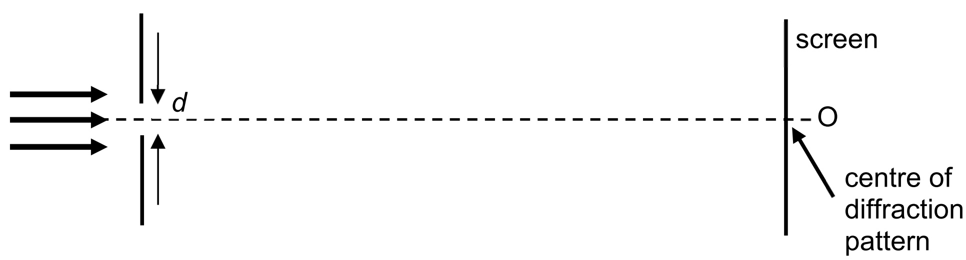

Fig. 4.3

(i) On Fig. 4.4 below, sketch the variation with distance along the screen of the intensity of the light in the single-slit diffraction pattern formed on the screen.

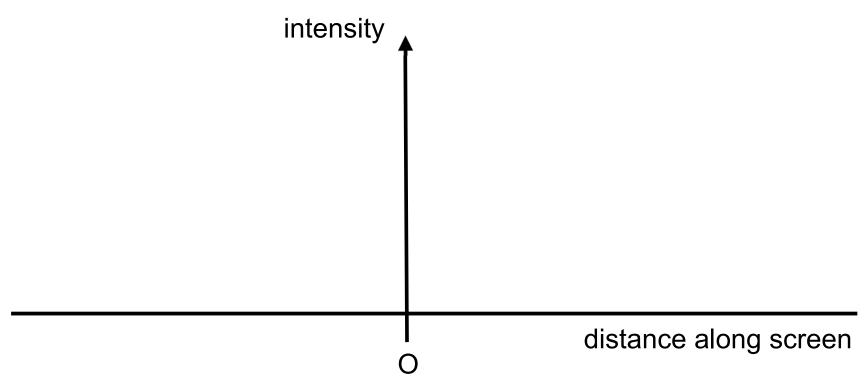

Fig. 4.4

[2]

(ii) Show that the width d of the slit is 5.7×10^{-4} m.

[1]

5 **(a)** Explain what is meant by the *resistance* of a resistor.

....

.... [1]

(b) A student is given a resistor of resistance R in the range of kilo-ohms and wishes to determine its value accurately. To do so, he sets up the circuit as shown in Fig. 5.1.

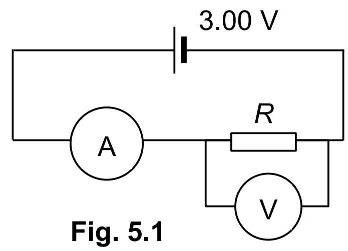

Fig. 5.1

The voltmeter has a resistance of 6000 Ω and the ammeter has negligible resistance. The voltmeter reading V is 3.00 V and the ammeter reading I is 1.50 mA.

(i) The student calculates the value of R using

$$R = \frac{V}{I}$$

Explain why this value of R is inaccurate.

....

.... [1]

(ii) Calculate the actual value of R.

R = ... Ω [3]

(iii) Using the circuit components in Fig. 5.1, draw a circuit that will allow the student to calculate R accurately with the equation in **(b)(i)**.

[1]

(c) The student then decides to use a second method to determine R. He sets up the potentiometer circuit as shown in Fig. 5.2.

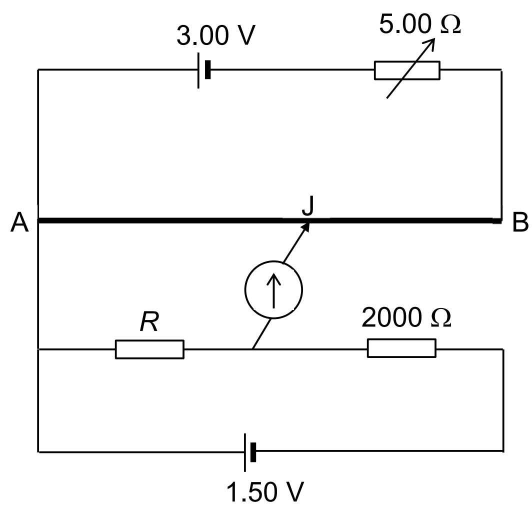

Fig. 5.2

In the potentiometer circuit, a variable resistor connected to the 3.00 V e.m.f. source is set to 5.00 Ω. The potentiometer wire AB has a length of 100 cm and a resistance of 10.0 Ω. No current flows through the galvanometer when the sliding contact is at point J.

(i) Calculate the potential difference across the wire AB.

potential difference = ... V [2]

(ii) Using your answer for R in **(b)(ii)**, determine the balance length AJ.

balance length = ... cm [2]

6 **(a)** Define the *tesla*.

....

....

.... [2]

(b) Fig. 6.1 shows a uniform metal rod resting on a smooth metal circular rail guide of negligible resistance and the rod is able to move freely along the rail guide. A uniform magnetic field of flux density 0.56 T is applied into the paper. A light carbon brush is placed in contact with the centre of the metal rod. The carbon brush and rail guide are connected to a d.c. supply as shown in Fig. 6.2.

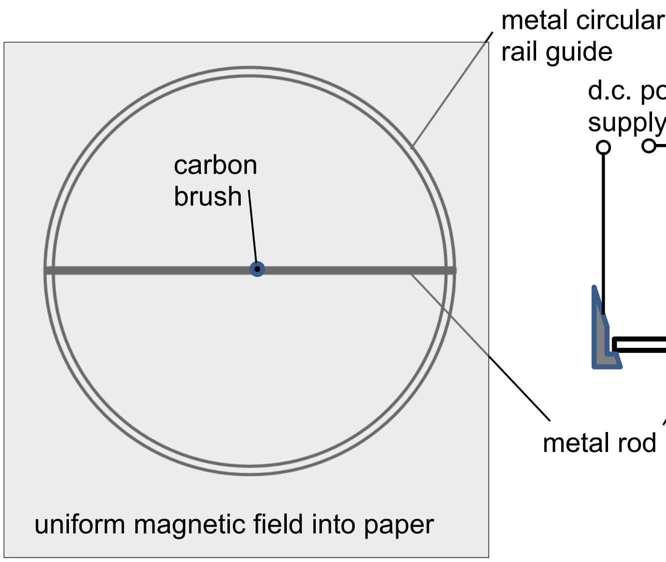

Fig. 6.1 (Top view)

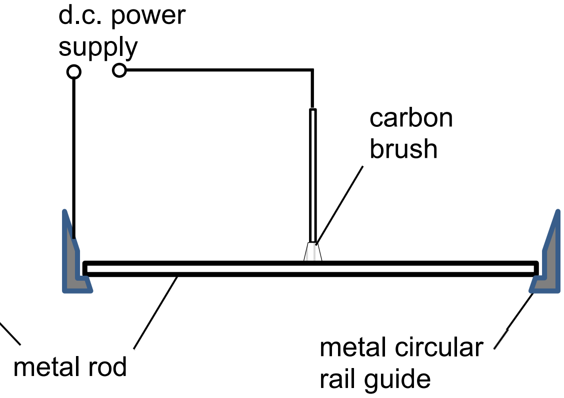

Fig. 6.2 (cross-sectional view)

(i) A current is passed through the circular rail guide and carbon brush such that the rod rotates in a clockwise direction as viewed from the top. On Fig. 6.2, draw arrows to show the direction of the current flow in the carbon brush and metal rod. [1]

(ii) With reference to Fig. 6.1, explain why the rod rotates in a clockwise direction.

....

....

....

....

....

....

.... [3]

(iii) The current flowing through the brush is 3.0 A. Calculate the force per unit length that is acting on the rod.

force per unit length = ... $N\ m^{-1}$ [2]

(iv) Explain why when the magnetic field is gradually rotated about the horizontal axis beyond a certain angle, the rod stops rotating.

....

....

.... [1]

7 **(a)** A simple generator consists of a coil with one turn that rotates at a constant rate in a uniform field as shown in Fig 7.1.

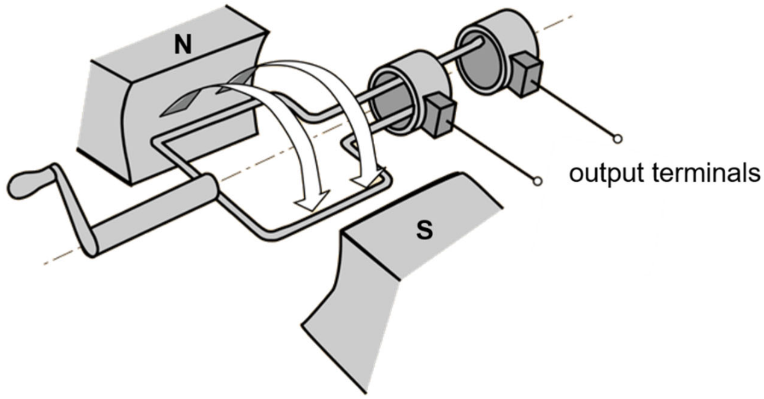

Fig. 7.1

(i) Explain why an e.m.f. is generated when the coil rotates.

....

....

.... [1]

(ii) The variation with time t of magnetic flux linkage Φ of the coil is shown in Fig 7.2. On the axes provided in Fig 7.2, sketch the variation with time of the induced e.m.f. E.

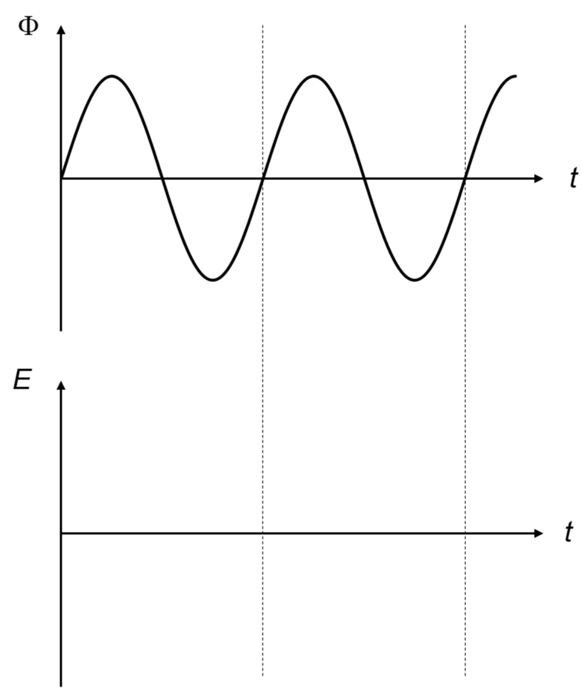

Fig 7.2

[1]

(b) The output from a similar generator is connected to the input of a transformer. The transformer has 12 turns on its primary coil and 600 turns on its secondary coil. The transformer may be considered to be ideal. The input e.m.f. is 2.3 kV root-mean-square.

(i) Explain what is meant by the *root-mean-square value* of an alternating voltage.

....

.... [2]

(ii) Determine the root-mean-square value of the induced e.m.f. across the secondary coil.

induced e.m.f. = ... V [2]

(iii) Explain the advantage of stepping up the voltage before transmission.

....

.... [1]

End of Paper 3 Section A