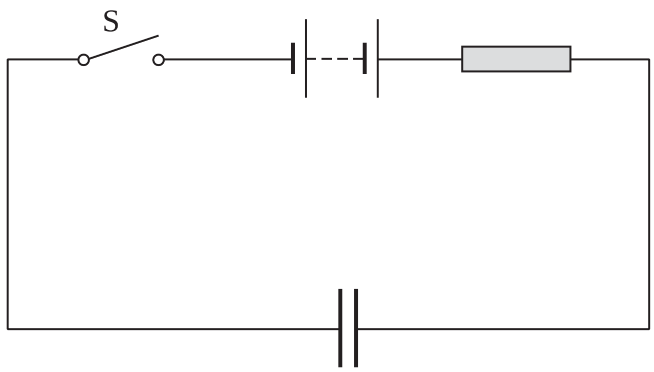
Edexcel Physics Unit 4

Topic Questions from Papers

Capacitors

13 An uncharged capacitor is connected into a circuit as shown.



(a) Describe what happens to the capacitor when the switch S is closed.

(2)

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(b) A student models the behaviour of the circuit using a spreadsheet. The student uses a 100 μF capacitor, a 3.00 kΩ resistor and 5.00 V power supply. The switch is closed at time t = 0 s.

	A	B	C	D	E
1	t / s	I / mA	ΔQ / μC	Q / μC	p.d. across capacitor / V
2	0	1.67	167	167	1.67
3	0.1	1.11	111	278	2.78
4	0.2	0.74	74	352	3.52
5	0.3	0.49	49	401	4.01
6	0.4	0.33	33	434	4.34
7	0.5	0.22	22	456	4.56
8	0.6	0.15	15	471	4.71
9	0.7	0.10	10	480	4.80
10	0.8	0.07	7	487	4.87

(i) Explain how the value in cell C4 is calculated.

(2)

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N 3 6 1 1 3 A 0 1 4 2 8

(ii) Explain how the value in cell E3 is calculated.

(2)

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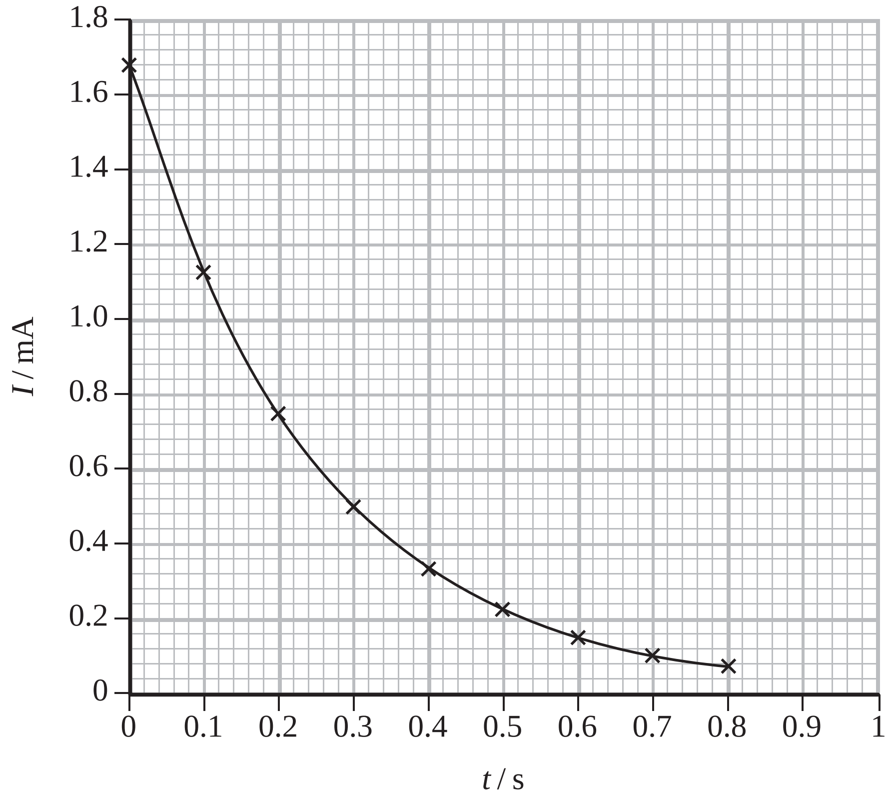
(c) The graph shows how the spreadsheet current varies with time.



(i) Use the graph to show that the time constant is approximately consistent with the component values.

(4)

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(ii) The student thinks that the graph is an exponential curve. How would you use another graph to confirm this?

(3)

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(Total for Question 13 = 13 marks)

16 Figure 1 shows the output from the terminals of a power supply labelled d.c. (direct current).

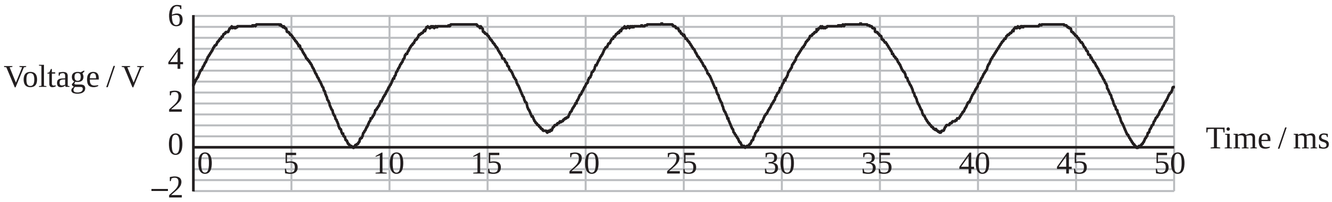

Figure 1

(a) An alternating current power supply provides a current that keeps switching direction.

Explain why the output shown in Figure 1 is consistent with the d.c. label.

(2)

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(b) A teacher suggests that certain electronic circuits require a constant voltage supply to operate correctly.

(i) A student places a capacitor across the terminals of this power supply. Suggest how this produces a constant voltage.

(2)

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(ii) She uses a 10 μF capacitor. Calculate the maximum energy stored in the capacitor.

(3)

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Maximum Energy = ...

(c) She now adds an electronic circuit to the power supply plus capacitor. Figure 2 shows the supply to the electronic circuit. This is shown in Figure 2.

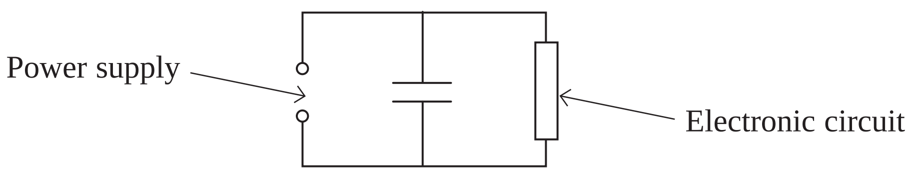

Figure 2

The variation in potential difference is shown by the graph in Figure 3.

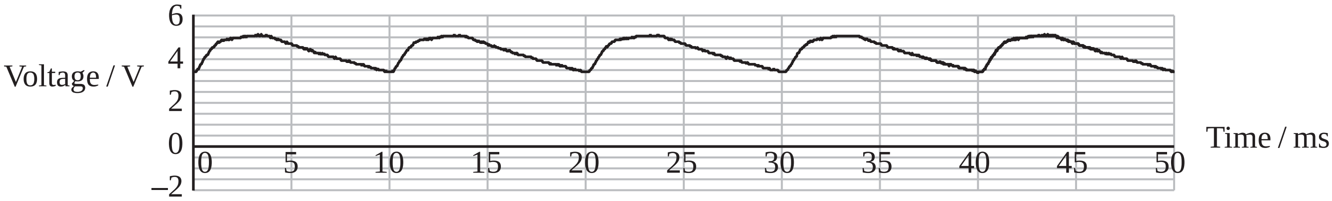

Figure 3

(i) Explain the shape of this graph.

(3)

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(ii) Take readings from the graph to show that the resistance of the electronic circuit is in the range 1000 Ω to 2000 Ω.

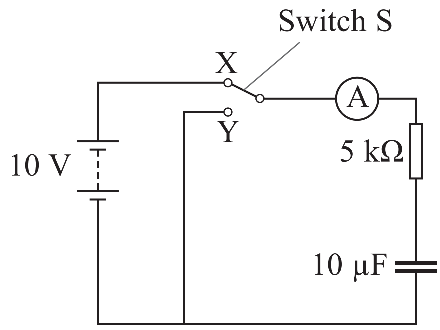
(3)

(iii) Figure 3 shows that the voltage supplied to the electronic circuit still varies. How could the student make it more constant?

(1)

(Total for Question 16 = 14 marks)

15 A student sets up the circuit shown in the diagram.



(a) (i) She moves switch S from X to Y. Explain what happens to the capacitor.

(2)

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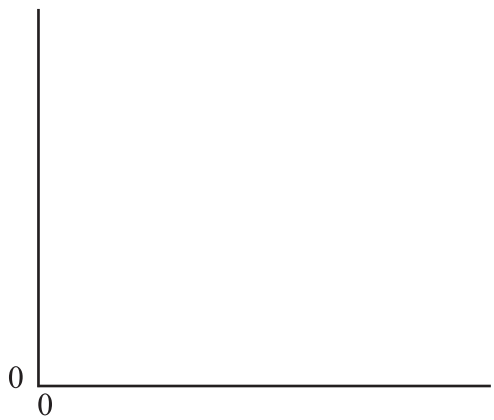
(ii) On the axis below, sketch a graph to show how the current in the ammeter varies with time from the moment the switch touches Y. Indicate typical values of current and time on the axes of your graph.

(3)



N 3 7 9 6 9 A 0 1 2 2 4

(iii) Describe how the graph would appear when the switch is moved back to X.

(2)

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(b) Calculate the maximum energy stored on the capacitor in this circuit.

(2)

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Maximum energy = ...

(c) The student wants to use this circuit to produce a short time delay, equal to the time it takes for the potential difference across the capacitor to fall to 0.07 of its maximum value.

Calculate this time delay.

(2)

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Time delay = ...

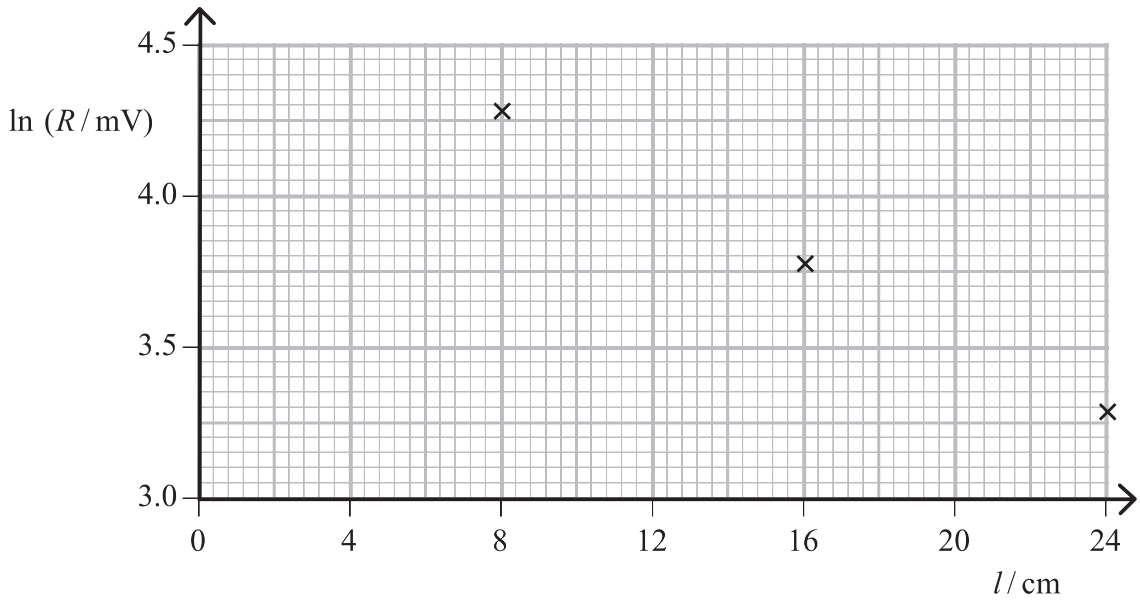
(Total for Question 15 = 11 marks)

12 A student carries out a practical involving a length of jelly. She places an infrared transmitter at one end and a receiver at the other. She obtains the following results.

Length of jelly *l* / cm	**Receiver reading *R* / mV**	**ln (*R* / mV)**
8.0	72	4.28
12.0	57	
16.0	43	3.76
20.0	33	
24.0	26	3.26

(a) Complete the table above and the graph below.

(2)



(b) The student reads that infrared light in jelly can be mathematically modelled using the equation $R = R_0 e^{-\mu l}$ where μ is a constant.

Use your graph to determine a value of μ for the jelly.

(2)

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μ = ...

(Total for Question 12 = 4 marks)

13 A student needs to order a capacitor for a project. He sees this picture on a web site accompanied by this information: capacitance tolerance ±20%.

Taking the tolerance into account, calculate

(a) the maximum charge a capacitor of this type can hold.

(3)

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Maximum charge = ...

(b) the maximum energy it can store.

(2)

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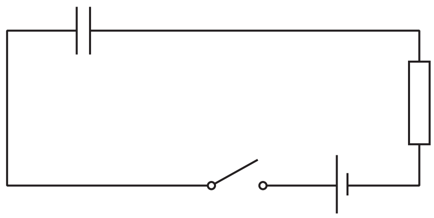
Maximum energy = ...

(Total for Question 13 = 5 marks)

16 The diagram shows a circuit that includes a capacitor.



(a) (i) Explain what happens to the capacitor when the switch is closed.

(2)

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(ii) The potential difference (p.d.) across the resistor rises to a maximum as the switch is closed.

Explain why this p.d. subsequently decreases to zero.

(2)

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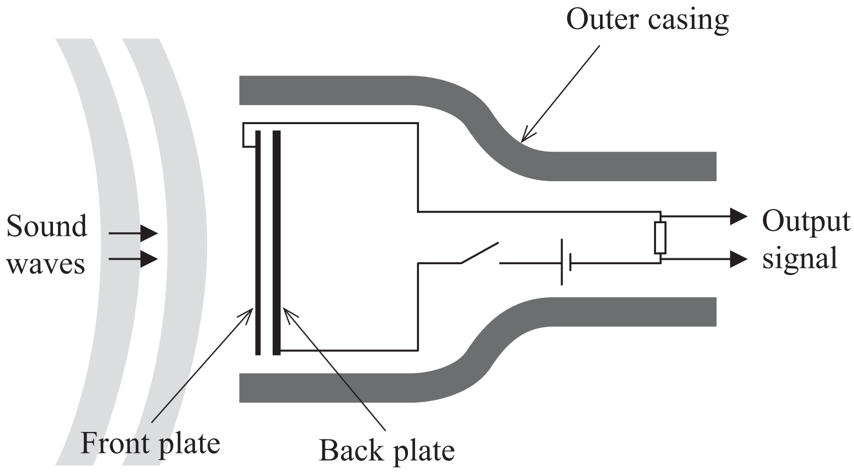
*(b) One type of microphone uses a capacitor. The capacitor consists of a flexible front plate (diaphragm) and a fixed back plate. The output signal is the potential difference across the resistor.



The sound waves cause the flexible front plate to vibrate and change the capacitance. Moving the plates closer together increases the capacitance. Moving the plates further apart decreases the capacitance.

Explain how the sound wave produces an alternating output signal.

(4)

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(c) A microphone has a capacitor of capacitance 500 pF and resistor of resistance 10 MΩ.

Explain why these values are suitable even for sounds of the lowest audible frequency of about 20 Hz.

(4)

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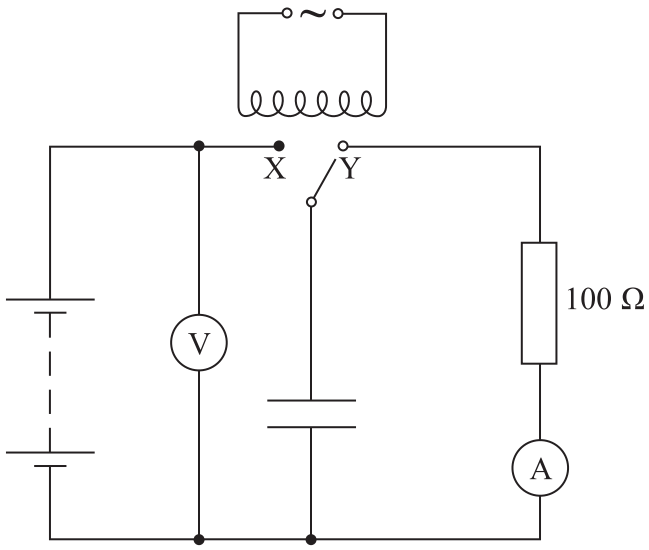
(Total for Question 16 = 12 marks)

16 A student is investigating capacitors. She uses the circuit below to check the capacitance of a capacitor labelled 2.2 μF which has a tolerance of ±30%.



The switch flicks between contacts, X and Y, so that the capacitor charges and discharges *f* times per second.

(a) The capacitor must discharge fully through the 100 Ω resistor.

(i) Explain why 400 Hz is a suitable value for *f*.

(3)

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(ii) Show that the capacitance C can be given by

$$C = \frac{I}{fV}$$

where I is the reading on the ammeter and V is the reading on the voltmeter.

(3)

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(iii) The student records I as 5.4 mA and V as 5.0 V.

Calculate the capacitance C.

(2)

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C = ...

(iv) Explain whether you think this value is consistent with the tolerance given for this capacitor.

(2)

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(b) Calculate the energy stored on the capacitor when it is charged to a potential difference of 5.0 V.

(2)

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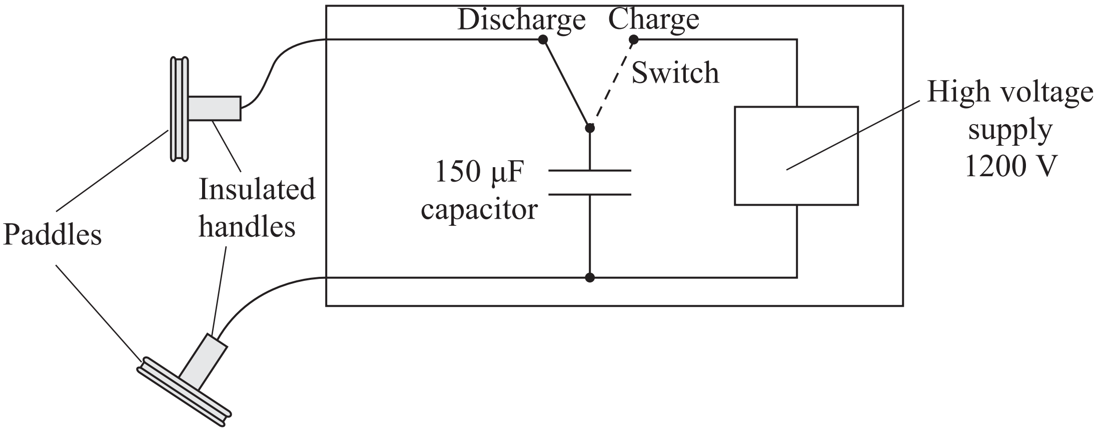
Energy = ...

(Total for Question 16 = 12 marks)

15 A defibrillator is a machine that is used to correct an irregular heartbeat or to start the heart of someone who is in cardiac arrest.

The defibrillator passes a large current through the heart for a short time.

The machine includes a high voltage supply which is used to charge a capacitor. Two defibrillation 'paddles' are placed on the chest of the patient and the capacitor is discharged through the patient.



(a) The 150 μF capacitor is first connected across the 1200 V supply.

Calculate the charge on the capacitor.

(2)

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Charge = ...

P 4 1 6 2 9 A 0 1 2 2 4

(b) Calculate the energy stored in the capacitor.

(2)

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Energy stored = ...

(c) When the capacitor discharges there is an initial current of 14 A in the chest of the patient.

(i) Show that the electrical resistance of the body tissue between the paddles is about 90 Ω.

(1)

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(ii) Calculate the time it will take for three quarters of the charge on the capacitor to discharge through the patient.

(3)

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Time = ...

(iii) Body resistance varies from person to person. If the body resistance was lower, the initial current would be greater.

State how this lower body resistance affects the charge passed through the body from the defibrillator.

(1)

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(Total for Question 15 = 9 marks)

14 A student is investigating how the potential difference across a capacitor varies with time as the capacitor is charging.

He uses a 100 μF capacitor, a 5.0 V d.c. supply, a resistor, a voltmeter and a switch.

(a) (i) Draw a diagram of the circuit he should use.

(2)

(ii) Suggest why a voltage sensor connected to a data logger might be a suitable instrument for measuring the potential difference across the capacitor in this investigation.

(1)

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Turn over for Question 14(b)

(b) Calculate the maximum charge stored on the capacitor.

(2)

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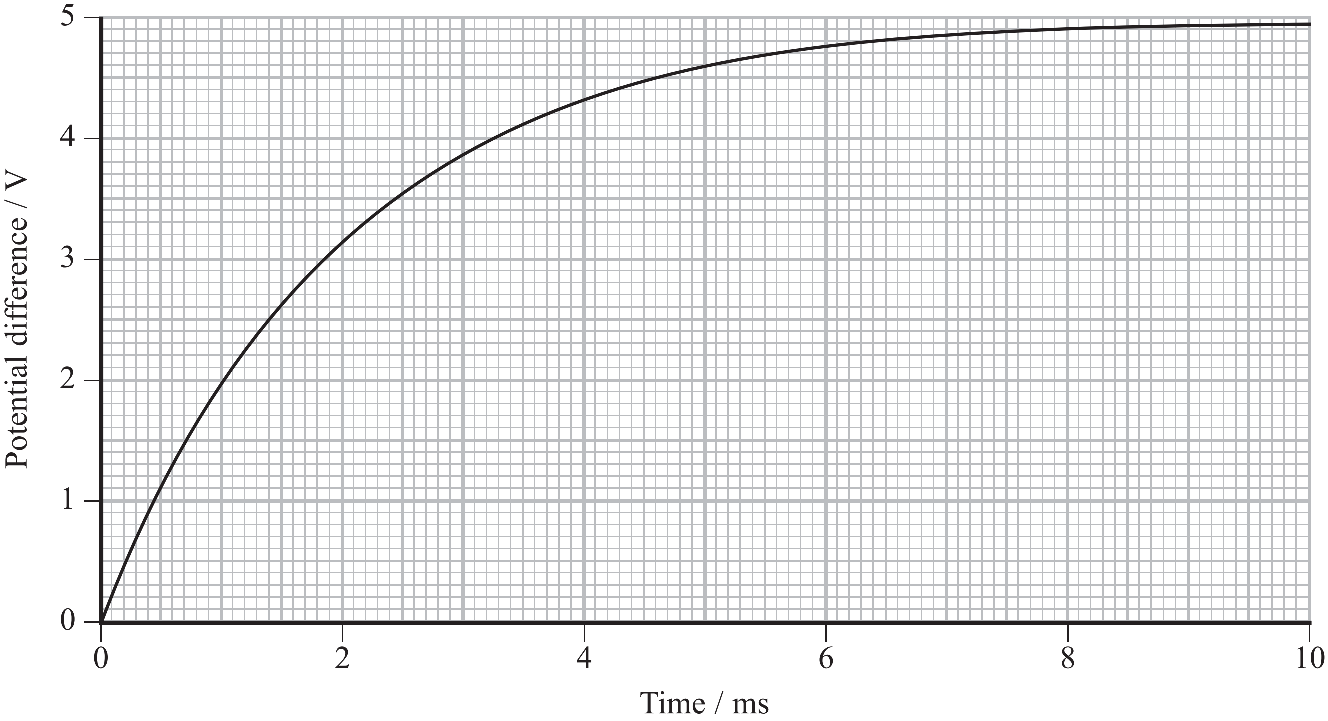
Charge = ...

(c) The graph shows how the potential difference across the capacitor varies with time as the capacitor is charging.



(i) Estimate the average charging current over the first 10 ms.

(2)

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Average charging current = ...

(ii) Use the graph to estimate the initial rate of increase of potential difference across the capacitor and hence find the initial charging current.

(3)

Initial charging current = ...

(iii) Use the value of the initial charging current to find the resistance of the resistor.

(2)

Resistance = ...

(Total for Question 14 = 12 marks)

15 A particular experiment requires a very large current to be provided for a short time.

(a) An average current of 2.0×10^3 A is to be supplied to a coil of wire for a time of 1.4×10^{-3} s. The resistance of the coil is 0.50 Ω.

(i) Show that the charge that flows through the coil during this time is about 3 C.

(2)

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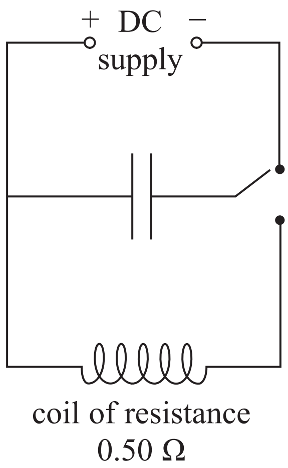
(ii) The circuit shows how a capacitor could be charged and then discharged through the coil to provide the current.



The circuit contains a capacitor of capacitance 600 μF. This capacitor is suitable to provide the current for 1.4×10^{-3} s.

Explain why the capacitor is suitable.

(3)

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(b) It can be assumed that the 600 μF capacitor completely discharges in 1.4×10^{-3} s.

(i) Calculate the potential difference of the power supply.

(2)

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Potential difference = ...

(ii) Calculate the average power delivered to the coil in this time.

(3)

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Average power = ...

(Total for Question 15 = 10 marks)

List of data, formulae and relationships

Acceleration of free fall	$g = 9.81\ \text{m s}^{-2}$	(close to Earth's surface)
Boltzmann constant	$k = 1.38 \times 10^{-23}\ \text{J K}^{-1}$	
Coulomb's law constant	$k = 1/4\pi\varepsilon_0$ $= 8.99 \times 10^{9}\ \text{N m}^{2}\ \text{C}^{-2}$	
Electron charge	$e = -1.60 \times 10^{-19}\ \text{C}$	
Electron mass	$m_e = 9.11 \times 10^{-31}\ \text{kg}$	
Electronvolt	$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$	
Gravitational constant	$G = 6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$	
Gravitational field strength	$g = 9.81\ \text{N kg}^{-1}$	(close to Earth's surface)
Permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{F m}^{-1}$	
Planck constant	$h = 6.63 \times 10^{-34}\ \text{J s}$	
Proton mass	$m_p = 1.67 \times 10^{-27}\ \text{kg}$	
Speed of light in a vacuum	$c = 3.00 \times 10^{8}\ \text{m s}^{-1}$	
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$	
Unified atomic mass unit	$u = 1.66 \times 10^{-27}\ \text{kg}$	

Unit 1

Mechanics

Kinematic equations of motion
$v = u + at$
$s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$

Forces
$\Sigma F = ma$
$g = F/m$
$W = mg$

Work and energy
$\Delta W = F\Delta s$
$E_k = \frac{1}{2}mv^2$
$\Delta E_{grav} = mg\Delta h$

Materials

Stokes' law
$F = 6\pi\eta rv$

Hooke's law
$F = k\Delta x$

Density
$\rho = m/V$

Pressure
$p = F/A$

Young modulus
$E = \sigma/\varepsilon$ where
Stress $\sigma = F/A$
Strain $\varepsilon = \Delta x/x$

Elastic strain energy
$E_{el} = \frac{1}{2}F\Delta x$

Unit 2

Waves

Wave speed	$v = f\lambda$
Refractive index	${}_1\mu_2 = \sin i/\sin r = v_1/v_2$

Electricity

Potential difference	$V = W/Q$
Resistance	$R = V/I$
Electrical power, energy and efficiency	$P = VI$ $P = I^2R$ $P = V^2/R$ $W = VIt$
	$\% \text{ efficiency} = \dfrac{\text{useful energy output}}{\text{total energy input}} \times 100$
	$\% \text{ efficiency} = \dfrac{\text{useful power output}}{\text{total power input}} \times 100$
Resistivity	$R = \rho l/A$
Current	$I = \Delta Q/\Delta t$ $I = nqvA$
Resistors in series	$R = R_1 + R_2 + R_3$
Resistors in parallel	$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dfrac{1}{R_3}$

Quantum physics

Photon model	$E = hf$
Einstein's photoelectric equation	$hf = \phi + \frac{1}{2}mv^2_{max}$

Unit 4

Mechanics

Momentum	$p = mv$
Kinetic energy of a non-relativistic particle	$E_k = p^2/2m$
Motion in a circle	$v = \omega r$ $T = 2\pi/\omega$ $F = ma = mv^2/r$ $a = v^2/r$ $a = r\omega^2$

Fields

Coulomb's law	$F = kQ_1Q_2/r^2$ where $k = 1/4\pi\varepsilon_0$
Electric field	$E = F/Q$ $E = kQ/r^2$ $E = V/d$
Capacitance	$C = Q/V$
Energy stored in capacitor	$W = \frac{1}{2}QV$
Capacitor discharge	$Q = Q_0 e^{-t/RC}$
In a magnetic field	$F = BIl \sin\theta$ $F = Bqv \sin\theta$ $r = p/BQ$
Faraday's and Lenz's Laws	$\varepsilon = -d(N\phi)/dt$

Particle physics

Mass-energy	$\Delta E = c^2 \Delta m$
de Broglie wavelength	$\lambda = h/p$

P 4 3 3 2 3 A 0 2 3 2 4