Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

General Certificate of Education
January 2005
Advanced Level Examination

AQA

ASSESSMENT and
QUALIFICATIONS
ALLIANCE

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

Wednesday 26 January 2005   Morning Session

In addition to this paper you will require:
• 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 in the spaces provided. All working must be shown.
• Do all rough work in this book. Cross through any work you do not want marked.

Information
• The maximum mark for this paper is 40.
• Mark allocations are shown in brackets.
• The paper carries 10% of the total marks for Physics Advanced.
• 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.
• In questions requiring description and explanation you will be assessed on your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary where appropriate. The degree of legibility of your handwriting and the level of accuracy of your spelling, punctuation and grammar will also be taken into account.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
Total (Column 1)			
Total (Column 2)			
TOTAL			
Examiner's Initials			

PHA9/W

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	3.00×10^8	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}
charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	N m^2 kg^{-2}
the Avogadro constant	N_A	6.02×10^{23}	mol^{-1}
molar gas constant	R	8.31	J K^{-1} mol^{-1}
the Boltzmann constant	k	1.38×10^{-23}	J K^{-1}
the Stefan constant	σ	5.67×10^{-8}	W m^{-2} K^{-4}
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4}u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	e/m_e	1.76×10^{11}	C kg^{-1}
proton rest mass (equivalent to 1.00728u)	m_p	1.67×10^{-27}	kg
proton charge/mass ratio	e/m_p	9.58×10^7	C kg^{-1}
neutron rest mass (equivalent to 1.00867u)	m_n	1.67×10^{-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	1.661×10^{-27}	kg

Fundamental particles

Class	Name	Symbol	Rest energy /MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	pion	$\pi^\pm$	139.576
		π^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

$$v = u + at$$

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

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

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

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

$$P = Fv$$

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

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

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

$$I = \sum mr^2$$

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

$$\omega_2 = \omega_1 + \alpha t$$

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

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

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

$$T = I\alpha$$

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

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

$$\in = I(R + r)$$

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

$$P = I^2 R$$

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

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

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

$$F = BIl$$

$$F = BQv$$

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

$$\Phi = BA$$

Turn over ▶

Data Sheet

$$\text{magnitude of induced e.m.f.} = N\frac{\Delta\Phi}{\Delta t}$$

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

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

Mechanical and Thermal Properties

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

$$\text{energy stored} = \tfrac{1}{2}Fe$$

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

$$\Delta Q = ml$$

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

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

Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

$$\text{work done} = eV$$

$$F = 6\pi\eta rv$$

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

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

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

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

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

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

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$$E = mc^2 = \frac{m_0 c^2}{\left(1 - \frac{v^2}{c^2}\right)^{\frac{1}{2}}}$$

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

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

Astrophysics and Medical Physics

Body	Mass/kg	Mean radius/m
Sun	2.00×10^{30}	7.00×10^8
Earth	6.00×10^{24}	6.40×10^6

1 astronomical unit = 1.50×10^{11} m

1 parsec = 206265 AU = 3.08×10^{16} m = 3.26 ly

1 light year = 9.45×10^{15} m

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

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

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

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

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

$$v = Hd$$

$$P = \sigma A T^4$$

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

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

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

Medical Physics

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

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

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

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

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

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

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

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

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

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

SECTION A: NUCLEAR INSTABILITY

Answer **all** of this question

1   The high energy electron diffraction apparatus represented in **Figure 1** can be used to determine nuclear radii. The intensity of the electron beam received by the detector is measured at various diffraction angles, θ.
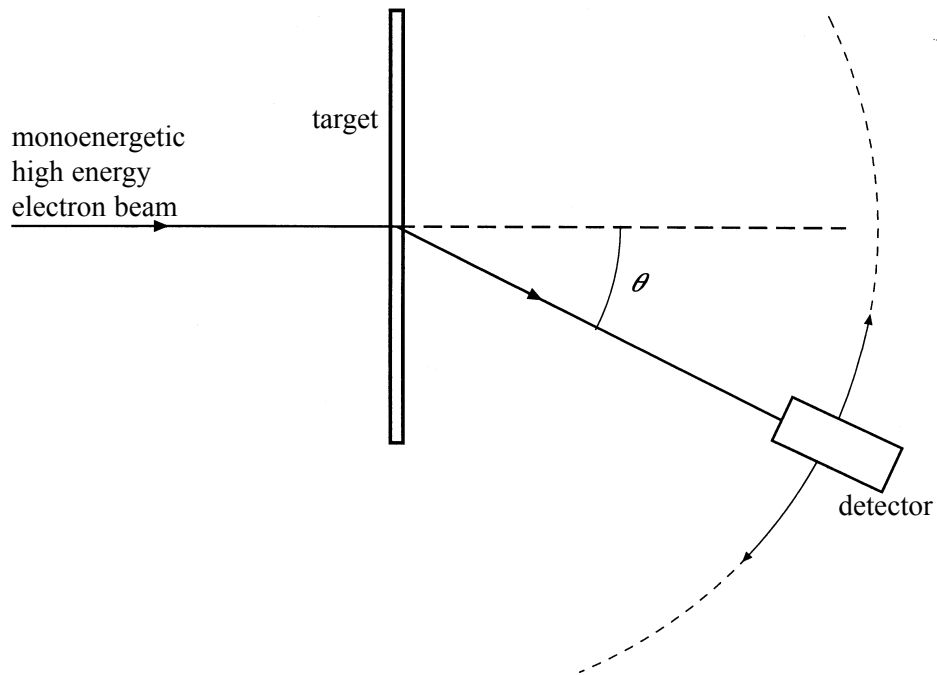
Figure 1

(a)   Sketch on the axes below a graph of the results expected from such an electron diffraction experiment.

(2 marks)

Turn over ▶

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(b)   (i)   Use the data in the table to plot a straight line graph that confirms the relationship $R = r_0 A^{\frac{1}{3}}$.

element	radius of nucleus, R 10^{-15}m	nucleon number, A	
lead	6.66	208	
tin	5.49	120	
iron	4.35	56	
silicon	3.43	28	
carbon	2.66	12	

(ii)   Estimate the value of r_0 from the graph.

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(5 marks)

(c)   Discuss the merits of using high energy electrons to determine nuclear radii rather than using α particles.

You may be awarded marks for the quality of written communication in your answer.

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(3 marks)

$\overline{10}$
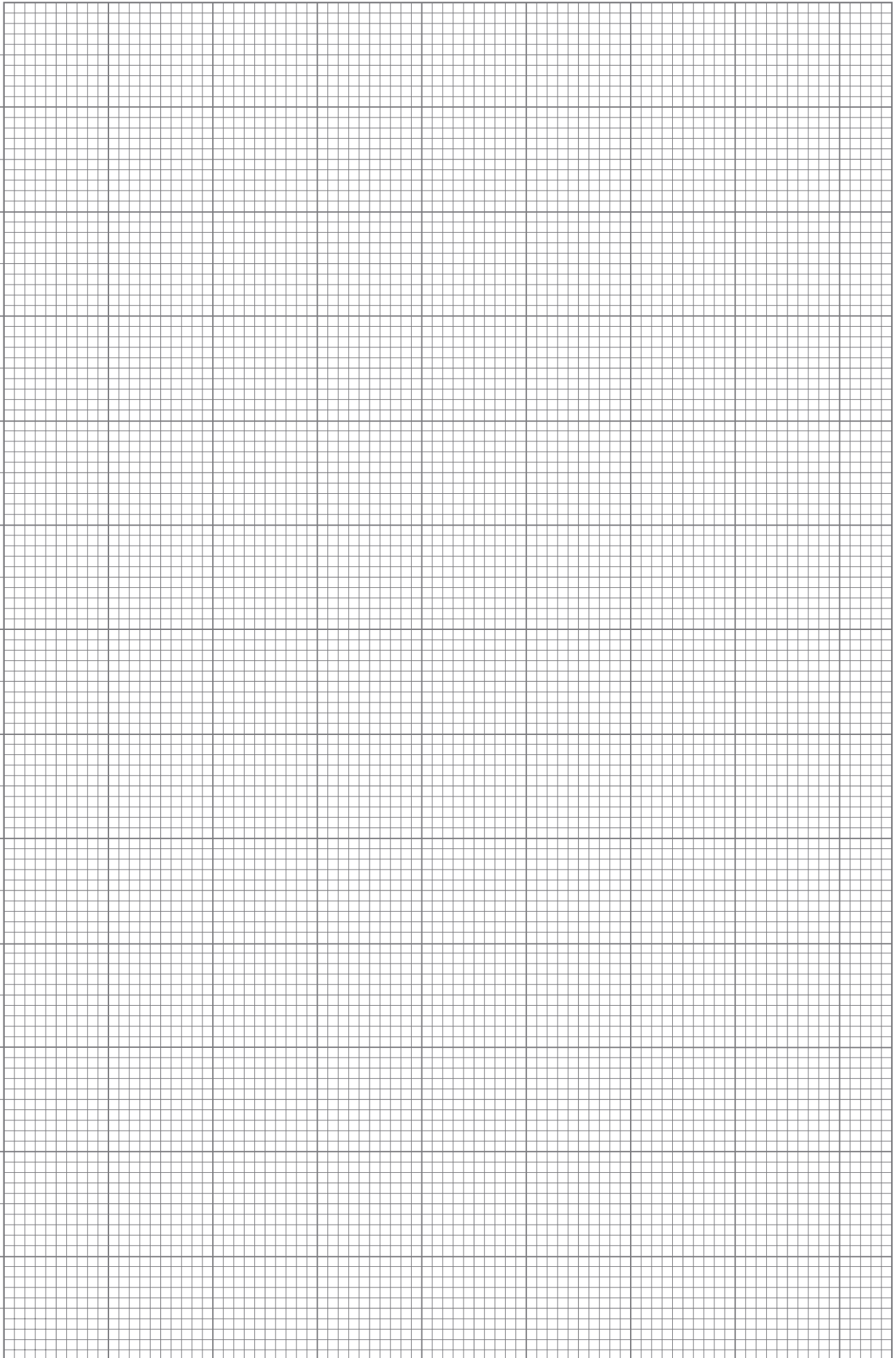
SECTION B: ELECTRONICS

Answer **all** questions.

2 A capacitor-resistor circuit is shown in **Figure 2**. The input voltage, V_{in} , is a 2.0 kHz square wave, shown in **Figure 3**.
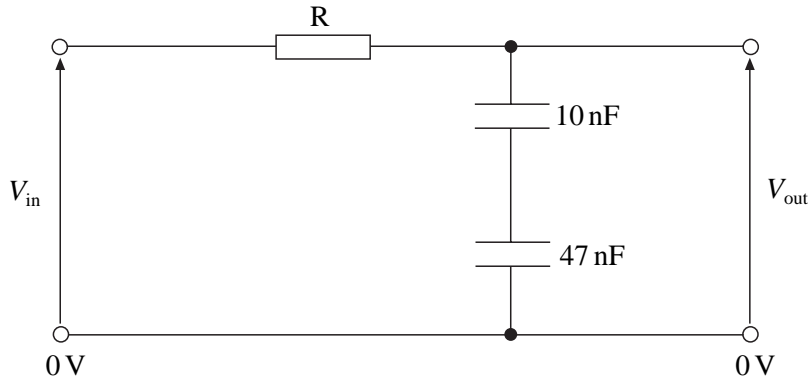
Figure 2
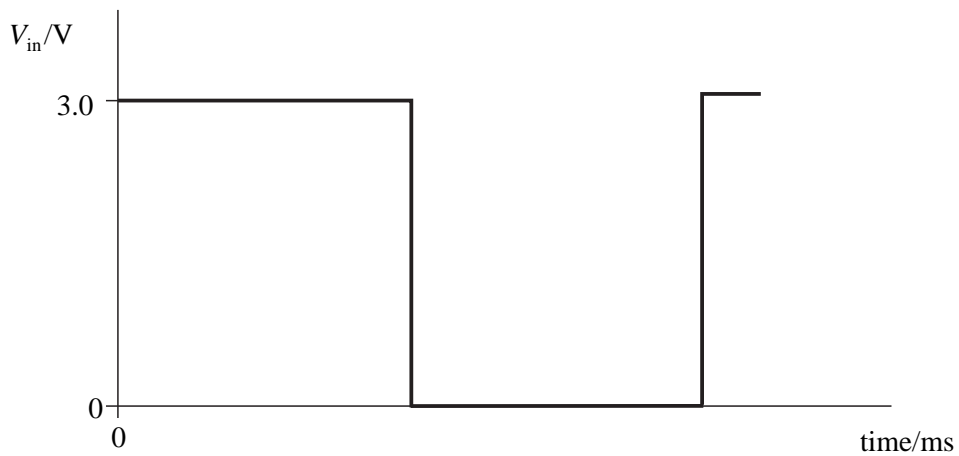
Figure 3

(a) Calculate the period of the input square wave. Hence add a scale to the time axis on **Figure 3**.

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(2 marks)

(b) (i) Show that the two capacitors in **Figure 2** are equivalent to a single capacitor of capacitance 8.25 nF.

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(ii) The resistor R has a value of $5.6\,k\Omega$. Calculate the time constant of the RC network.

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(iii) On **Figure 4**, sketch the waveform of the output voltage, V_{out}, and label the curve A.
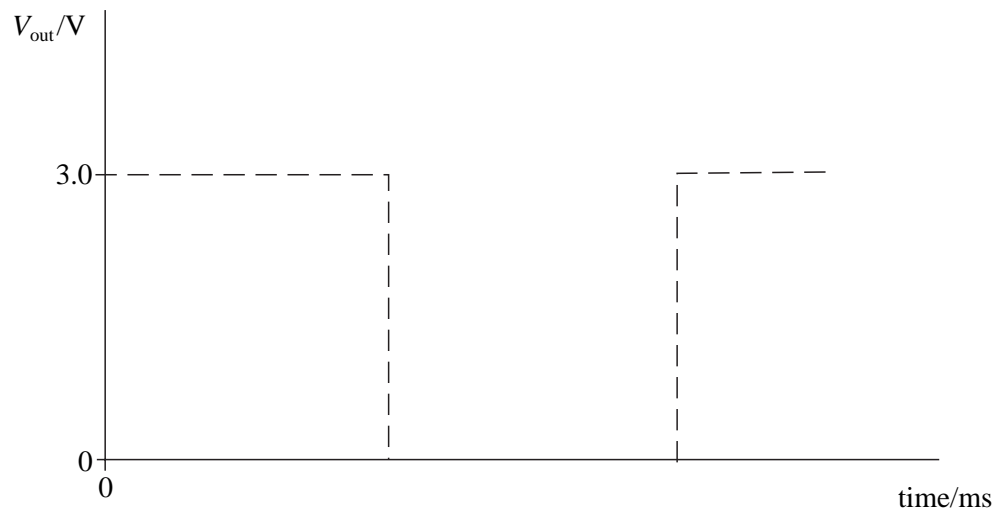
Figure 4

(4 marks)

(c) The $5.6\,k\Omega$ resistor is replaced with a $33\,k\Omega$ resistor.
On **Figure 4**, sketch the new waveform of the output voltage, V_{out}, and label this curve B.
Explain why curve B has this shape.

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(4 marks)

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Turn over ▶

3 (a) **Figure 5** shows a circuit which produces an output voltage, V_{out}, which changes as the intensity of the light incident on component X changes.
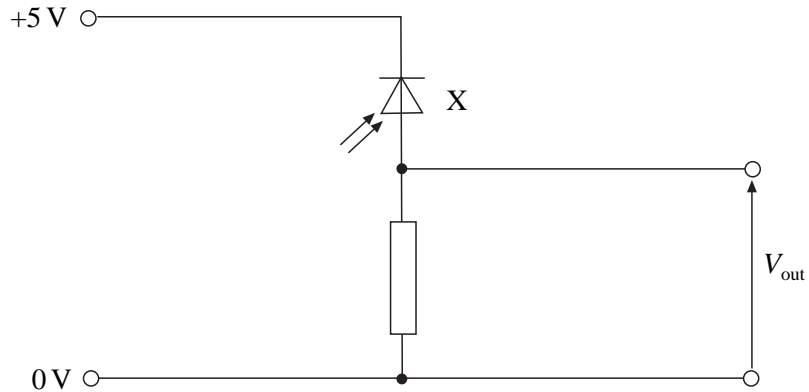
Figure 5

(i) Name component X. ....

(ii) Explain why V_{out} changes as the intensity of the light incident on component X changes.

You may be awarded marks for the quality of your written communication in your answer.

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(4 marks)

(b) A light-emitting diode (LED) has a *forward voltage drop* of 1.8 V and a *reverse breakdown voltage* of 5.0 V. Explain what is meant by

(i) forward voltage drop,

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(ii) reverse breakdown voltage.

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(2 marks)

(c) The circuit in **Figure 6** shows this LED used as an indicator.
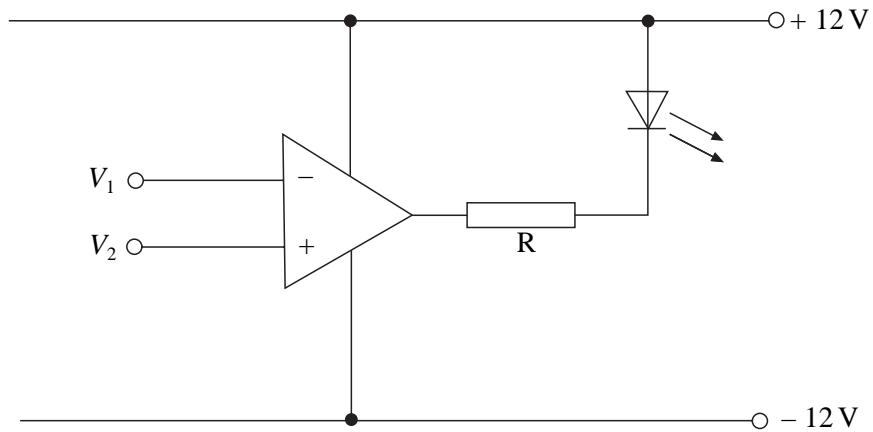
Figure 6

(i) Explain how the state of the LED is related to the input voltages V_1 and V_2.

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(ii) Explain why reverse breakdown voltage is **not** a problem in this circuit.

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(iii) The current passing through the LED when lit is 20 mA. Calculate the value of the resistor R.

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(iv) Which resistor from the E24 series would be used in practice for R?

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(6 marks)

Turn over ▶

4 **Figure 7** shows an operational amplifier used as a summing amplifier.
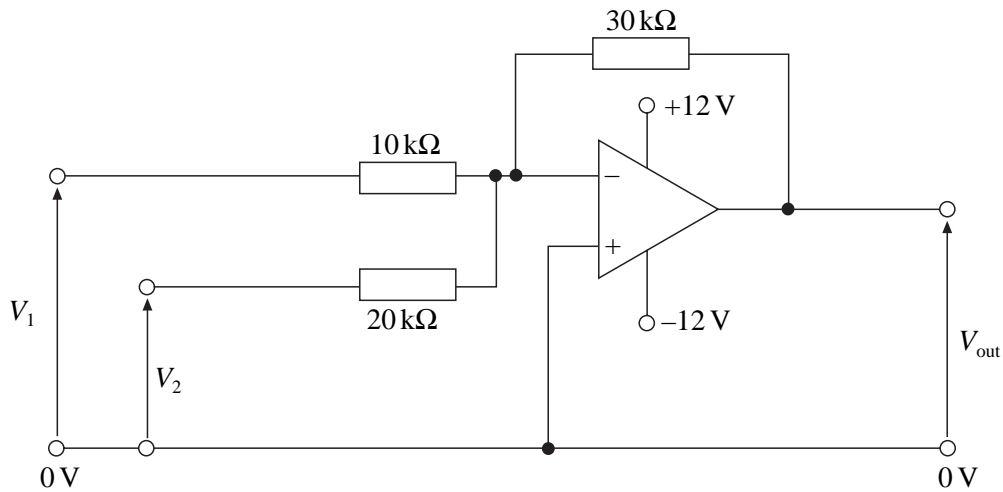
Figure 7

(a) State what type of feedback is used in this circuit.

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(1 mark)

(b) Calculate the output voltage, V_{out}, when the input voltages are $V_1 = -3.0$ V and $V_2 = +2.0$ V.

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(3 marks)

(c) Calculate the new output voltage if both input voltages are set to -3.0 V.

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(2 marks)

$\overline{6}$

QUALITY OF WRITTEN COMMUNICATION

$\overline{2}$

END OF QUESTIONS