Centre Number	Candidate Number	Name

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

PHYSICS **9702/06**

Paper 6

May/June 2004

45 minutes

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

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen in the spaces provided on the Question Paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** of the questions in any **two** options.
The number of marks is given in brackets [ ] at the end of each question or part question.
You may lose marks if you do not show your working or if you do not use appropriate units.

If you have been given a label, look at the details. If any details are incorrect or missing, please fill in your correct details in the space given at the top of this page.

Stick your personal label here, if provided.

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A	
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Total	

This document consists of **22** printed pages and **2** blank pages.

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Data

speed of light in free space,	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$
permeability of free space,	$\mu_0 = 4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space,	$\epsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$
elementary charge,	$e = 1.60 \times 10^{-19}\ \text{C}$
the Planck constant,	$h = 6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant,	$u = 1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron,	$m_e = 9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton,	$m_p = 1.67 \times 10^{-27}\ \text{kg}$
molar gas constant,	$R = 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant,	$N_A = 6.02 \times 10^{23}\ \text{mol}^{-1}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant,	$G = 6.67 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$
acceleration of free fall,	$g = 9.81\ \text{m s}^{-2}$

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Formulae

uniformly accelerated motion, $s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$

work done on/by a gas, $W = p\Delta V$

gravitational potential, $\phi = -\frac{Gm}{r}$

simple harmonic motion, $a = -\omega^2 x$

velocity of particle in s.h.m., $v = v_0 \cos \omega t$
$v = \pm \omega \sqrt{(x_0^2 - x^2)}$

resistors in series, $R = R_1 + R_2 + \ldots$

resistors in parallel, $1/R = 1/R_1 + 1/R_2 + \ldots$

electric potential, $V = \frac{Q}{4\pi\epsilon_0 r}$

capacitors in series, $1/C = 1/C_1 + 1/C_2 + \ldots$

capacitors in parallel, $C = C_1 + C_2 + \ldots$

energy of charged capacitor, $W = \frac{1}{2}QV$

alternating current/voltage, $x = x_0 \sin \omega t$

hydrostatic pressure, $p = \rho g h$

pressure of an ideal gas, $p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$

radioactive decay, $x = x_0 \exp(-\lambda t)$

decay constant, $\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

critical density of matter in the Universe, $\rho_0 = \frac{3H_0^2}{8\pi G}$

equation of continuity, $Av = \text{constant}$

Bernoulli equation (simplified), $p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$

Stokes' law, $F = Ar\eta v$

Reynolds' number, $R_e = \frac{\rho v r}{\eta}$

drag force in turbulent flow, $F = Br^2\rho v^2$

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[Turn over

Answer **all** of the questions in any **two** of the Options.

Answer the questions in the spaces provided on the Question Paper.

The Options are as follows.

Option A	Astrophysics and Cosmology	questions 1, 2, 3 and 4
Option F	The Physics of Fluids	questions 5, 6 and 7
Option M	Medical Physics	questions 8, 9 and 10
Option P	Environmental Physics	questions 11, 12 and 13
Option T	Telecommunications	questions 14, 15 and 16

Option A

Astrophysics and Cosmology

1 **(a)** State Olbers' paradox.

.....

.....

.....

..... [3]

(b) Suggest how Olbers' paradox is resolved by a model based on an expanding Universe.

.....

.....

.....

..... [2]

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2 The star Altair is 16 light-years from the Sun.

(a) Calculate the distance between Altair and the Sun in parsecs (pc).

distance = ... pc [2]

(b) Fig. 2.1 shows the position of Altair relative to Earth at two positions of Earth, separated in time by 0.5 years.

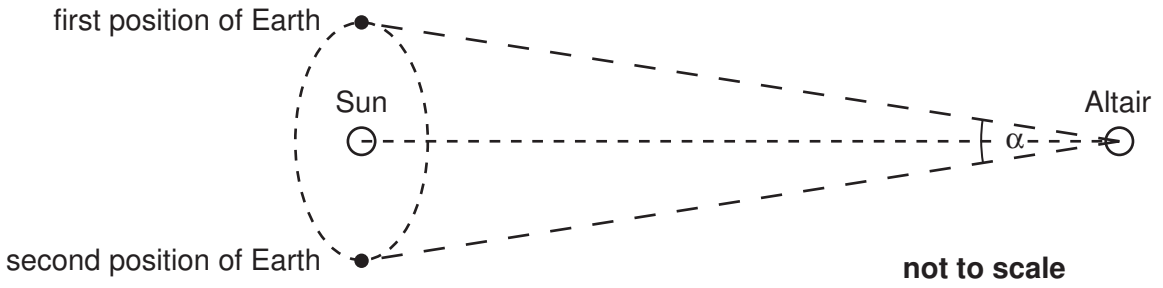

Fig. 2.1

The angle α is equal to the parallax angle of Altair.
Determine the angle α.

α = ... arc sec [2]

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3 **(a)** State the Cosmological Principle.

.....

.....

..... [2]

(b) Describe the nature of cosmic microwave background radiation and suggest how this supports the Cosmological Principle.

.....

.....

.....

..... [3]

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4 Planets have been discovered orbiting stars other than the Sun.

(a) Suggest and explain two reasons why direct observation of such planets is **not** possible.

1. .....

.....

.....

2. .....

.....

..... [4]

(b) Suggest and explain how their existence can be inferred.

.....

.....

..... [2]

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Option F

The Physics of Fluids

5 **(a)** Expanded polystyrene has a density of 15 kg m^{-3}.

Calculate the volume of expanded polystyrene required as a buoyancy aid so that it provides a resultant upward force of 25 N when totally submerged in water of density 1.0×10^3 kg m^{-3}.

volume = ... m^3 [3]

(b) A rowing boat has a cross-section as illustrated in Fig. 5.1.

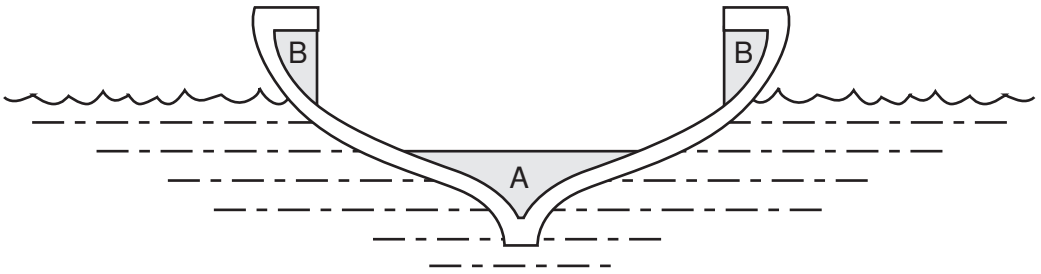

Fig. 5.1

In order to improve its buoyancy in the event that it turns over, expanded polystyrene blocks are to be fitted inside the boat.

Suggest, with a reason, whether the blocks should be fixed at position A on the keel or at the two positions marked B.

.....

.....

..... [2]

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6 Fig. 6.1 represents one type of car.

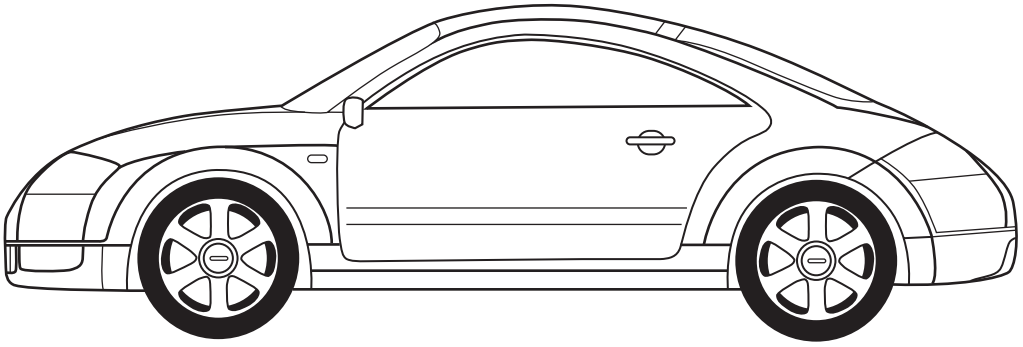

Fig. 6.1

(a) Suggest why, as the car travels at increasing speeds, the downward force that the car exerts on the road can become less.

.....

.....

.....

.....

..... [4]

(b) The effect in **(a)** can lead to a loss of control of the car at high speeds. To prevent this, a 'spoiler' may be fitted to the back of the car, as illustrated in Fig. 6.2.

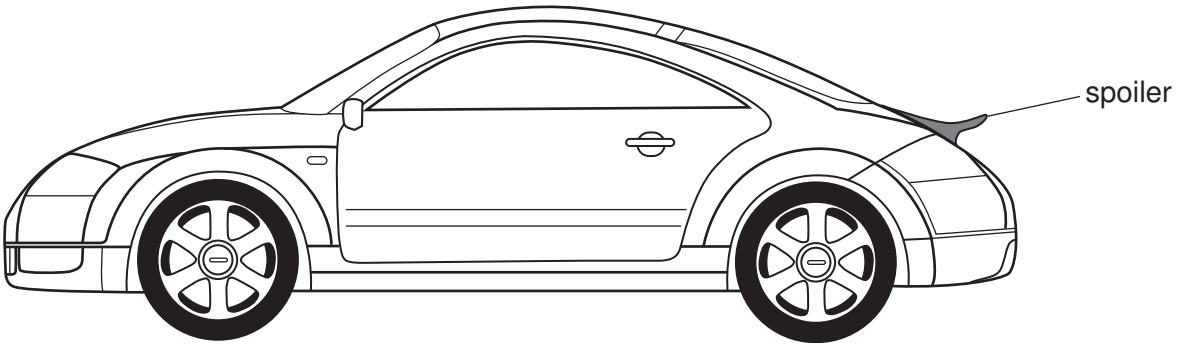

Fig. 6.2

Suggest why the spoiler reduces this problem.

.....

.....

.....

..... [2]

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7 The drag force F on a spherical particle of radius r moving with streamline flow at speed v through a fluid of viscosity η is given by the expression

$$F = 6\pi r\eta v.$$

(a) Complete Fig. 7.1 to show streamline flow of a fluid around a sphere. [2]

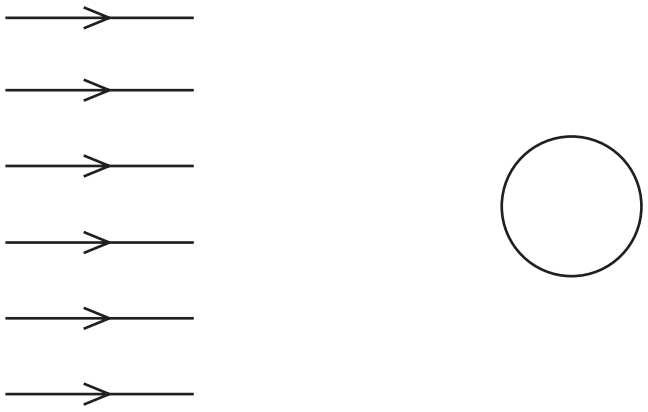

Fig. 7.1

(b) Spherical particles of radius 4.5×10^{-7} m and density 3.9×10^{3} kg m^{-3} are initially distributed uniformly throughout some water of density 1.0×10^{3} kg m^{-3} and viscosity 9.5×10^{-4} Pa s.

The water is 8.0 mm deep. Assume that there are no currents in the water.

(i) Calculate the terminal speed at which a particle falls through the water.

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

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(ii) After some time, the water near the surface becomes clear as the particles settle, as illustrated in Fig. 7.2.

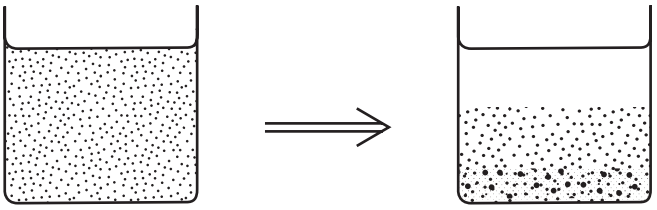

Fig. 7.2

Calculate the approximate fraction of the particles that remain suspended in the water after a time of 1.0 hour.

fraction = ... [3]

Option M

Medical Physics

8 **(a)** Briefly explain the principles of the **generation** of ultrasound.

.....

.....

.....

.....

.....

..... [4]

(b) An ultrasound pulse is transmitted into the body of a patient. The pulse is partially reflected at a fat/muscle boundary and then at a muscle/bone boundary. The reflected pulses are received back at the transmitter and are displayed, after processing, on the screen of a cathode-ray oscilloscope (c.r.o.). The trace is shown in Fig. 8.1.

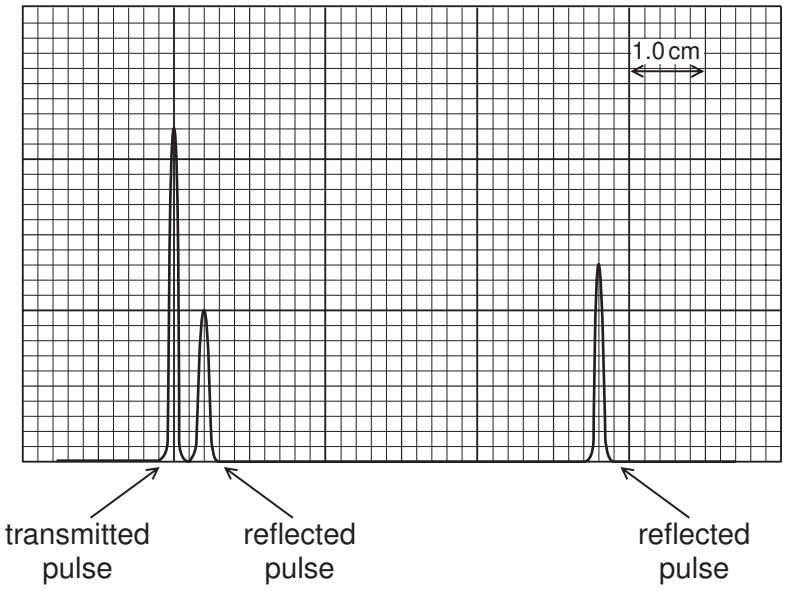

Fig. 8.1

The time-base of the c.r.o. is $10\,\mu s\,cm^{-1}$.

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Use Fig. 8.1 to determine

(i) the thickness of the layer of fat given that the speed of ultrasound in fat is $1450\,m\,s^{-1}$,

thickness = ... cm [3]

(ii) the muscle thickness given that the speed of ultrasound in muscle is $1590\,m\,s^{-1}$.

thickness = ... cm [2]

9 **(a)** The human eye is able to accommodate. Explain what is meant by *accommodation*.

.....

.....

..... [2]

(b) The range of distinct vision of an elderly person is 1.2 m to 4.0 m.

(i) State the range of distinct vision for a person with normal vision.

..... [1]

(ii) In order to correct the elderly person's vision, two pairs of spectacles are required.

Calculate the power of the lenses in each pair of spectacles.

power of lenses = ... D and ..... D [3]

(iii) Suggest how the inconvenience of changing spectacles for distant vision and then close-up vision may be overcome.

.....

.....

..... [2]

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10 Fig. 10.1 shows the variation with frequency f of the threshold intensity level *I.L.* of a person with defective hearing.

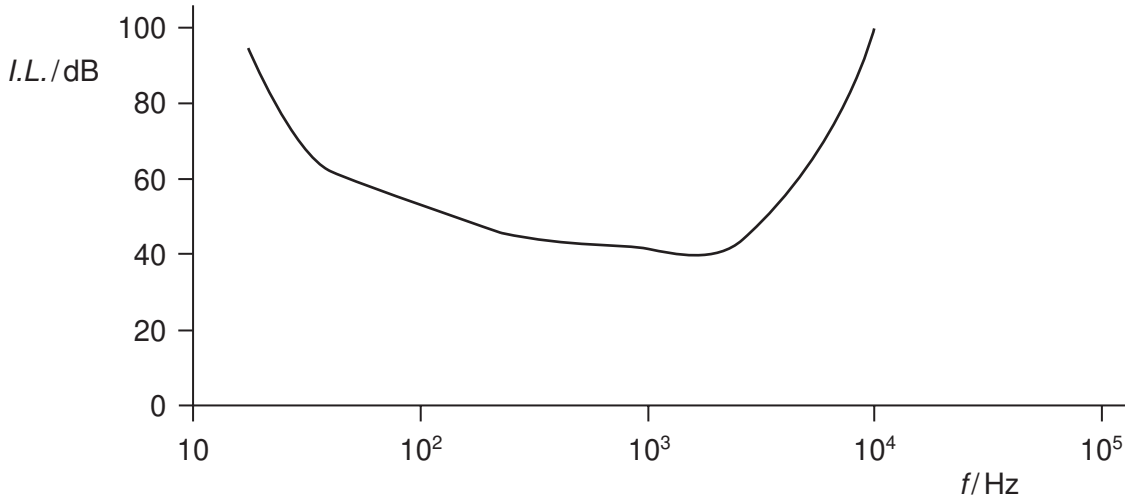

Fig. 10.1

Describe and explain these defects.

.....

.....

.....

..... [3]

Option P

Environmental Physics

11 (a) (i) Explain what is meant by the *solar constant*.

.....

.....

..... [2]

(ii) The Sun radiates energy at a rate of 3.9×10^{26} W. The radius of the Earth's orbit about the Sun is 1.5×10^{8} km. Calculate the solar constant.

solar constant = ... $W\,m^{-2}$ [2]

(b) Fig. 11.1 illustrates sunlight incident on the Earth.

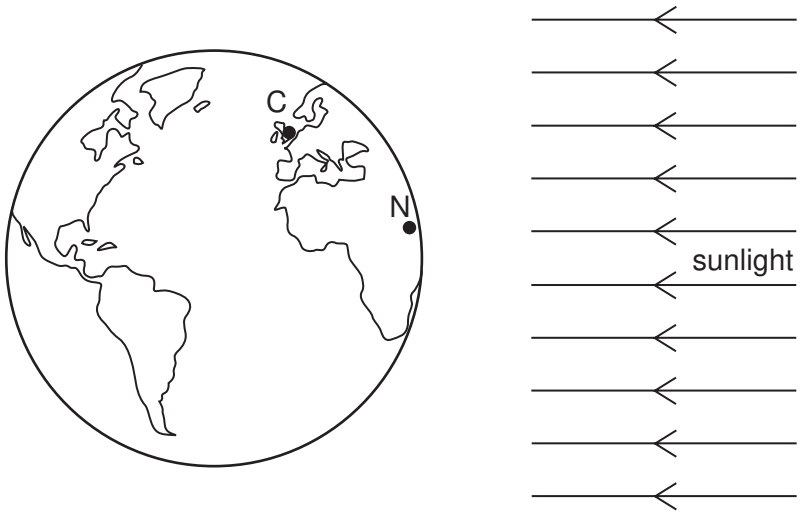

Fig. 11.1

Explain why the power of the sunlight per unit surface area is greater at N (Nairobi) than at C (Cambridge).

.....

.....

.....

..... [3]

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12 In many countries, there are daily and seasonal variations in demand for electrical power.

(a) Explain why there are variations in demand.

.....

.....

.....

..... [3]

(b) Explain the advantage of having some form of pumped water storage scheme for the generation of electrical energy.

.....

.....

.....

..... [3]

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13 A certain engine operates on the cycle illustrated in Fig. 13.1.

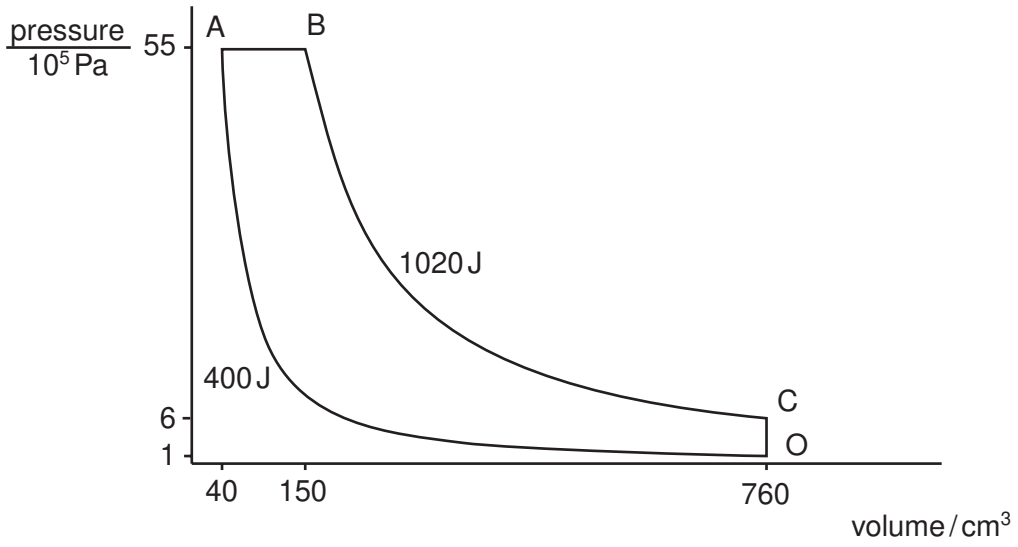

Fig. 13.1

A mass of gas is firstly compressed adiabatically (O → A) such that 400 J of work is done on the gas. During the stage A → B, fuel is injected into the gas and this causes heating at constant pressure as the fuel burns. The gas and burned fuel then expand adiabatically (B → C) and, during this process, 1020 J of work is done by the gas and burned fuel. Finally, during the stage C → O, energy is wasted.

(a) (i) During the stage A → B, 2500 J of energy is supplied to the gas. Show that the work done by the gas as it expands during this stage is 605 J.

(ii) Calculate the energy wasted during the stage C → O.

energy = ... J

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(iii) Determine the efficiency E of the engine, given that

$$E = \frac{\text{useful work done during the expansion from A to C}}{\text{total energy input}}.$$

E = ...
[5]

(b) State one similarity and one difference between the operating cycle of this engine and that of a four-stroke petrol engine.

similarity: .....

.....

difference: .....

..... [2]

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[Turn over

Option T

Telecommunications

14 In a certain telephone system, the actual signal power in a wire is expressed as the number of decibels (dB) above or below a reference power level of 1.0 mW.

(a) State a formula for the ratio of two powers P_1 and P_2, expressed in decibels (dB).

..... [1]

(b) A signal in a wire has a power of 25.4 mW. Express this signal power as a number of dB above or below the reference level.

number of dB = ...

..... the reference level [2]

(c) The wire has an attenuation per unit length of 3.2 dB km^{-1}.

(i) Explain what is meant by *attenuation*.

.....

.....

(ii) Calculate the length of the wire for the signal in **(b)** to be reduced to the reference level.

length = ... km
[3]

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15 **(a)** Explain what is meant by *amplitude modulation*.

.....

.....

..... [2]

(b) The variation with frequency f of the power P of an amplitude-modulated signal from a radio station is shown in Fig. 15.1.

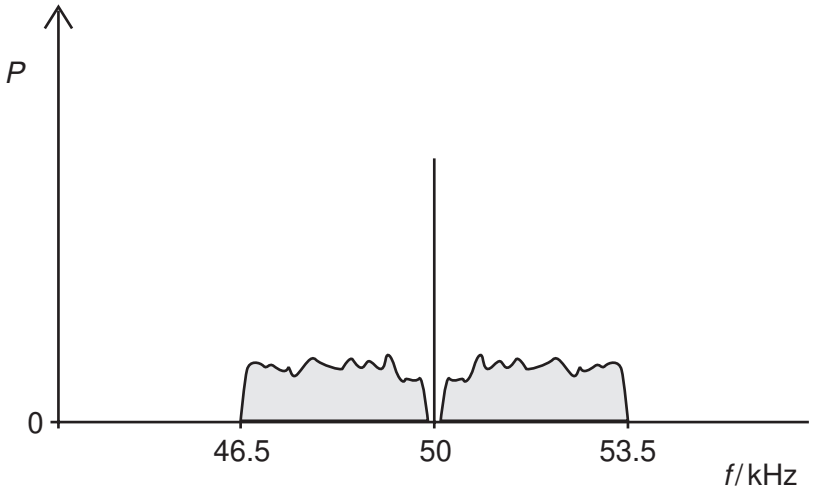

Fig. 15.1

Use Fig. 15.1 to determine

(i) the wavelength at which the radio station is broadcasting,

wavelength = ... m

(ii) the bandwidth of the radio signal,

bandwidth = ... kHz

(iii) the maximum frequency of the demodulated signal.

frequency = ... kHz
[5]

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16 **(a)** Describe the orbit of a geostationary satellite.

.....

.....

.....

..... [3]

(b) **(i)** State a typical frequency for communication between the Earth's surface and a geostationary satellite.

frequency = ... Hz

(ii) Suggest why the frequency of transmission from the satellite is different from that received by the satellite from Earth.

.....

..... [2]

(c) Give one advantage and one disadvantage of the use of geostationary satellites when compared with polar-orbiting satellites for telephone communication.

advantage: .....

.....

disadvantage: .....

..... [2]

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