Surname		Other Names	
Centre Number		Candidate Number	
Candidate Signature			

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General Certificate of Education
June 2005
Advanced Level Examination

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

Thursday 16 June 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			

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

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

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

$I = \sum mr^2$

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

$\omega_2 = \omega_1 + \alpha t$

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

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

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

$T = I\alpha$

angular momentum $= I\omega$

$W = T\theta$

$P = T\omega$

angular impulse = change of angular momentum $= Tt$

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

$\Delta W = p\Delta V$

$pV^\gamma = \text{constant}$

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

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

$\epsilon = I(R + r)$

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

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

$P = I^2R$

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

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

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

$F = BIl$

$F = BQv$

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

$\Phi = BA$

Turn over ▶

Data Sheet

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

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

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

Mechanical and Thermal Properties

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

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

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

$\Delta Q = ml$

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

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

Nuclear Physics and Turning Points in Physics

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

$force = Bev$

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

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

$work\ done = eV$

$F = 6\pi\eta rv$

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

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

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

$N = N_0e^{-\lambda t}$

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

$R = r_0A^{\frac{1}{3}}$

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

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

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

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}

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

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

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

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

$v = Hd$

$P = \sigma AT^4$

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

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

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

Medical Physics

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

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

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

$I = I_0e^{-\mu x}$

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

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

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

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

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

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

Alternating Currents

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

Operational amplifier

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

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

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

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

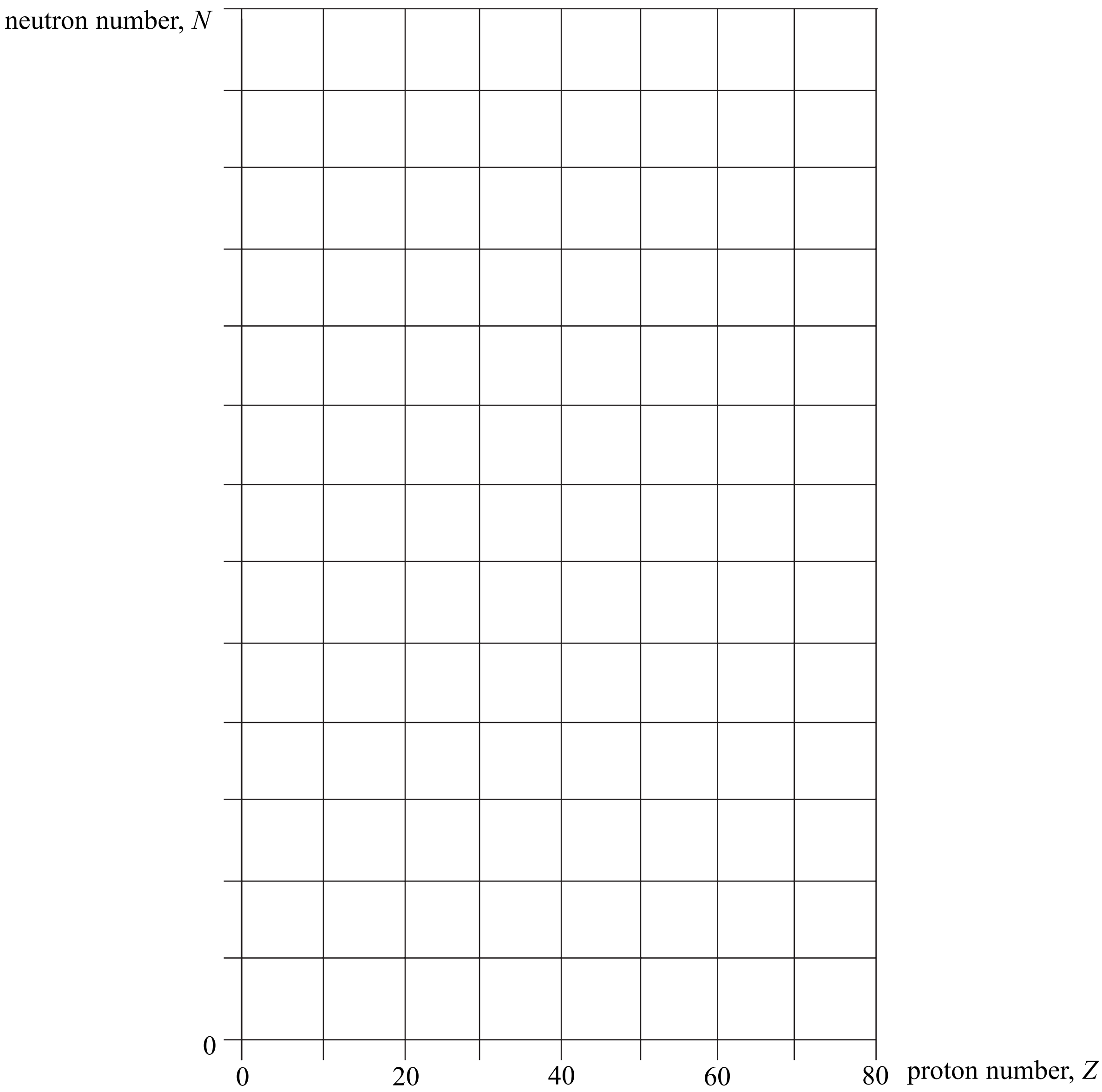
TURN OVER FOR THE FIRST QUESTION

LEAVE MARGIN BLANK

SECTION A: NUCLEAR INSTABILITY

Answer **all** parts of the question.

1 (a) Sketch, using the axes provided, a graph of neutron number, N, against proton number, Z, for stable nuclei over the range $Z = 0$ to $Z = 80$. Show suitable numerical values on the N axis.



(2 marks)

(b) On the graph indicate, for each of the following, a possible position of a nuclide that may decay by

(i) α emission, labelling the position with **W**,

(ii) β^- emission, labelling the position with **X**,

(iii) β^+ emission, labelling the position with **Y**.

(3 marks)

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(c) The isotope $^{222}_{86}$Rn decays sequentially by emitting α particles and β^- particles, eventually forming the isotope $^{206}_{82}$Pb. Four α particles are emitted in the sequence.

Calculate the number of β^- particles in the sequence.

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(2 marks)

(d) A particular nuclide is described as proton-rich. Discuss **two** ways in which the nuclide may decay.

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

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(3 marks)

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TURN OVER FOR SECTION B

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SECTION B: ELECTRONICS

Answer **all** questions.

2 **Figure 1** shows part of a full-wave rectified power supply. The power supply is connected to an 82 Ω load resistor.

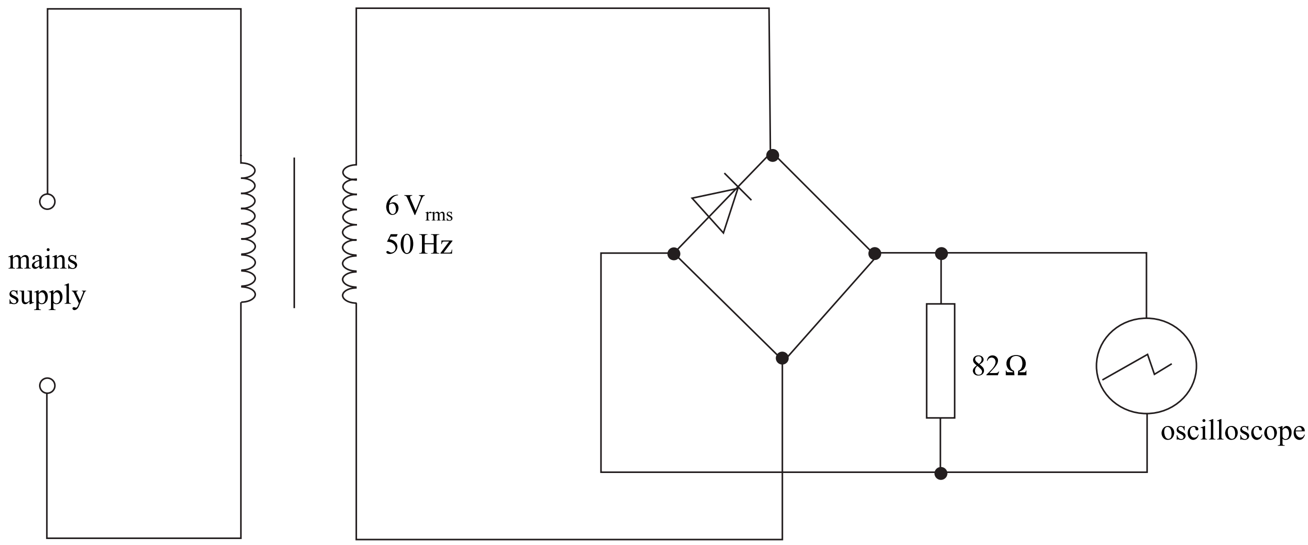

Figure 1

(a) Complete **Figure 1** by adding the **three** diodes needed to complete the rectifier. *(1 mark)*

(b) Calculate

(i) the peak voltage across the load resistor,

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(ii) the peak power dissipated in the load resistor.

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(4 marks)

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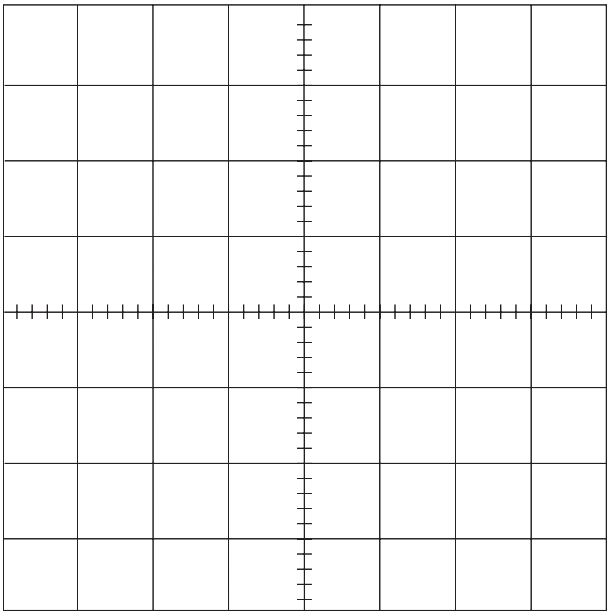
(c) The oscilloscope was set to a voltage sensitivity of 2 V cm^{-1} and a time base of 5 ms cm^{-1}.
Draw on the grid below the trace that would be seen on the oscilloscope.
Label this trace A.



(3 marks)

(d) Many power supplies incorporate a capacitor to smooth the output voltage. Add such a capacitor to **Figure 1** and label it C.
Add to the grid the new trace that you would expect to see with such a capacitor in place. Label this trace B. *(2 marks)*

10

TURN OVER FOR THE NEXT QUESTION

3 The circuit shown in **Figure 2** can be used to sound a buzzer when the intensity of the light incident on the LDR changes.

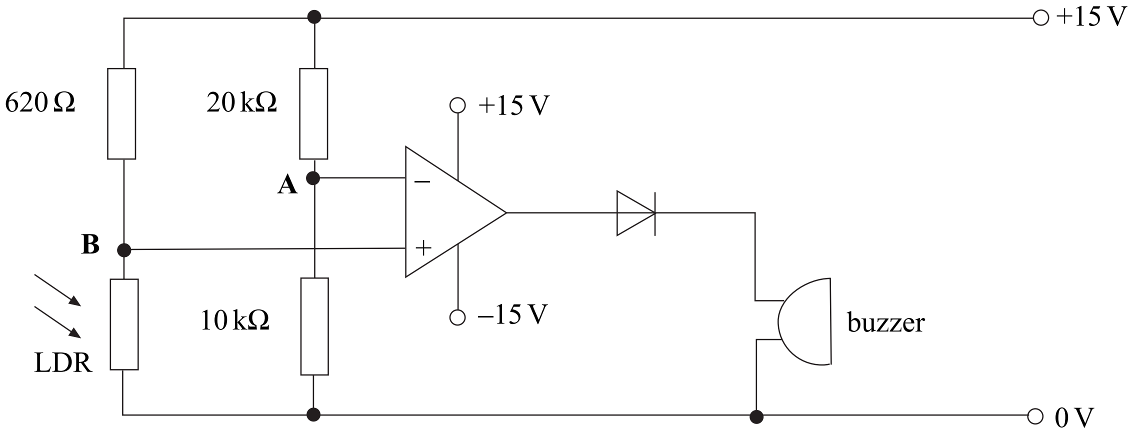


Figure 2

The variation of the resistance of the LDR with light intensity is given in **Figure 3**.

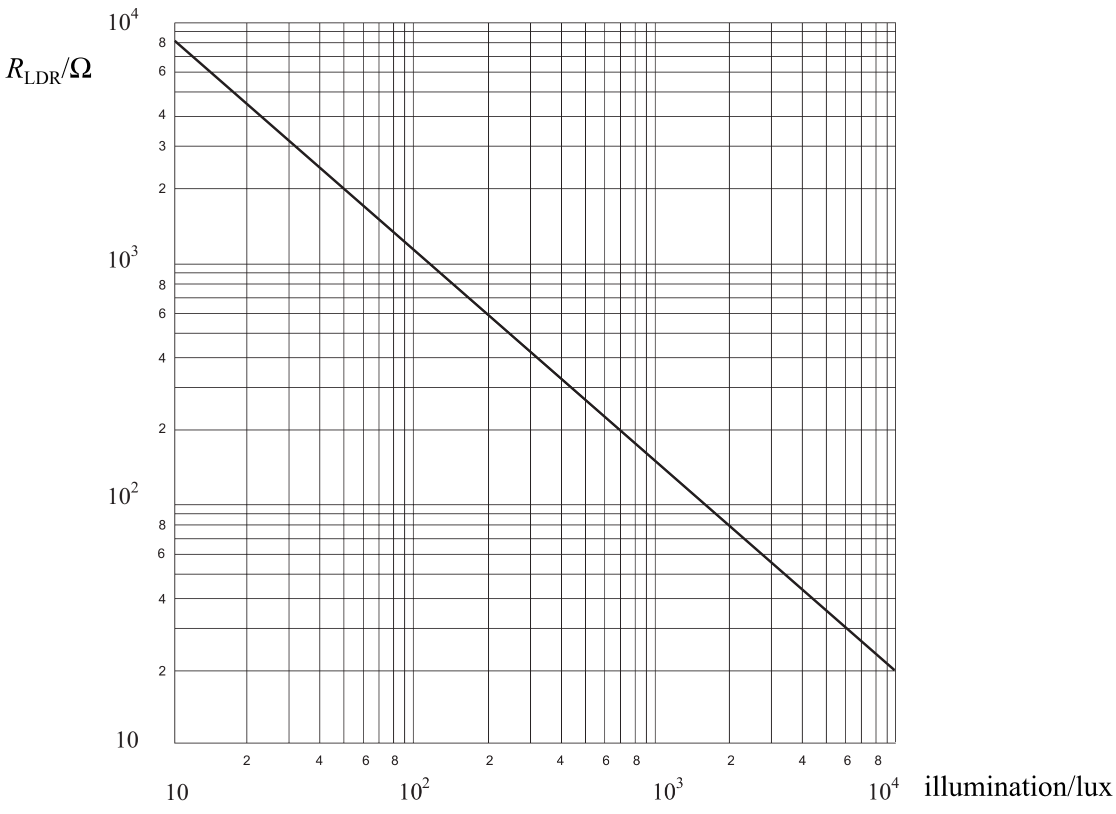


Figure 3

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(a) Calculate

(i) the voltage at point **A,**

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(ii) the voltage at point **B** when the light intensity is 700 lux,

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(iii) the voltage at point **B** when the light intensity is 200 lux.

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(4 marks)

(b) Explain how the output of the op-amp changes as the light level changes from 700 lux to 200 lux and the resulting effect on the state of the buzzer.

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

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(4 marks)

(c) Calculate the light intensity at which the buzzer first starts to sound.

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(2 marks)

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Turn over ▶

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4 **Figure 4** shows a frequency dependent voltage divider circuit.

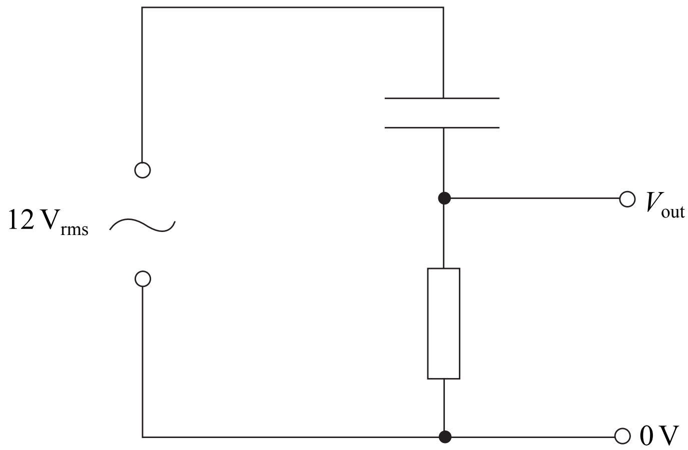

Figure 4

(a) (i) Explain how the voltage, V_{out}, changes as the frequency of the input voltage increases.

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(ii) Name the RC filter this represents.

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(4 marks)

(b) At a frequency of 520 Hz the capacitor has a reactance of 14 Ω. Calculate the capacitance of the capacitor.

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(2 marks)

(c) A second identical capacitor is added in parallel with the first capacitor. Calculate the reactance of the combination of capacitors at a frequency of 520 Hz.

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(2 marks)

8

QUALITY OF WRITTEN COMMUNICATION *(2 marks)*

2

END OF QUESTIONS