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Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education  
June 2006  
Advanced Level Examination



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

**PHA9/W**

Thursday 15 June 2006 9.00 am to 10.15 am

<p><b>For this paper you must have:</b></p> <ul style="list-style-type: none"> <li>• a calculator</li> <li>• a pencil and ruler</li> </ul>
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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 marked.

**Information**

- The maximum mark for this paper is 40. This includes up to 2 marks for the Quality of Written Communication.
- 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.
- You are reminded of the need for good English and clear presentation in your answers. Questions indicated on the paper should be answered in continuous prose. Quality of Written Communication will be assessed in these answers.

For Examiner's Use			
Number	Mark	Number	Mark
1			
2			
3			
4			
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				Mechanics and Applied Physics		Fields, Waves, Quantum Phenomena	
Quantity	Symbol	Value	Units				
speed of light in vacuo	$c$	$3.00 \times 10^8$	$\text{m s}^{-1}$	$v = u + at$	$g = \frac{F}{m}$		
permeability of free space	$\mu_0$	$4\pi \times 10^{-7}$	$\text{H m}^{-1}$	$s = \left(\frac{u+v}{2}\right)t$	$g = -\frac{GM}{r^2}$		
permittivity of free space	$\epsilon_0$	$8.85 \times 10^{-12}$	$\text{F m}^{-1}$	$s = ut + \frac{at^2}{2}$	$g = -\frac{\Delta V}{\Delta x}$		
charge of electron	$e$	$1.60 \times 10^{-19}$	C	$v^2 = u^2 + 2as$	$V = -\frac{GM}{r}$		
the Planck constant	$h$	$6.63 \times 10^{-34}$	J s	$F = \frac{\Delta(mv)}{\Delta t}$	$a = -(2\pi f)^2 x$		
gravitational constant	$G$	$6.67 \times 10^{-11}$	$\text{N m}^2 \text{kg}^{-2}$	$P = Fv$	$v = \pm 2\pi f \sqrt{A^2 - x^2}$		
the Avogadro constant	$N_A$	$6.02 \times 10^{23}$	$\text{mol}^{-1}$	$\text{efficiency} = \frac{\text{power output}}{\text{power input}}$	$x = A \cos 2\pi ft$		
molar gas constant	$R$	8.31	$\text{J K}^{-1} \text{mol}^{-1}$	$\omega = \frac{v}{r} = 2\pi f$	$T = 2\pi \sqrt{\frac{m}{k}}$		
the Boltzmann constant	$k$	$1.38 \times 10^{-23}$	$\text{J K}^{-1}$	$a = \frac{v^2}{r} = r\omega^2$	$T = 2\pi \sqrt{\frac{l}{g}}$		
the Stefan constant	$\sigma$	$5.67 \times 10^{-8}$	$\text{W m}^{-2} \text{K}^{-4}$	$I = \sum mr^2$	$\lambda = \frac{ws}{D}$		
the Wien constant	$\alpha$	$2.90 \times 10^{-3}$	m K	$E_k = \frac{1}{2} I\omega^2$	$d \sin \theta = n\lambda$		
electron rest mass	$m_e$	$9.11 \times 10^{-31}$	kg	$\omega_2 = \omega_1 + at$	$\theta \approx \frac{\lambda}{D}$		
(equivalent to $5.5 \times 10^{-4}u$ )				$\theta = \omega_1 t + \frac{1}{2} at^2$	$1n_2 = \frac{\sin \theta_1}{\sin \theta_2} = \frac{c_1}{c_2}$		
electron charge/mass ratio	$e/m_e$	$1.76 \times 10^{11}$	$\text{C kg}^{-1}$	$\omega_2^2 = \omega_1^2 + 2a\theta$	$1n_2 = \frac{n_2}{n_1}$		
proton rest mass	$m_p$	$1.67 \times 10^{-27}$	kg	$\theta = \frac{1}{2}(\omega_1 + \omega_2)t$	$\sin \theta_c = \frac{1}{n}$		
(equivalent to 1.00728u)				$T = I\alpha$	$E = hf$		
proton charge/mass ratio	$e/m_p$	$9.58 \times 10^7$	$\text{C kg}^{-1}$	$\text{angular momentum} = I\omega$	$hf = \phi + E_k$		
neutron rest mass	$m_n$	$1.67 \times 10^{-27}$	kg	$W = T\theta$	$hf = E_1 - E_2$		
(equivalent to 1.00867u)				$P = T\omega$	$\lambda = \frac{h}{p} = \frac{h}{mv}$		
gravitational field strength	$g$	9.81	$\text{N kg}^{-1}$	$\text{angular impulse} = \text{change of angular momentum} = Tt$	$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$		
acceleration due to gravity	$g$	9.81	$\text{m s}^{-2}$	$\Delta Q = \Delta U + \Delta W$	<b>Electricity</b>		
atomic mass unit	$u$	$1.661 \times 10^{-27}$	kg	$\Delta W = p\Delta V$	$\epsilon = \frac{E}{Q}$		
(1u is equivalent to 931.3 MeV)				$pV^\gamma = \text{constant}$	$\epsilon = I(R+r)$		
<b>Fundamental particles</b>				$\text{work done per cycle} = \text{area of loop}$	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$		
<i>Class</i>	<i>Name</i>	<i>Symbol</i>	<i>Rest energy</i>	$\text{input power} = \text{calorific value} \times \text{fuel flow rate}$	$R_T = R_1 + R_2 + R_3 + \dots$		
			/MeV	$\text{indicated power as (area of } p-V \text{ loop)} \times (\text{no. of cycles/s}) \times (\text{no. of cylinders})$	$P = I^2 R$		
photon	photon	$\gamma$	0	$\text{friction power} = \text{indicated power} - \text{brake power}$	$E = \frac{F}{Q} = \frac{V}{d}$		
lepton	neutrino	$\nu_e$	0	$\text{efficiency} = \frac{W}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$	$E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$		
		$\nu_\mu$	0	$\text{maximum possible efficiency} = \frac{T_H - T_C}{T_H}$	$E = \frac{1}{2} QV$		
	electron	$e^\pm$	0.510999		$F = BI$		
	muon	$\mu^\pm$	105.659		$F = BQv$		
mesons	pion	$\pi^\pm$	139.576		$Q = Q_0 e^{-t/RC}$		
		$\pi^0$	134.972		$\Phi = BA$		
	kaon	$K^\pm$	493.821				
		$K^0$	497.762				
baryons	proton	$p$	938.257				
	neutron	$n$	939.551				
<b>Properties of quarks</b>							
<i>Type</i>	<i>Charge</i>	<i>Baryon number</i>	<i>Strangeness</i>				
u	$+\frac{2}{3}$	$+\frac{1}{3}$	0				
d	$-\frac{1}{3}$	$+\frac{1}{3}$	0				
s	$-\frac{1}{3}$	$+\frac{1}{3}$	-1				
<b>Geometrical equations</b>							
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 = $\frac{4}{3}\pi r^3$							

## Data Sheet

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

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

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

### Mechanical and Thermal Properties

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

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

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

$$\Delta Q = ml$$

$$pV = \frac{1}{3} Nmc^2$$

$$\frac{1}{2} mc^2 = \frac{3}{2} kT = \frac{3RT}{2N_A}$$

### Nuclear Physics and Turning Points in Physics

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

$$\text{force} = Bev$$

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

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

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

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

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

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

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

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

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

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

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

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

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

### Astrophysics and Medical Physics

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

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

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

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

$$\text{Hubble constant } (H) = 65 \text{ kms}^{-1} \text{ Mpc}^{-1}$$

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

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

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

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

$$v = Hd$$

$$P = \sigma AT^4$$

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

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

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

### Medical Physics

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

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

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

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

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

### 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

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

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

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

$$X_C = \frac{1}{2\pi f C}$$

### Alternating Currents

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

### Operational amplifier

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

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

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

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

**Turn over for the first question**

**Turn over ▶**

**SECTION A: NUCLEAR INSTABILITY**Answer **all** of this question.

- 1 (a) Calculate the radius of the  ${}_{92}^{238}\text{U}$  nucleus.

$$r_0 = 1.3 \times 10^{-15} \text{ m}$$

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(2 marks)

- (b) At a distance of 30 mm from a point source of  $\gamma$  rays the corrected count rate is  $C$ . Calculate the distance from the source at which the corrected count rate is  $0.10 C$ , assuming that there is no absorption.

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(2 marks)

- (c) The activity of a source of  $\beta$  particles falls to 85% of its initial value in 52 s. Calculate the decay constant of the source.

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(3 marks)

- (d) Explain why the isotope of technetium,  $^{99}\text{Tc}_m$ , is often chosen as a suitable source of radiation for use in medical diagnosis.

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)

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**Turn over for the next question**

**Turn over ▶**

## SECTION B: ELECTRONICS

Answer **all** questions.

- 2 An RC circuit is shown in **Figure 1**. The input voltage,  $V_{in}$ , is the square wave shown in **Figure 2**. At time  $t = 0$  ms, the capacitors are uncharged.

Figure 1

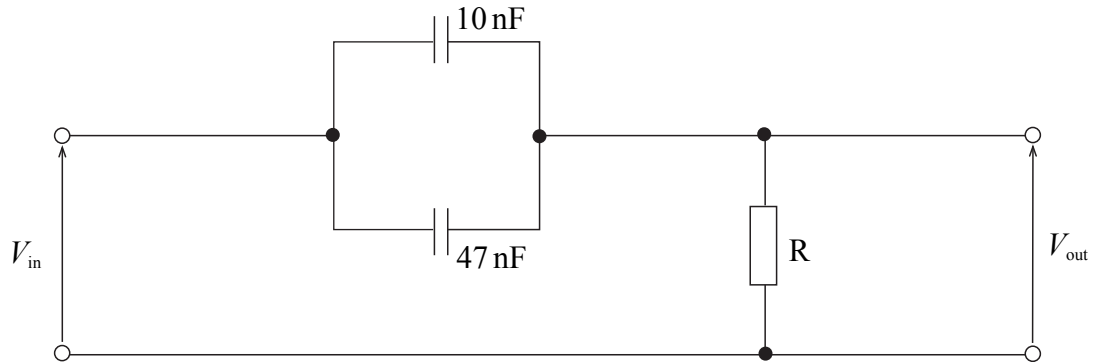
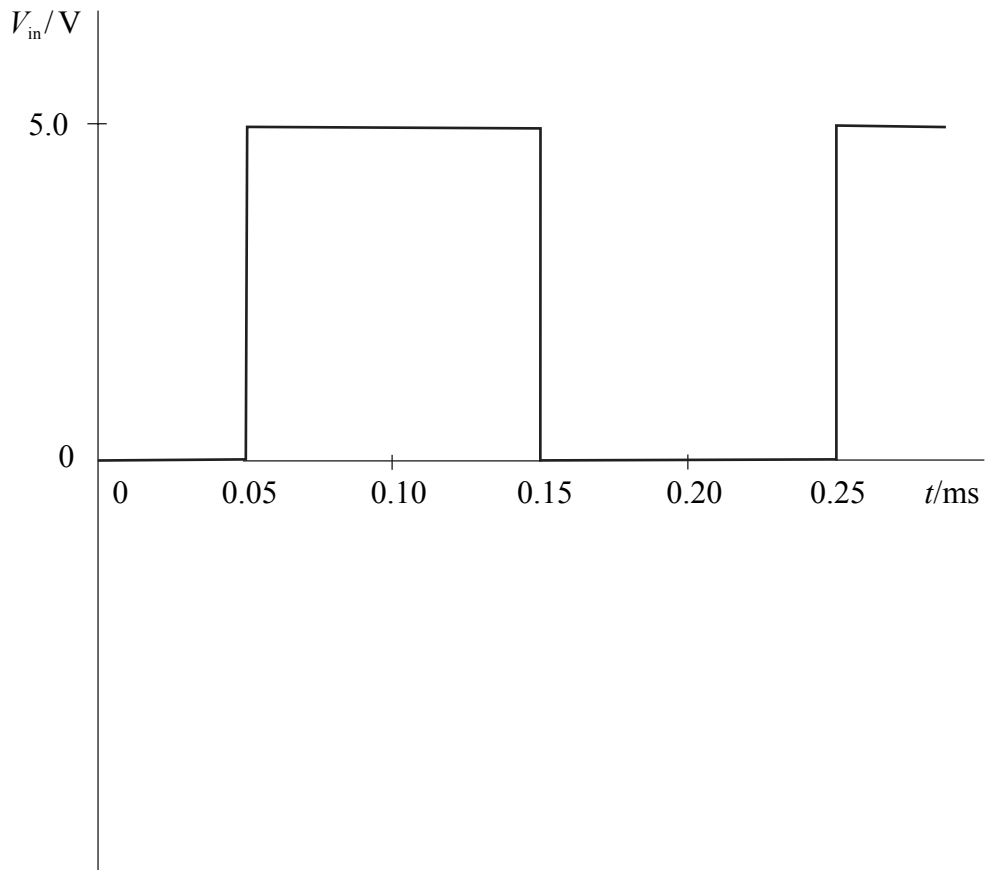


Figure 2





(a) Calculate the frequency of the input square wave.

.....  
.....

(2 marks)

(b) The resistor, R, has a value of 330 Ω.

(i) Calculate the time constant of the RC circuit.

.....  
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.....  
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(ii) On **Figure 2** sketch the output voltage,  $V_{\text{outs}}$  and label the curve A. Explain why curve A has this shape.

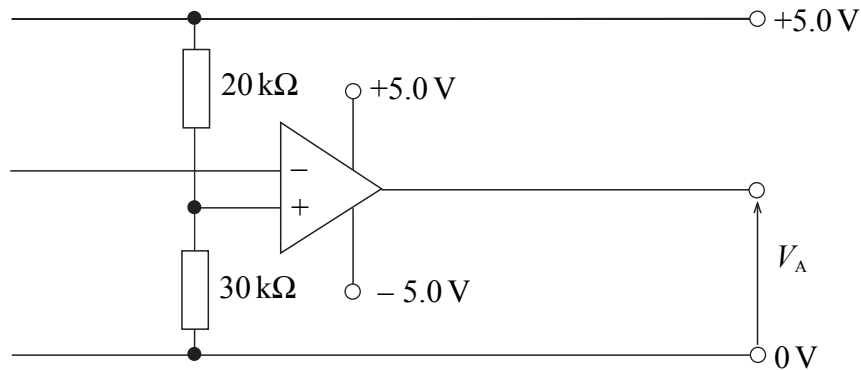
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(6 marks)

(c) The 330 Ω resistor is now replaced with a 3.3 kΩ resistor. On **Figure 2** sketch the new output voltage and label this curve B. (2 marks)

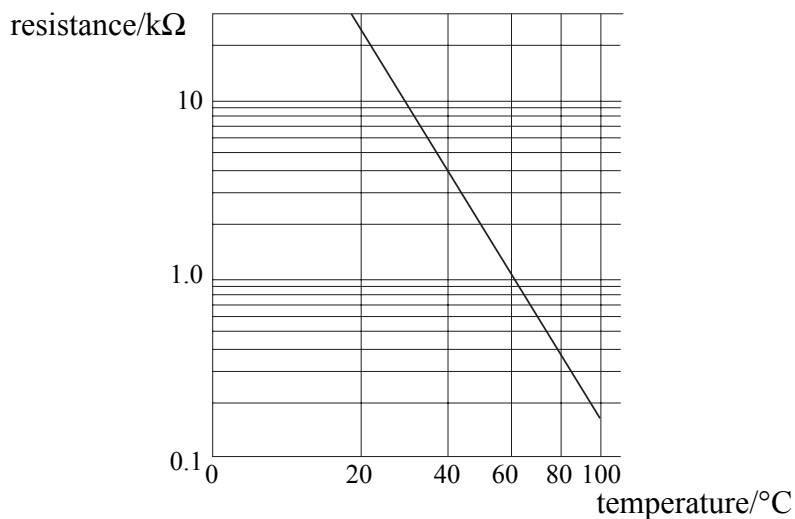
- 3 (a) A student designs a circuit to give an output voltage,  $V_A$ , of +5.0 V when the temperature exceeds a certain value. The incomplete circuit diagram is shown in **Figure 3**.

**Figure 3**



- (i) Complete the circuit in **Figure 3** by adding a thermistor and a variable resistor to allow the circuit to function correctly.
- (ii) State the purpose of the variable resistor.
- .....
- .....
- (iii) If the circuit switches at a temperature of 40 °C, calculate the value of the variable resistor. The characteristic curve of the thermistor is shown in **Figure 4**.

**Figure 4**



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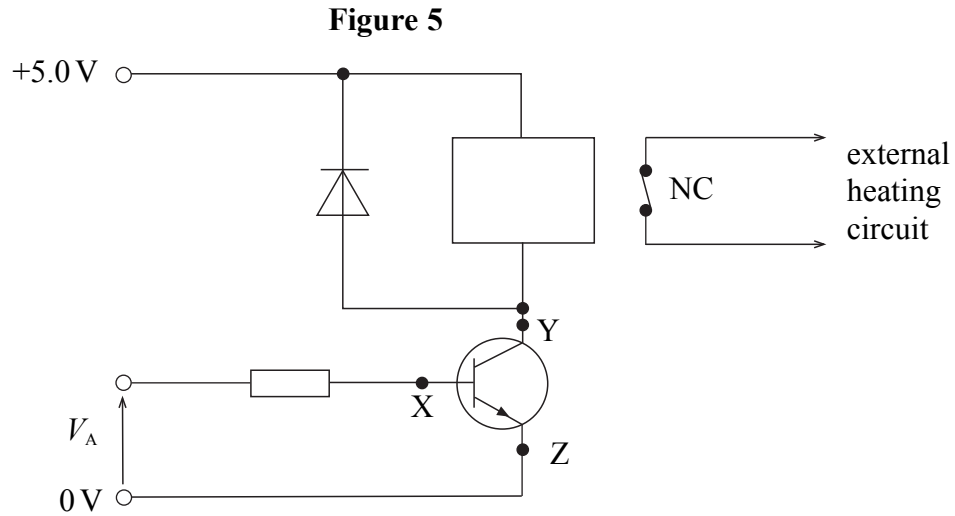
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(5 marks)

- (b) The output of the circuit in **Figure 3** cannot be used to operate a relay directly. The student now adds the circuit shown in **Figure 5** to operate a relay which controls an external heating circuit.



- (i) Name the terminals of the junction transistor.

X .....

Y .....

Z .....

- (ii) Explain in detail the action of the circuit as  $V_A$  changes from  $-5.0\text{ V}$  to  $+5.0\text{ V}$ . You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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- (iii) Explain why the diode must be included in the circuit shown in **Figure 5**.

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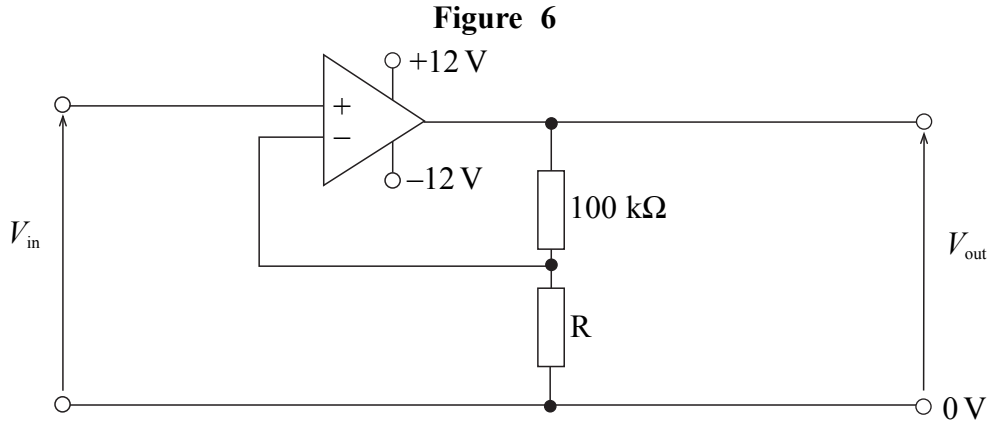
**Turn over for the next question**

(7 marks)

**Turn over** ▶

- 4 (a) For an ideal operational amplifier, state the value of
- (i) the output impedance, .....
  - (ii) the input impedance, .....
  - (iii) the open loop gain. ....
- (2 marks)*

(b) **Figure 6** shows an operational amplifier being used as a non-inverting amplifier.



- (i) Name the type of feedback used in this circuit.  
.....
  - (ii) State **one** advantage of this type of feedback in an amplifier circuit.  
.....  
.....
- (2 marks)*

- (c) Calculate the value of the resistor R when
- $V_{in} = 200 \text{ mV}$   
 $V_{out} = 5.0 \text{ V}.$
- .....  
.....  
.....  
.....
- (2 marks)*

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

**END OF QUESTIONS**