UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

9061759643

PHYSICS **9702/41**

Paper 4 A2 Structured Questions **October/November 2012**

2 hours

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.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
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Total	

This document consists of **19** printed pages and **1** blank page.

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UNIVERSITY *of* CAMBRIDGE International Examinations

[Turn over

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,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \mathrm{F\,m^{-1}}$
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,	$u = 1.66 \times 10^{-27}\ \mathrm{kg}$
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,	$N_A = 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
the Boltzmann constant,	$k = 1.38 \times 10^{-23}\ \mathrm{J\,K^{-1}}$
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,	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
gravitational potential,	$\phi = -\frac{Gm}{r}$
hydrostatic pressure,	$p = \rho gh$
pressure of an ideal gas,	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$
simple harmonic motion,	$a = -\omega^2 x$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$ $v = \pm \omega\sqrt{(x_0^2 - x^2)}$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_0 r}$
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,	$W = \frac{1}{2}QV$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
alternating current/voltage,	$x = x_0 \sin \omega t$
radioactive decay,	$x = x_0 \exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Section A

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

For Examiner's Use

1 **(a)** State Newton's law of gravitation.

....

....

.... [2]

(b) A satellite of mass m is in a circular orbit of radius r about a planet of mass M.
For this planet, the product GM is $4.00 \times 10^{14}\,\mathrm{N\,m^2\,kg^{-1}}$, where G is the gravitational constant.
The planet may be assumed to be isolated in space.

(i) By considering the gravitational force on the satellite and the centripetal force, show that the kinetic energy E_K of the satellite is given by the expression

$$E_K = \frac{GMm}{2r}.$$

[2]

(ii) The satellite has mass 620 kg and is initially in a circular orbit of radius 7.34×10^6 m, as illustrated in Fig. 1.1.

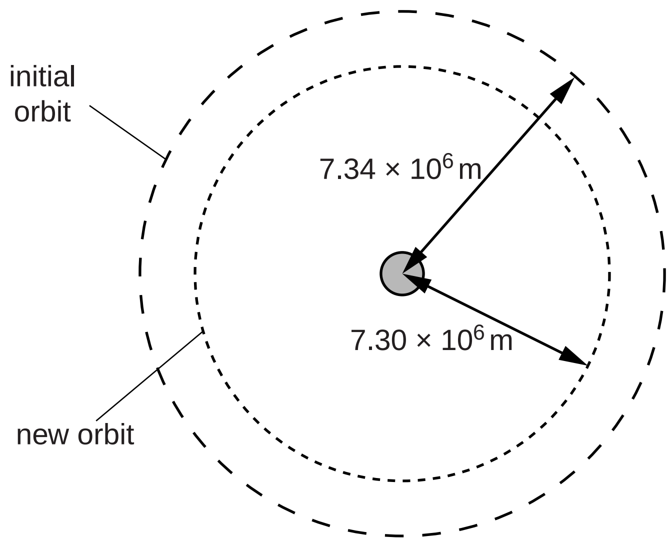

Fig. 1.1 (not to scale)

Resistive forces cause the satellite to move into a new orbit of radius 7.30×10^6 m.

Determine, for the satellite, the change in

1. kinetic energy,

change in kinetic energy = ... J [2]

2. gravitational potential energy.

change in potential energy = ... J [2]

(iii) Use your answers in **(ii)** to explain whether the linear speed of the satellite increases, decreases or remains unchanged when the radius of the orbit decreases.

....

....

.... [2]

For Examiner's Use

2 A student suggests that, when an ideal gas is heated from 100 °C to 200 °C, the internal energy of the gas is doubled.

(a) (i) State what is meant by *internal energy*.

....

....

.... [2]

(ii) By reference to one of the assumptions of the kinetic theory of gases and your answer in **(i)**, deduce what is meant by the internal energy of an ideal gas.

....

....

....

.... [3]

(b) State and explain whether the student's suggestion is correct.

....

....

.... [2]

3 **(a)** Two metal spheres are in thermal equilibrium.
State and explain what is meant by *thermal equilibrium*.

....

....

.... [2]

(b) An electric water heater contains a tube through which water flows at a constant rate. The water in the tube passes over a heating coil, as shown in Fig. 3.1.

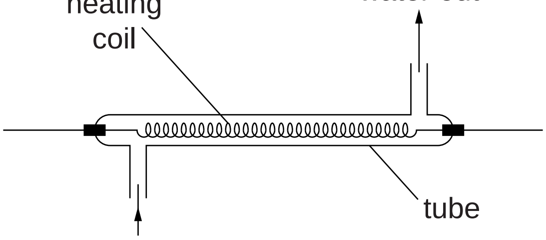

Fig. 3.1

The water flows into the tube at a temperature of 18 °C. When the power of the heater is 3.8 kW, the temperature of the water at the outlet is 42 °C.
The specific heat capacity of water is $4.2\,\mathrm{J\,g^{-1}\,K^{-1}}$.

(i) Use the data to calculate the flow rate, in $\mathrm{g\,s^{-1}}$, of water through the tube.

flow rate = ... $\mathrm{g\,s^{-1}}$ [3]

(ii) State and explain whether your answer in **(i)** is likely to be an overestimate or an underestimate of the flow rate.

....

....

.... [2]

4 A ball is held between two fixed points A and B by means of two stretched springs, as shown in Fig. 4.1.

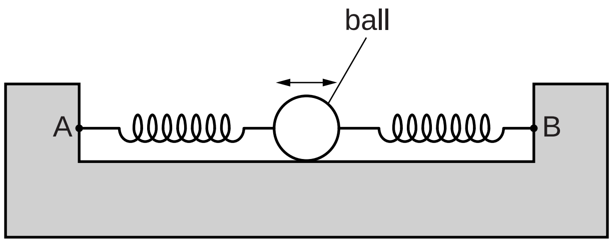

Fig. 4.1

The ball is free to oscillate horizontally along the line AB. During the oscillations, the springs remain stretched and do not exceed their limits of proportionality.

The variation of the acceleration *a* of the ball with its displacement *x* from its equilibrium position is shown in Fig. 4.2.

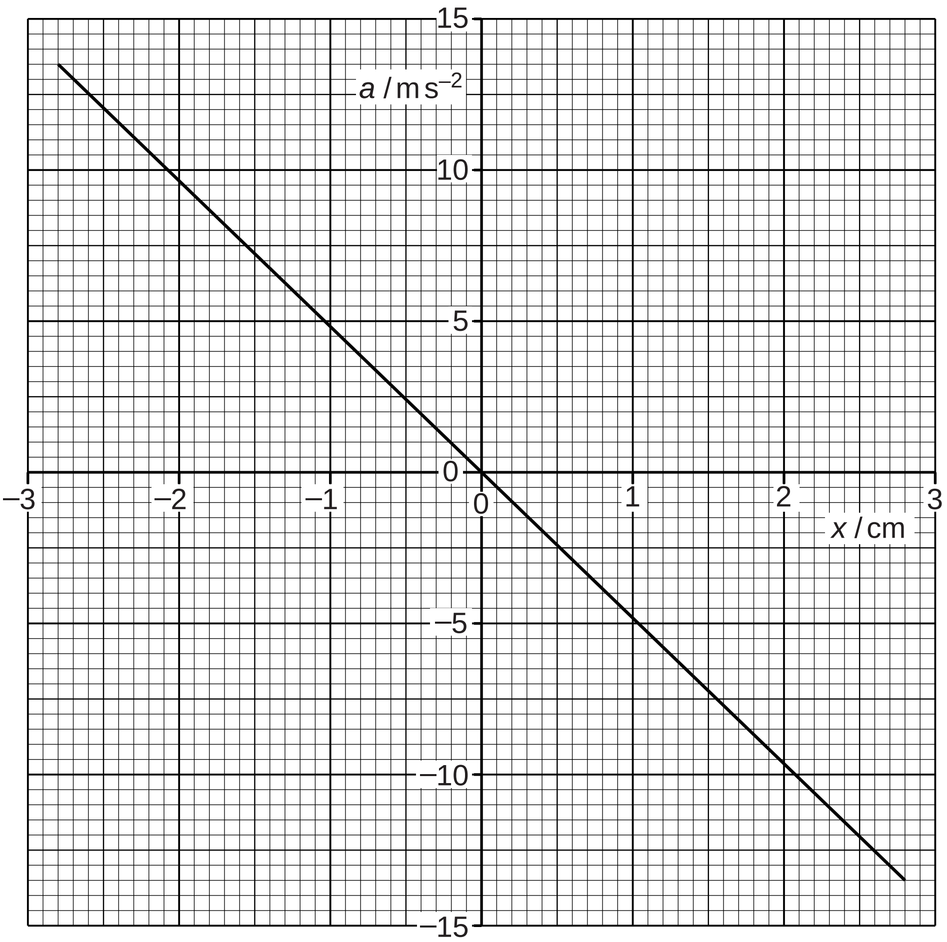

Fig. 4.2

For Examiner's Use

(a) State and explain the features of Fig. 4.2 that indicate that the motion of the ball is simple harmonic.

....

....

....

....

.... [4]

(b) Use Fig. 4.2 to determine, for the oscillations of the ball,

(i) the amplitude,

amplitude = ... cm [1]

(ii) the frequency.

frequency = ... Hz [3]

(c) The arrangement in Fig. 4.1 is now rotated through 90° so that the line AB is vertical. The ball now oscillates in a vertical plane.

Suggest one reason why the oscillations may no longer be simple harmonic.

....

.... [1]

5 **(a)** **(i)** Define *capacitance*.

For Examiner's Use

....

.... [1]

(ii) A capacitor is made of two metal plates, insulated from one another, as shown in Fig. 5.1.

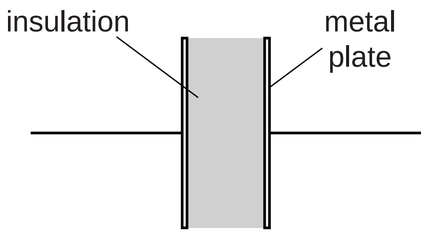

Fig. 5.1

Explain why the capacitor is said to store energy but not charge.

....

....

....

....

.... [4]

(b) Three uncharged capacitors X, Y and Z, each of capacitance 12 μF, are connected as shown in Fig. 5.2.

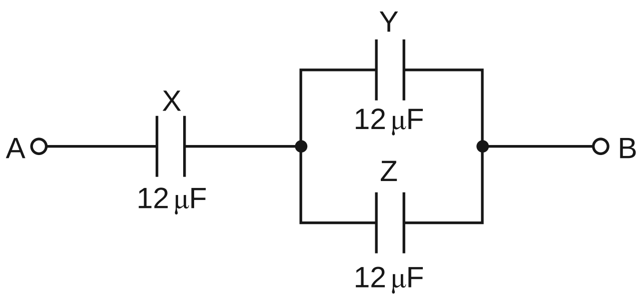

Fig. 5.2

A potential difference of 9.0 V is applied between points A and B.

For Examiner's Use

(i) Calculate the combined capacitance of the capacitors X, Y and Z.

capacitance = ... μF [2]

(ii) Explain why, when the potential difference of 9.0 V is applied, the charge on one plate of capacitor X is 72 μC.

....

....

....[2]

(iii) Determine

1. the potential difference across capacitor X,

potential difference = ... V [1]

2. the charge on one plate of capacitor Y.

charge = ... μC [2]

For Examiner's Use

6 **(a)** **(i)** State the condition for a charged particle to experience a force in a magnetic field.

....

....

.... [2]

(ii) State an expression for the magnetic force F acting on a charged particle in a magnetic field of flux density B. Explain any other symbols you use.

....

....

.... [2]

(b) A sample of a conductor with rectangular faces is situated in a magnetic field, as shown in Fig. 6.1.

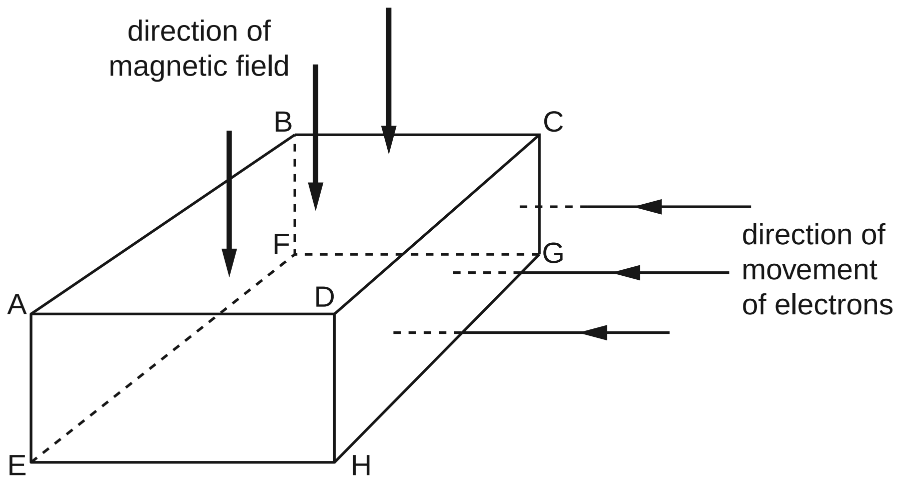

Fig. 6.1

The magnetic field is normal to face ABCD in the downward direction.

Electrons enter face CDHG at right-angles to the face. As the electrons pass through the conductor, they experience a force due to the magnetic field.

(i) On Fig. 6.1, shade the face to which the electrons tend to move as a result of this force. [1]

(ii) The movement of the electrons in the magnetic field causes a potential difference between two faces of the conductor.
Using the lettering from Fig. 6.1, state the faces between which this potential difference will occur.

face .... and face ....[1]

(c) Explain why the potential difference in **(b)** causes an additional force on the moving electrons in the conductor.

....

....

.... [2]

For Examiner's Use

7 **(a)** State Lenz's law.

....

....

.... [2]

(b) A simple transformer with a soft-iron core is illustrated in Fig. 7.1.

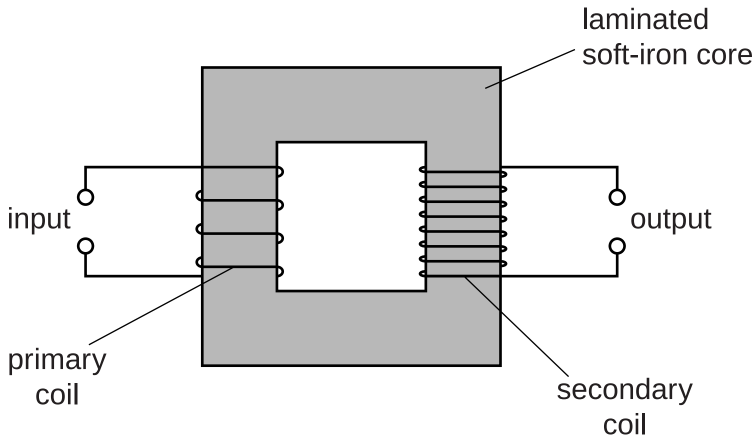

Fig. 7.1

(i) Explain why the core is

1. made of iron,

....

.... [1]

2. laminated.

....

....

.... [2]

(ii) An e.m.f. is induced in the secondary coil of the transformer.
Explain how a current in the primary coil gives rise to this induced e.m.f.

....

....

....

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....

.... [4]

8 **(a)** State what is meant by a *photon*.

....

....

.... [2]

(b) It has been observed that, where photoelectric emission of electrons takes place, there is negligible time delay between illumination of the surface and emission of an electron.

State three other pieces of evidence provided by the photoelectric effect for the particulate nature of electromagnetic radiation.

1. ....

....

2. ....

....

3. ....

....
[3]

(c) The work function of a metal surface is 3.5 eV. Light of wavelength 450 nm is incident on the surface.
Determine whether electrons will be emitted, by the photoelectric effect, from the surface.

[3]

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Please turn over for Section B.

Section B

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

For Examiner's Use

9 An operational amplifier (op-amp) may be used as part of the processing unit in an electronic sensor.

(a) State three properties of an ideal op-amp.

1. ....

2. ....

3. ....
[3]

(b) A comparator circuit incorporating an ideal op-amp is shown in Fig. 9.1.

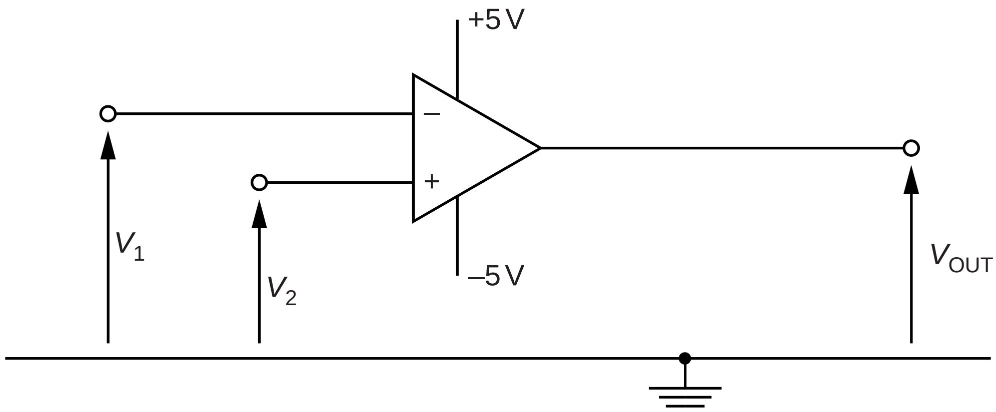

Fig. 9.1

(i) In one application of the comparator, V_2 is kept constant at +1.5 V.
The variation with time t of the potential V_1 is shown in Fig. 9.2. The potential V_2 is also shown.

For Examiner's Use

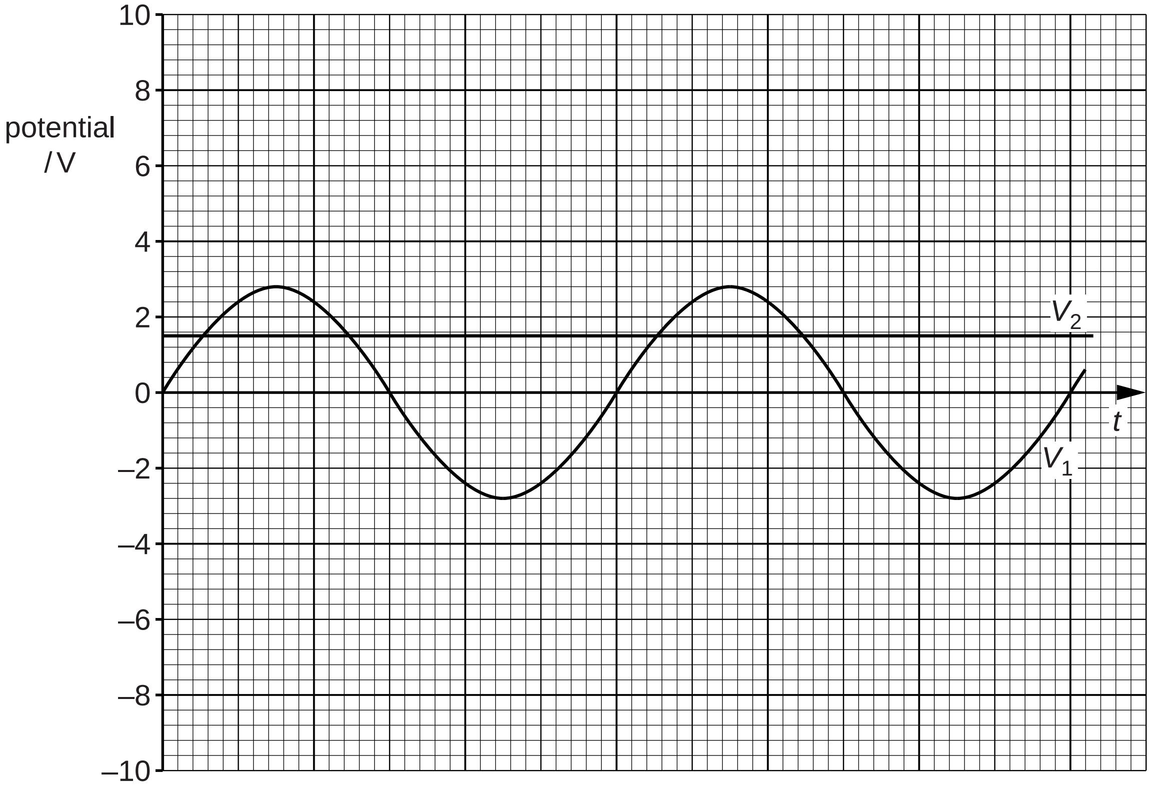

Fig. 9.2

On Fig. 9.2, show the variation with time t of the output potential V_{OUT}. [4]

(ii) Two light-emitting diodes (LEDs) R and G are connected to the output of the op-amp in Fig. 9.1 such that R emits light for a longer time than G.

On Fig. 9.1, draw the symbols for the two diodes connected to the output of the op-amp and label the diodes R and G. [3]

10 Outline the principles of CT scanning.

For Examiner's Use

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....

....

....

....

.... [6]

For Examiner's Use

11 **(a)** In modern communications systems, the majority of data is transmitted in digital form rather than analogue form.
Suggest three advantages of the transmission of data in digital form.

1. ....

....

2. ....

....

3. ....

....
[3]

(b) A recording is made of some music. For this recording, the music is sampled at a rate of 44.1 kHz and each sample consists of a 16-bit word.

(i) Suggest the effect on the quality of the recording of

1. sampling at a high frequency rather than a lower frequency,

....

....[1]

2. using a long word length rather than a shorter word length.

....

....[1]

(ii) The recording lasts for a total time of 5 minutes 40 seconds.
Calculate the number of bits generated during the recording.

number = ...[2]

12 (a) Wire pairs used for the transmission of telephone signals are subject to cross-linking.

For Examiner's Use

(i) Explain what is meant by *cross-linking*.

....

.... [1]

(ii) Suggest why cross-linking in coaxial cables is much less than in wire pairs.

....

....

.... [2]

(b) A wire pair has a length of 1.4 km and is connected to a receiver, as illustrated in Fig. 12.1.

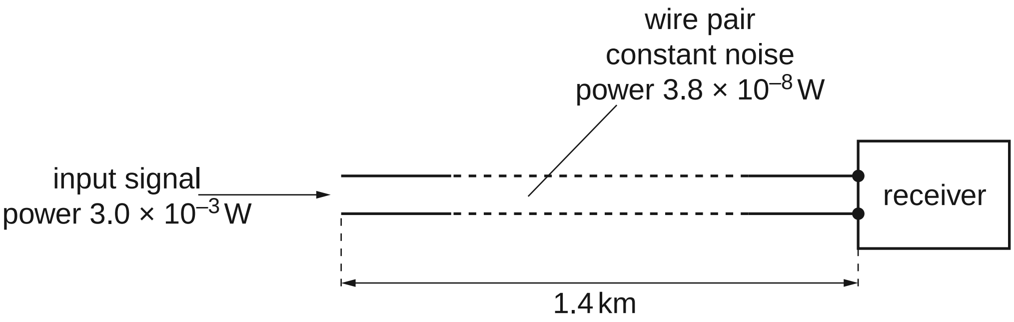

Fig. 12.1

The constant noise power in the wire pair is 3.8×10^{-8} W.
For an input signal to the wire pair of 3.0×10^{-3} W, the signal-to-noise ratio at the receiver is 25 dB.

Calculate the attenuation per unit length for the wire pair.

attenuation per unit length = ... dB km^{-1} [4]