| Surname | | Other Names | |
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| Centre Number | | Candidate Number | |
| Candidate Signature | | | |

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General Certificate of Education
June 2007
Advanced Level Examination

**PHYSICS (SPECIFICATION A)** **PHA9/W**
**Unit 9 Nuclear Instability: Electronics Option**

Thursday 14 June 2007 9.00 am to 10.15 am

**For this paper you must have:**
- a calculator
- a pencil and a ruler.

Time allowed: 1 hour 15 minutes

## Instructions
- Use blue or black ink or ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- Answer the questions in the spaces provided.
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want to be marked.

## Information
- The maximum mark for this paper is 40.
- Two of these marks will be awarded for using good English, organising information clearly and using specialist vocabulary where appropriate.
- The marks for questions are shown in brackets.
- A *Data Sheet* is provided on pages 3 and 4. You may wish to detach this perforated sheet at the start of the examination.
- You are expected to use a calculator where appropriate.
- Questions 1(a) and 5(a) should be answered in continuous prose. In these questions you will be marked on your ability to use good English, to organise information clearly and to use specialist vocabulary where appropriate.

| For Examiner's Use | | | |
|---|---|---|---|
| Question | Mark | Question | Mark |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
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| Total (Column 1) → | | | |
| Total (Column 2) → | | | |
| Quality of Written Communication | | | |
| TOTAL | | | |
| Examiner's Initials | | | |

**Data Sheet**

- A perforated *Data Sheet* is provided as pages 3 and 4 of this question paper.
- This sheet may be useful for answering some of the questions in the examination.
- You may wish to detach this sheet before you begin work.

# Data Sheet

## Fundamental constants and values

| *Quantity* | *Symbol* | *Value* | *Units* |
|---|---|---|---|
| speed of light in vacuo | $c$ | $3.00 \times 10^{8}$ | $m\ s^{-1}$ |
| permeability of free space | $\mu_0$ | $4\pi \times 10^{-7}$ | $H\ m^{-1}$ |
| permittivity of free space | $\varepsilon_0$ | $8.85 \times 10^{-12}$ | $F\ m^{-1}$ |
| charge of electron | $e$ | $1.60 \times 10^{-19}$ | C |
| the Planck constant | $h$ | $6.63 \times 10^{-34}$ | J s |
| gravitational constant | $G$ | $6.67 \times 10^{-11}$ | $N\ m^{2}\ kg^{-2}$ |
| the Avogadro constant | $N_A$ | $6.02 \times 10^{23}$ | $mol^{-1}$ |
| molar gas constant | $R$ | 8.31 | $J\ K^{-1}\ mol^{-1}$ |
| the Boltzmann constant | $k$ | $1.38 \times 10^{-23}$ | $J\ K^{-1}$ |
| the Stefan constant | $\sigma$ | $5.67 \times 10^{-8}$ | $W\ m^{-2}\ K^{-4}$ |
| the Wien constant | $\alpha$ | $2.90 \times 10^{-3}$ | m K |
| electron rest mass (equivalent to $5.5 \times 10^{-4}$u) | $m_e$ | $9.11 \times 10^{-31}$ | kg |
| electron charge/mass ratio | $e/m_e$ | $1.76 \times 10^{11}$ | $C\ kg^{-1}$ |
| proton rest mass (equivalent to 1.00728u) | $m_p$ | $1.67 \times 10^{-27}$ | kg |
| proton charge/mass ratio | $e/m_p$ | $9.58 \times 10^{7}$ | $C\ kg^{-1}$ |
| neutron rest mass (equivalent to 1.00867u) | $m_n$ | $1.67 \times 10^{-27}$ | kg |
| gravitational field strength | $g$ | 9.81 | $N\ kg^{-1}$ |
| acceleration due to gravity | $g$ | 9.81 | $m\ s^{-2}$ |
| atomic mass unit (1u is equivalent to 931.3 MeV) | u | $1.661 \times 10^{-27}$ | kg |

## Fundamental particles

| *Class* | *Name* | *Symbol* | *Rest energy /MeV* |
|---|---|---|---|
| photon | photon | $\gamma$ | 0 |
| lepton | neutrino | $\nu_e$ | 0 |
| | | $\nu_\mu$ | 0 |
| | electron | $e^{\pm}$ | 0.510999 |
| | muon | $\mu^{\pm}$ | 105.659 |
| mesons | pion | $\pi^{\pm}$ | 139.576 |
| | | $\pi^{0}$ | 134.972 |
| | kaon | $K^{\pm}$ | 493.821 |
| | | $K^{0}$ | 497.762 |
| baryons | proton | p | 938.257 |
| | neutron | n | 939.551 |

## Properties of quarks

| *Type* | *Charge* | *Baryon number* | *Strangeness* |
|---|---|---|---|
| u | $+\frac{2}{3}$ | $+\frac{1}{3}$ | 0 |
| d | $-\frac{1}{3}$ | $+\frac{1}{3}$ | 0 |
| s | $-\frac{1}{3}$ | $+\frac{1}{3}$ | $-1$ |

## Geometrical equations

*arc length* $= r\theta$

*circumference of circle* $= 2\pi r$

*area of circle* $= \pi r^2$

*area of cylinder* $= 2\pi rh$

*volume of cylinder* $= \pi r^2 h$

*area of sphere* $= 4\pi r^2$

*volume of sphere* $= \frac{4}{3}\pi r^3$

## Mechanics and Applied Physics

$v = u + at$

$s = \left(\frac{u+v}{2}\right)t$

$s = ut + \frac{at^2}{2}$

$v^2 = u^2 + 2as$

$F = \frac{\Delta(mv)}{\Delta t}$

$P = Fv$

*efficiency* $= \frac{\textit{power output}}{\textit{power input}}$

$\omega = \frac{v}{r} = 2\pi f$

$a = \frac{v^2}{r} = r\omega^2$

$I = \sum mr^2$

$E_k = \frac{1}{2} I\omega^2$

$\omega_2 = \omega_1 + \alpha t$

$\theta = \omega_1 t + \frac{1}{2}\alpha t^2$

$\omega_2^2 = \omega_1^2 + 2\alpha\theta$

$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$

$T = I\alpha$

*angular momentum* $= I\omega$

$W = T\theta$

$P = T\omega$

*angular impulse = change of angular momentum* $= Tt$

$\Delta Q = \Delta U + \Delta W$

$\Delta W = p\Delta V$

$pV^{\gamma} =$ constant

*work done per cycle = area of loop*

*input power = calorific value × fuel flow rate*

*indicated power as (area of* $p - V$ *loop) × (no. of cycles/s) × (no. of cylinders)*

*friction power = indicated power – brake power*

*efficiency* $= \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$

*maximum possible efficiency* $= \frac{T_H - T_C}{T_H}$

## Fields, Waves, Quantum Phenomena

$g = \frac{F}{m}$

$g = -\frac{GM}{r^2}$

$g = -\frac{\Delta V}{\Delta x}$

$V = -\frac{GM}{r}$

$a = -(2\pi f)^2 x$

$v = \pm 2\pi f\sqrt{A^2 - x^2}$

$x = A\cos 2\pi ft$

$T = 2\pi\sqrt{\frac{m}{k}}$

$T = 2\pi\sqrt{\frac{l}{g}}$

$\lambda = \frac{\omega s}{D}$

$d\sin\theta = n\lambda$

$\theta \approx \frac{\lambda}{D}$

${}_1n_2 = \frac{\sin\theta_1}{\sin\theta_2} = \frac{c_1}{c_2}$

${}_1n_2 = \frac{n_2}{n_1}$

$\sin\theta_c = \frac{1}{n}$

$E = hf$

$hf = \phi + E_k$

$hf = E_1 - E_2$

$\lambda = \frac{h}{p} = \frac{h}{mv}$

$c = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$

## Electricity

$\epsilon = \frac{E}{Q}$

$\epsilon = I(R + r)$

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$

$R_T = R_1 + R_2 + R_3 + \cdots$

$P = I^2 R$

$E = \frac{F}{Q} = \frac{V}{d}$

$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$

$E = \frac{1}{2}QV$

$F = BIl$

$F = BQv$

$Q = Q_0 e^{-t/RC}$

$\Phi = BA$

Turn over ▶

magnitude of induced emf $= N \frac{\Delta\Phi}{\Delta t}$

$I_{rms} = \frac{I_0}{\sqrt{2}}$

$V_{rms} = \frac{V_0}{\sqrt{2}}$

**Mechanical and Thermal Properties**

the Young modulus $= \frac{\text{tensile stress}}{\text{tensile strain}} = \frac{F}{A}\frac{l}{e}$

energy stored $= \frac{1}{2} Fe$

$\Delta Q = mc\,\Delta\theta$

$\Delta Q = ml$

$pV = \frac{1}{3} Nm\overline{c^2}$

$\frac{1}{2} m\overline{c^2} = \frac{3}{2} kT = \frac{3RT}{2N_A}$

**Nuclear Physics and Turning Points in Physics**

force $= \frac{eV_p}{d}$

force $= Bev$

radius of curvature $= \frac{mv}{Be}$

$\frac{eV}{d} = mg$

work done $= eV$

$F = 6\pi\eta rv$

$I = k\frac{I_0}{x^2}$

$\frac{\Delta N}{\Delta t} = -\lambda N$

$\lambda = \frac{h}{\sqrt{2meV}}$

$N = N_0 e^{-\lambda t}$

$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

$R = r_0 A^{\frac{1}{3}}$

$E = mc^2 = \frac{m_0c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

$l = l_0\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}$

$t = \frac{t_0}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$

**Astrophysics and Medical Physics**

| Body | Mass/kg | Mean radius/m |
|---|---|---|
| Sun | $2.00 \times 10^{30}$ | $7.00 \times 10^{8}$ |
| Earth | $6.00 \times 10^{24}$ | $6.40 \times 10^{6}$ |

1 astronomical unit $= 1.50 \times 10^{11}$ m

1 parsec $= 206265$ AU $= 3.08 \times 10^{16}$ m $=$ 3.26 ly

1 light year $= 9.45 \times 10^{15}$ m

Hubble constant ($H$) $= 65$ km s$^{-1}$ Mpc$^{-1}$

$M = \frac{\text{angle subtended by image at eye}}{\text{angle subtended by object at unaided eye}}$

$M = \frac{f_o}{f_e}$

$m - M = 5 \log \frac{d}{10}$

$\lambda_{max} T = \text{constant} = 0.0029$ m K

$v = Hd$

$P = \sigma AT^4$

$\frac{\Delta f}{f} = \frac{v}{c}$

$\frac{\Delta\lambda}{\lambda} = -\frac{v}{c}$

$R_s \approx \frac{2GM}{c^2}$

**Medical Physics**

power $= \frac{1}{f}$

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ and $m = \frac{v}{u}$

intensity level $= 10 \log \frac{I}{I_0}$

$I = I_0 e^{-\mu x}$

$\mu_m = \frac{\mu}{\rho}$

**Electronics**

Resistors

Preferred values for resistors (E24)
Series: 1.0 1.1 1.2 1.3 1.5 1.6 1.8 2.0 2.2 2.4 2.7 3.0 3.3 3.6 3.9 4.3 4.7 5.1 5.6 6.2 6.8 7.5 8.2 9.1 ohms
and multiples that are ten times greater

$Z = \frac{V_{rms}}{I_{rms}}$

$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \cdots$

$C_T = C_1 + C_2 + C_3 + \cdots$

$X_C = \frac{1}{2\pi fC}$

**Alternating Currents**

$f = \frac{1}{T}$

**Operational amplifier**

$G = \frac{V_{out}}{V_{in}}$ voltage gain

$G = -\frac{R_f}{R_1}$ inverting

$G = 1 + \frac{R_f}{R_1}$ non-inverting

$V_{out} = -R_f\left(\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right)$ summing

**Turn over for the first question**

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## SECTION A: NUCLEAR INSTABILITY

Answer **all** of this question.

**1** (a) X and Y are two different β emitting sources. Initially they contain the same number of unstable nuclei. Both sources have their emissions recorded over a period of time. The *decay constant* of source X is greater than that of Y. State what is meant by decay constant and describe **two** differences in the recordings from the two sources.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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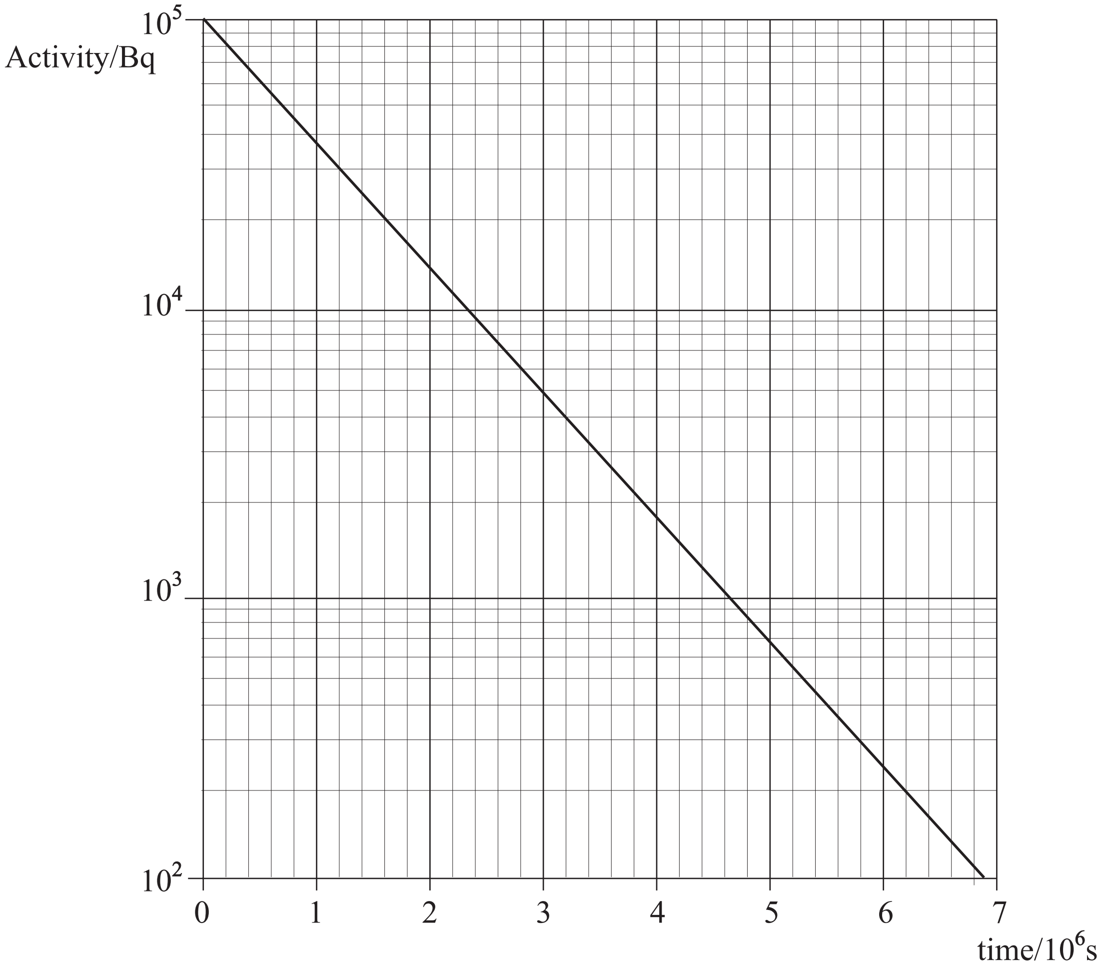
*(3 marks)*

(b) The activity of a sample of radioactive iodine, $^{131}_{53}I$, is presented in the following graph.



(i) Show that the decay constant of ${}^{131}_{53}\mathrm{I}$ is about $1 \times 10^{-6}\ \mathrm{s}^{-1}$.

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(ii) Calculate the half-life of ${}^{131}_{53}\mathrm{I}$ in days.

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(iii) Calculate the initial number of ${}^{131}_{53}\mathrm{I}$ atoms in the sample.

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*(7 marks)*

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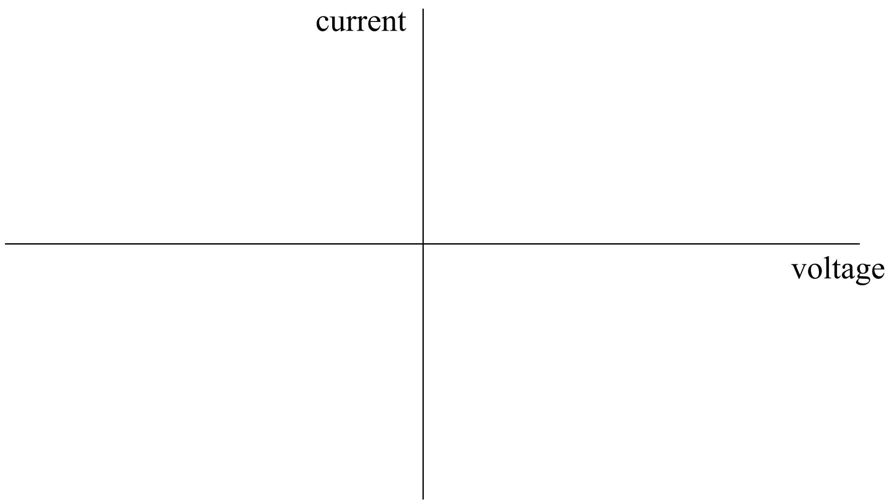
| 10 |

**Turn over for the next question**

**SECTION B: ELECTRONICS**

Answer **all** questions.

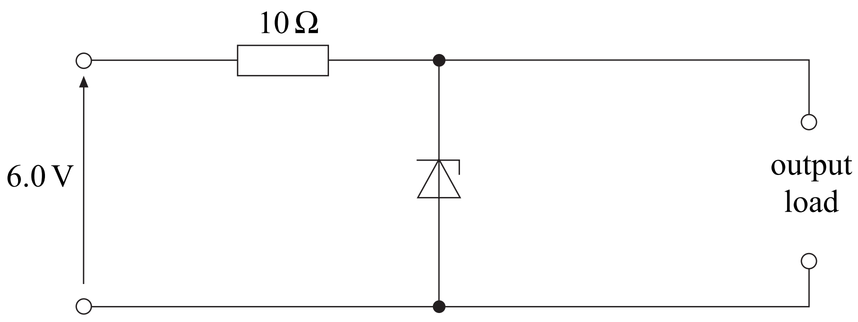
**2** (a) On the axes below sketch the current – voltage characteristic for a 3.9 V zener diode. Show appropriate values on the voltage axis.




*(3 marks)*

(b) The zener diode is used to provide a stabilised output voltage of 3.9 V. The circuit used is shown in **Figure 1**. The zener diode must have a minimum current of 10 mA flowing through it for it to function correctly.

**Figure 1**



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Calculate the maximum current that can be provided to the output.

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*(3 marks)*

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**Turn over for the next question**

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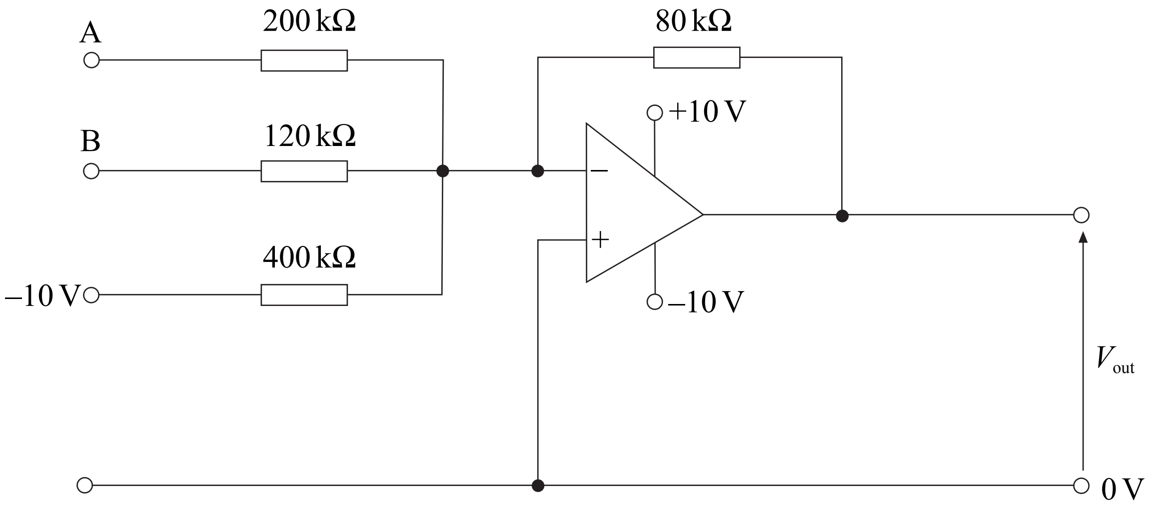
**3** **Figure 2** shows an amplifier circuit.

**Figure 2**




(a) Name this type of amplifier circuit.

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*(1 mark)*

(b) When the inputs at A and B are at 0 V, show that the output voltage, $V_{out}$, is + 2.0 V.

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*(1 mark)*

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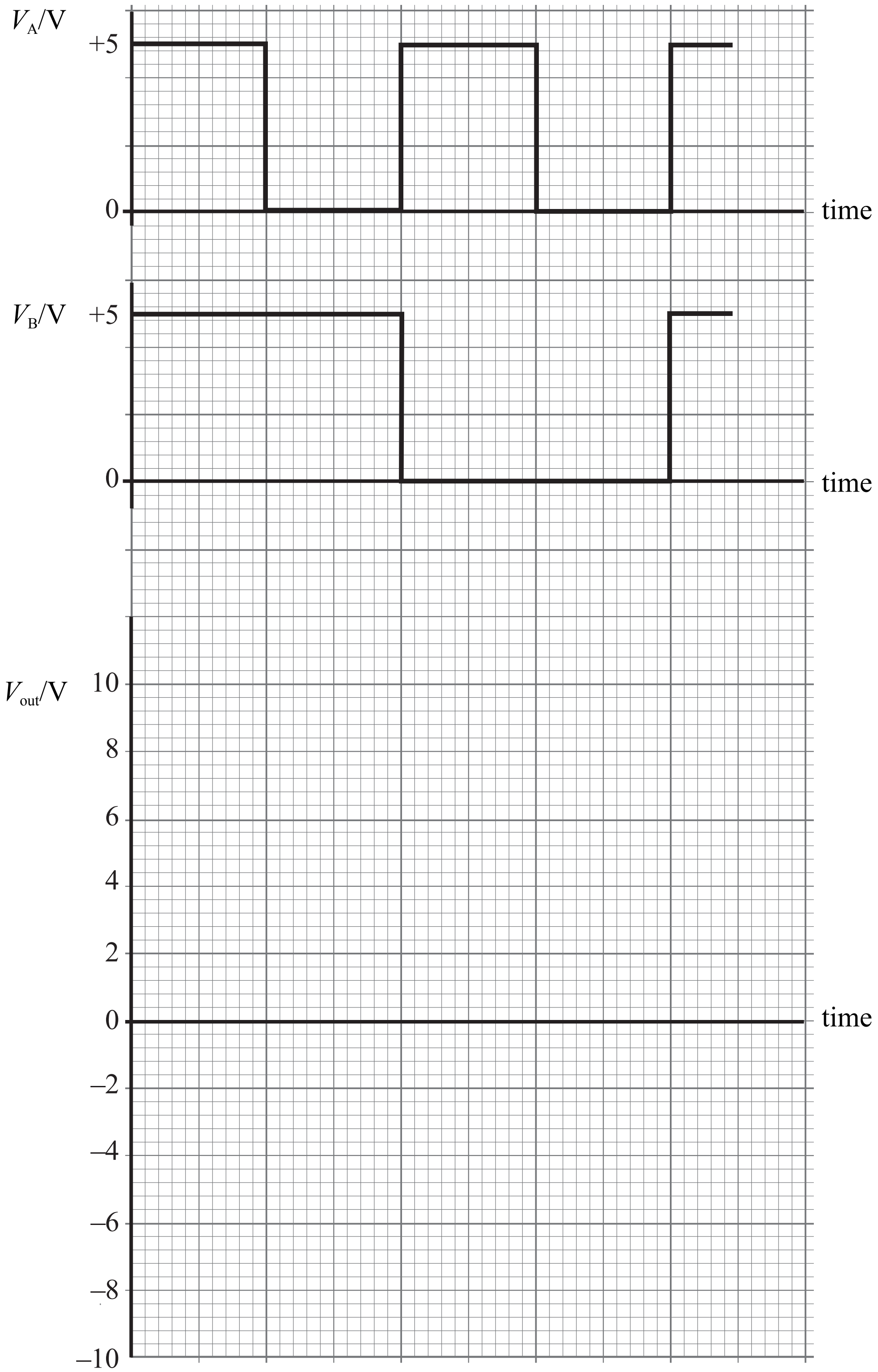
(c) Voltage signals $V_A$ and $V_B$ are applied to A and B respectively. These signals are shown in **Figure 3**. The input to the 400 kΩ resistor remains at –10 V. Complete on **Figure 3** the graph of output voltage against time.

**Figure 3**




*(5 marks)*

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**4** When *negative feedback* is used with an amplifier, the *bandwidth* of the amplifier is increased.

(i) Explain what is meant by negative feedback.

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(ii) Give **one** other advantage of negative feedback.

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(iii) State what is meant by the bandwidth of the amplifier.

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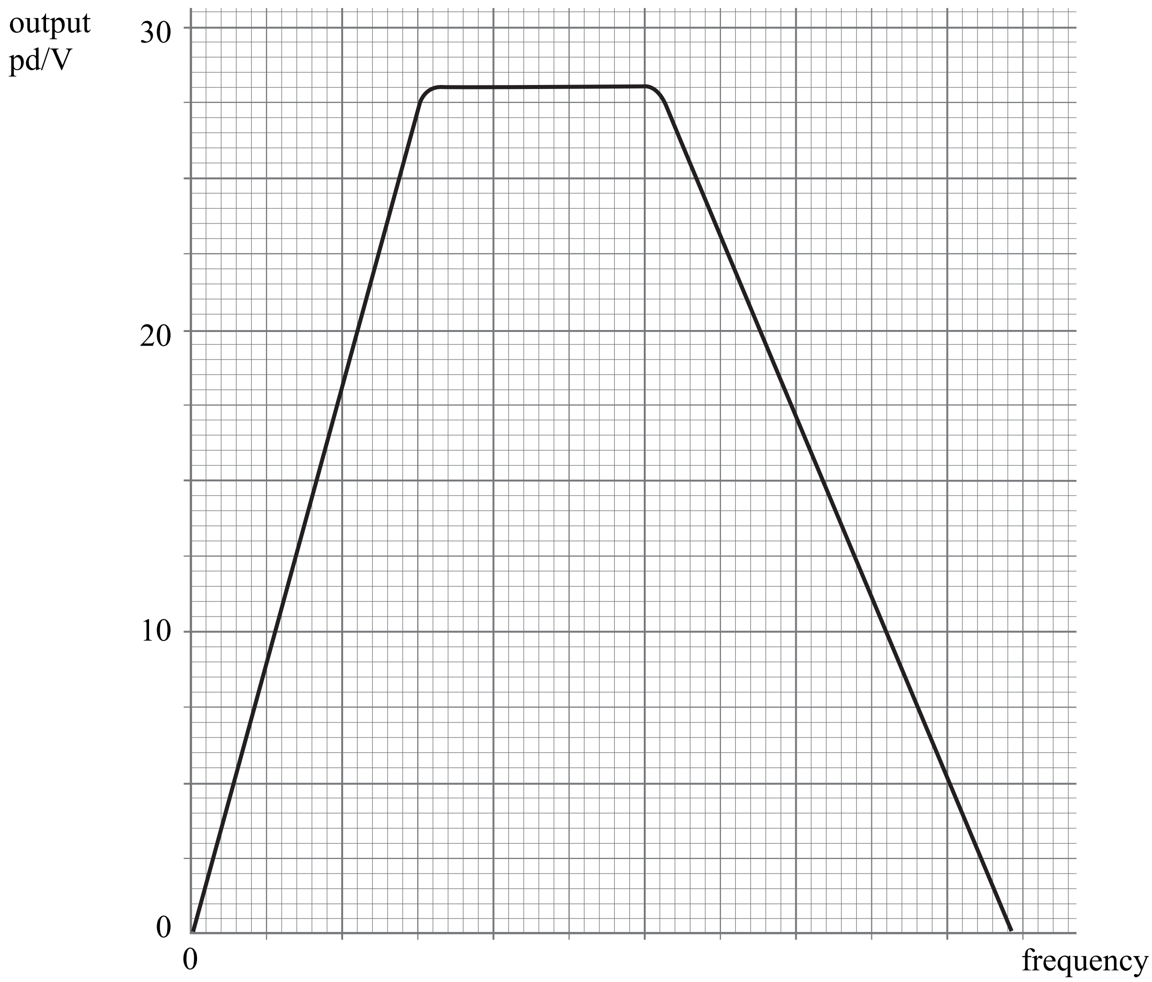
(iv) The graph below shows the characteristic curve of an amplifier. Indicate the bandwidth of the amplifier on the graph.



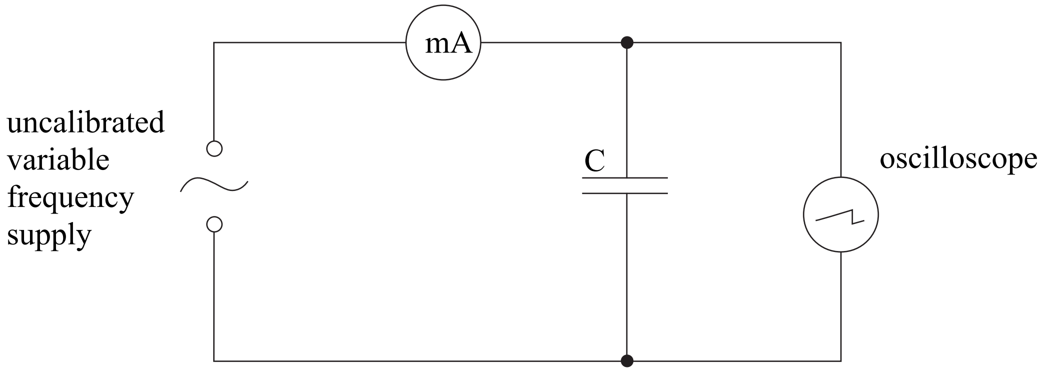

*(6 marks)*

6

**Turn over for the next question**

**5** The circuit shown in **Figure 4** was used to investigate the relationship between the reactance of the capacitor C and the frequency of the alternating voltage supply.

**Figure 4**




You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer to part (a).

(a) State the readings which would be taken, and explain how they would be used, to determine

(i) the frequency of the supply,

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(ii) the reactance of the capacitor.

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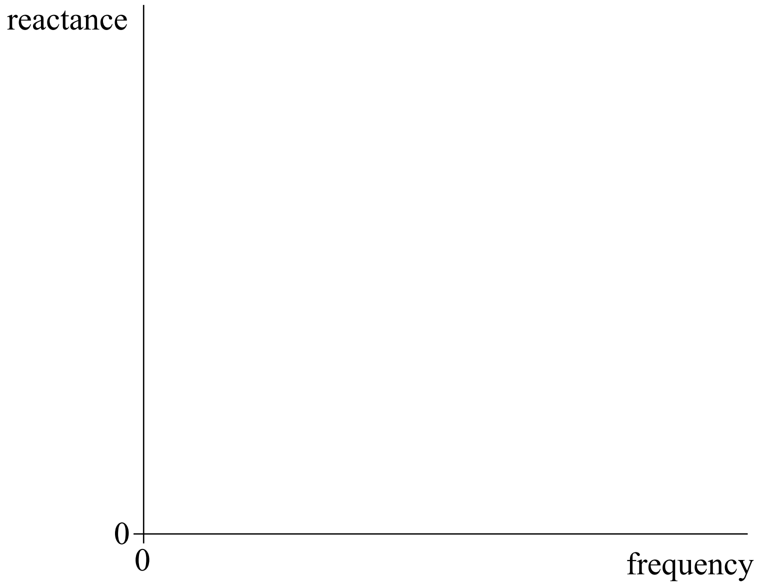
*(6 marks)*

(b) On the axes below, sketch the curve expected for reactance against frequency.




*(1 mark)*

(c) The capacitor has a reactance of 12 Ω at a frequency of 2.5 kHz. Calculate its capacitance.

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*(2 marks)*

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**Quality of Written Communication** *(2 marks)*

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**END OF QUESTIONS**

**There are no questions printed on this page**