UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

*8781528465*

**PHYSICS** **9702/04**

Paper 4 A2 Structured Questions **May/June 2009**

**1 hour 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.
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 | |
|---|---|
| 1 | |
| 2 | |
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| 12 | |
| 13 | |
| 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, | $\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$ |
| 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, $\phi = -\frac{Gm}{r}$

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

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**[Turn over**

## Section A

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

**1** **(a)** Define *gravitational field strength*.

.....

..... [1]

**(b)** A spherical planet has diameter $1.2 \times 10^4$ km. The gravitational field strength at the surface of the planet is $8.6\,\text{N kg}^{-1}$.
The planet may be assumed to be isolated in space and to have its mass concentrated at its centre.
Calculate the mass of the planet.

mass = ..... kg [3]

**(c)** The gravitational potential at a point X above the surface of the planet in **(b)** is $-5.3 \times 10^7\,\text{J kg}^{-1}$.
For point Y above the surface of the planet, the gravitational potential is $-6.8 \times 10^7\,\text{J kg}^{-1}$.

**(i)** State, with a reason, whether point X or point Y is nearer to the planet.

.....

.....

..... [2]

**(ii)** A rock falls radially from rest towards the planet from one point to the other.
Calculate the final speed of the rock.

speed = ..... $\text{m s}^{-1}$ [2]

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**2** Sources of $\alpha$-particles are frequently found to contain traces of helium gas.
A radioactive source emits $\alpha$-particles at a constant rate of $3.5 \times 10^6\,s^{-1}$. The $\alpha$-particles are collected for a period of 40 days. Each $\alpha$-particle becomes one helium atom.

**(a)** By reference to the half-life of the source, suggest why it may be assumed that the rate of emission of $\alpha$-particles is constant.

.....

..... [1]

**(b)** The helium gas may be assumed to be an ideal gas. Calculate the volume of gas that is collected at a pressure of $1.5 \times 10^5\,Pa$ and at a temperature of 17 °C.

volume = ..... $m^3$ [3]

**3** When a liquid is boiling, thermal energy must be supplied in order to maintain a constant temperature.

**(a)** State two processes for which thermal energy is required during boiling.

1. .....

.....

2. .....

.....

[2]

**(b)** A student carries out an experiment to determine the specific latent heat of vaporisation of a liquid.
Some liquid in a beaker is heated electrically as shown in Fig. 3.1.

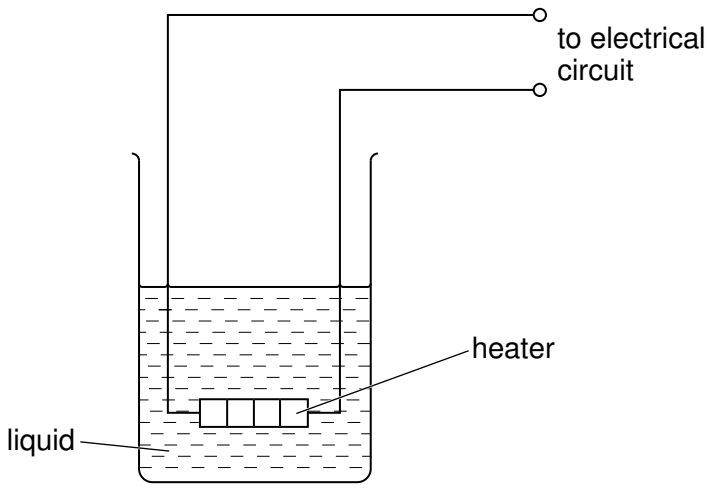


**Fig. 3.1**

Energy is supplied at a constant rate to the heater. When the liquid is boiling at a constant rate, the mass of liquid evaporated in 5.0 minutes is measured.
The power of the heater is then changed and the procedure is repeated.
Data for the two power ratings are given in Fig. 3.2.

| power of heater /W | mass evaporated in 5.0 minutes /g |
|---|---|
| 50.0 | 6.5 |
| 70.0 | 13.6 |

**Fig. 3.2**

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**(i)** Suggest

**1.** how it may be checked that the liquid is boiling at a constant rate,

.....

..... [1]

**2.** why the rate of evaporation is determined for two different power ratings.

.....

..... [1]

**(ii)** Calculate the specific latent heat of vaporisation of the liquid.

specific latent heat of vaporisation = ..... $J\,g^{-1}$ [3]

**4** A vertical peg is attached to the edge of a horizontal disc of radius *r*, as shown in Fig. 4.1.

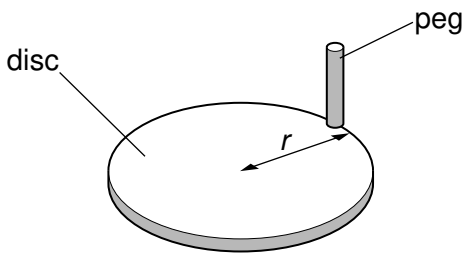


**Fig. 4.1**

The disc rotates at constant angular speed $\omega$. A horizontal beam of parallel light produces a shadow of the peg on a screen, as shown in Fig. 4.2.

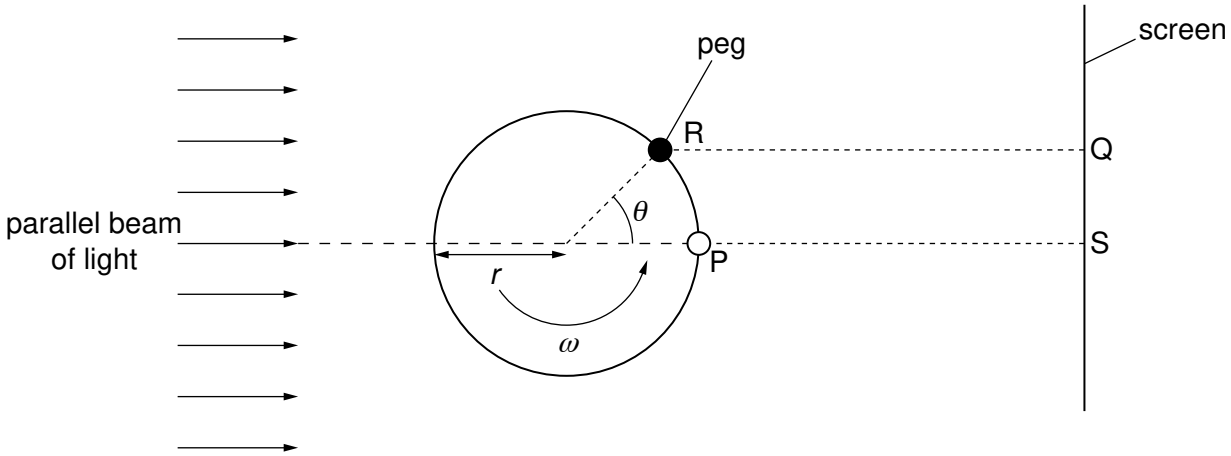


**Fig. 4.2** (plan view)

At time zero, the peg is at P, producing a shadow on the screen at S.
At time *t*, the disc has rotated through angle $\theta$. The peg is now at R, producing a shadow at Q.

**(a)** Determine,

**(i)** in terms of $\omega$ and *t*, the angle $\theta$,

..... [1]

**(ii)** in terms of $\omega$, *t* and *r*, the distance SQ.

..... [1]

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**(b)** Use your answer to **(a)(ii)** to show that the shadow on the screen performs simple harmonic motion.

.....

.....

..... [2]

**(c)** The disc has radius $r$ of 12 cm and is rotating with angular speed $\omega$ of 4.7 rad s$^{-1}$.

Determine, for the shadow on the screen,

**(i)** the frequency of oscillation,

frequency = ..... Hz [2]

**(ii)** its maximum speed.

speed = ..... cm s$^{-1}$ [2]

**5** A solid metal sphere, of radius $r$, is insulated from its surroundings. The sphere has charge $+Q$.
This charge is on the surface of the sphere but it may be considered to be a point charge at its centre, as illustrated in Fig. 5.1.

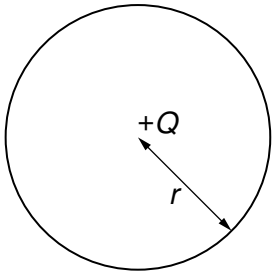


**Fig. 5.1**

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

.....

..... [1]

**(ii)** Show that the capacitance $C$ of the sphere is given by the expression

$$C = 4\pi\varepsilon_0 r.$$

[1]

**(b)** The sphere has radius 36 cm.
Determine, for this sphere,

**(i)** the capacitance,

capacitance = ..... F [1]

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**(ii)** the charge required to raise the potential of the sphere from zero to $7.0 \times 10^5$ V.

charge = ..... C [1]

**(c)** Suggest why your calculations in **(b)** for the metal sphere would not apply to a plastic sphere.

.....

.....

.....

..... [3]

**(d)** A spark suddenly connects the metal sphere in **(b)** to the Earth, causing the potential of the sphere to be reduced from $7.0 \times 10^5$V to $2.5 \times 10^5$V.

Calculate the energy dissipated in the spark.

energy = ..... J [3]

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**[Turn over**

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

.....

.....

.....

..... [3]

**(b)** A large horseshoe magnet produces a uniform magnetic field of flux density *B* between its poles. Outside the region of the poles, the flux density is zero.
The magnet is placed on a top-pan balance and a stiff wire XY is situated between its poles, as shown in Fig. 6.1.

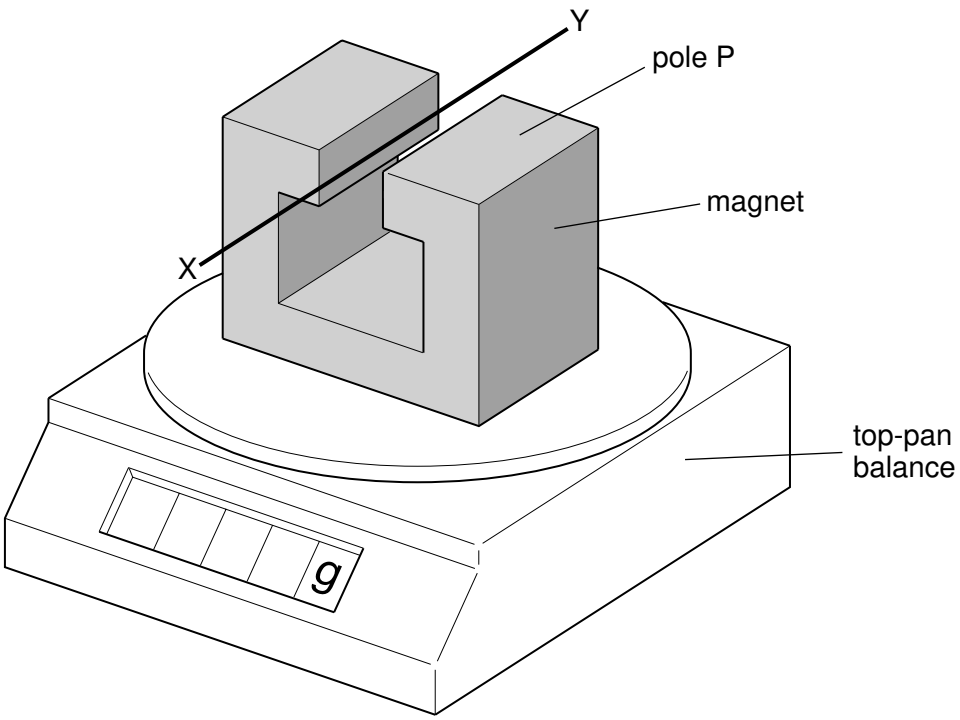


**Fig. 6.1**

The wire XY is horizontal and normal to the magnetic field. The length of wire between the poles is 4.4 cm.
A direct current of magnitude 2.6 A is passed through the wire in the direction from X to Y.
The reading on the top-pan balance increases by 2.3 g.

**(i)** State and explain the polarity of the pole P of the magnet.

.....

.....

.....

..... [3]

**(ii)** Calculate the flux density between the poles.

flux density = ..... T [3]

**(c)** The direct current in **(b)** is now replaced by a very low frequency sinusoidal current of r.m.s. value 2.6 A.
Calculate the variation in the reading of the top-pan balance.

variation in reading = ..... g [2]

**7** You are provided with a coil of wire, a bar magnet and a sensitive ammeter.

Outline an experiment to verify Lenz's law.

.....

.....

.....

.....

.....

.....

.....

..... [6]

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**8** **(a)** Explain why, for the photoelectric effect, the existence of a threshold frequency and a very short emission time provide evidence for the particulate nature of electromagnetic radiation, as opposed to a wave theory.

.....

.....

.....

.....

.....

..... [4]

**(b)** State and explain two relations in which the Planck constant *h* is the constant of proportionality.

1. .....

.....

.....

.....

2. .....

.....

.....

.....

[6]

**9** **(a)** A sample of a radioactive isotope contains $N$ nuclei at time $t$. At time $(t + \Delta t)$, it contains $(N - \Delta N)$ nuclei of the isotope.

For the period $\Delta t$, state, in terms of $N$, $\Delta N$ and $\Delta t$,

**(i)** the mean activity of the sample,

activity = ..... [1]

**(ii)** the probability of decay of a nucleus.

probability = ..... [1]

**(b)** A cobalt-60 source having a half-life of 5.27 years is calibrated and found to have an activity of $3.50 \times 10^5$ Bq. The uncertainty in the calibration is ±2%.

Calculate the length of time, in days, after the calibration has been made, for the stated activity of $3.50 \times 10^5$ Bq to have a maximum possible error of 10%.

time = ..... days [4]

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## Section B

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

**10** **(a)** By reference to an amplifier, explain what is meant by *negative feedback*.

.....

.....

..... [2]

**(b)** An amplifier circuit incorporating an ideal operational amplifier (op-amp) is shown in Fig. 10.1.

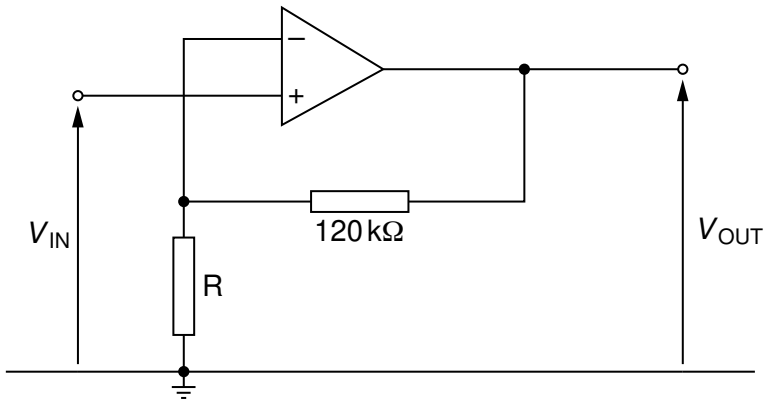


**Fig. 10.1**

The supply for the op-amp is ±9.0 V.
The amplifier circuit is to have a gain of 25.

Calculate the resistance of resistor R.

resistance = ..... Ω [2]

**(c)** State the value of the output voltage $V_{OUT}$ of the amplifier in **(b)** for input voltages $V_{IN}$ of

**(i)** −0.08 V,

$V_{OUT}$ = ..... V [1]

**(ii)** +0.4 V.

$V_{OUT}$ = ..... V [1]

**11 (a)** Explain the main principles behind the **use** of ultrasound to obtain diagnostic information about internal body structures.

.....

.....

.....

.....

.....

.....

.....

..... [4]

**(b)** Data for the acoustic impedances and absorption (attenuation) coefficients of muscle and bone are given in Fig. 11.1.

| | acoustic impedance / $kg\,m^{-2}\,s^{-1}$ | absorption coefficient / $m^{-1}$ |
|---|---|---|
| muscle | $1.7 \times 10^6$ | 23 |
| bone | $6.3 \times 10^6$ | 130 |

**Fig. 11.1**

The intensity reflection coefficient is given by the expression

$$\frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}.$$

The attenuation of ultrasound in muscle follows a similar relation to the attenuation of X-rays in matter.

A parallel beam of ultrasound of intensity $I$ enters the surface of a layer of muscle of thickness 4.1 cm as shown in Fig. 11.2.

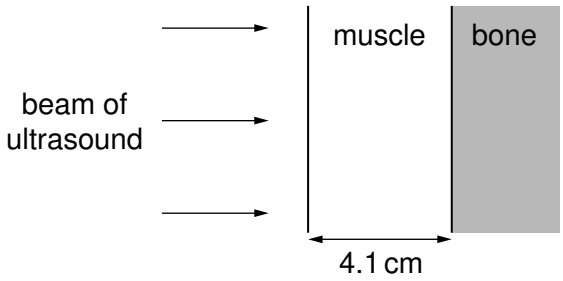


**Fig. 11.2**

The ultrasound is reflected at a muscle-bone boundary and returns to the surface of the muscle.

Calculate

**(i)** the intensity reflection coefficient at the muscle-bone boundary,

coefficient = ..... [2]

**(ii)** the fraction of the incident intensity that is transmitted from the surface of the muscle to the surface of the bone,

fraction = ..... [2]

**(iii)** the intensity, in terms of $I$, that is received back at the surface of the muscle.

intensity = ..... $I$ [2]

**12** A signal is to be transmitted along a cable system of total length 125 km.
The cable has an attenuation of 7 dB $km^{-1}$. Amplifiers, each having a gain of 43 dB, are placed at 6 km intervals along the cable, as illustrated in Fig. 12.1.

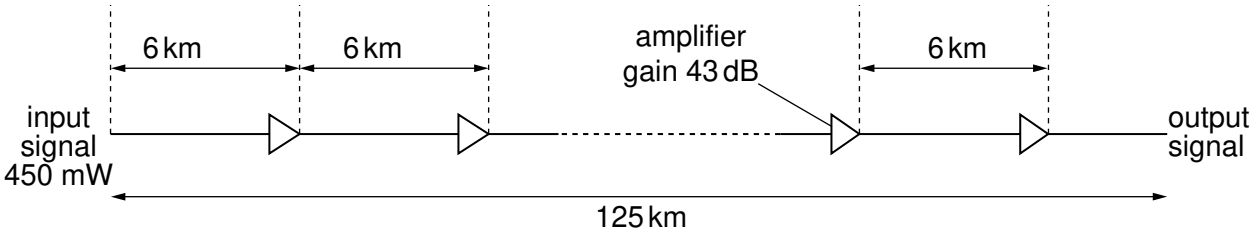


**Fig. 12.1**

**(a)** State what is meant by the *attenuation* of a signal.

.....

..... [1]

**(b)** Calculate

**(i)** the total attenuation caused by the transmission of the signal along the cable,

attenuation = ..... dB [1]

**(ii)** the total signal gain as a result of amplification by all of the amplifiers along the cable.

gain = ..... dB [1]

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**(c)** The input signal has a power of 450 mW. Use your answers in **(b)** to calculate the output power of the signal as it leaves the cable system.

power = ..... mW [3]

**13** **(a)** Fig. 13.1 is a block diagram illustrating part of a mobile phone handset used for receiving a signal from a base station.

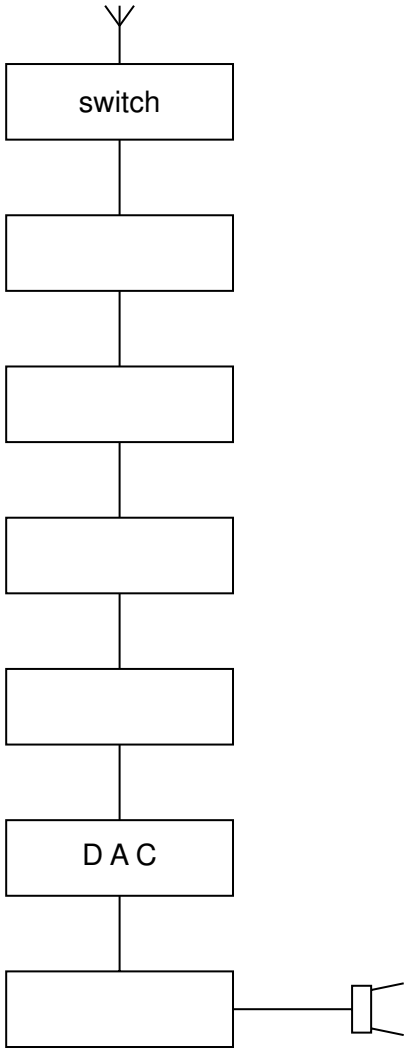


**Fig. 13.1**

Complete Fig. 13.1 by labelling each of the blocks. [4]

**(b)** Explain the role of the base station and the cellular exchange when a mobile phone is switched on and before a call is made or received.

.....

.....

.....

.....

.....

.....

.....

..... [4]

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