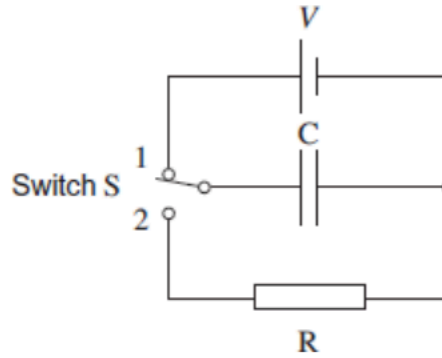


- 1** Switch S in the circuit is held in position 1, so that the capacitor C becomes fully charged to a pd V and stores energy E .



The switch is then moved quickly to position 2, allowing C to discharge through the fixed resistor R . It takes 36 ms for the pd across C to fall to $\frac{V}{2}$. What period of time must elapse, after the switch has moved to position 2, before the energy stored by C has fallen to $\frac{E}{16}$?

- A** 51 ms
- B** 72 ms
- C** 432 ms
- D** 576 ms

(Total 1 mark)

- 2** A $680 \mu\text{F}$ capacitor is charged fully from a 12 V battery. At time $t = 0$ the capacitor begins to discharge through a resistor. When $t = 25 \text{ s}$ the energy remaining in the capacitor is one quarter of the energy it stored at 12 V.

- (a) Determine the pd across the capacitor when $t = 25 \text{ s}$.

(2)

- (b) (i) Show that the time constant of the discharge circuit is 36 s.

- (ii) Calculate the resistance of the resistor.

(4)

(Total 6 marks)

3

A capacitor of capacitance $330\ \mu\text{F}$ is charged to a potential difference of $9.0\ \text{V}$. It is then discharged through a resistor of resistance $470\ \text{k}\Omega$.

Calculate

- (a) the energy stored by the capacitor when it is fully charged,

(2)

- (b) the time constant of the discharging circuit,

(1)

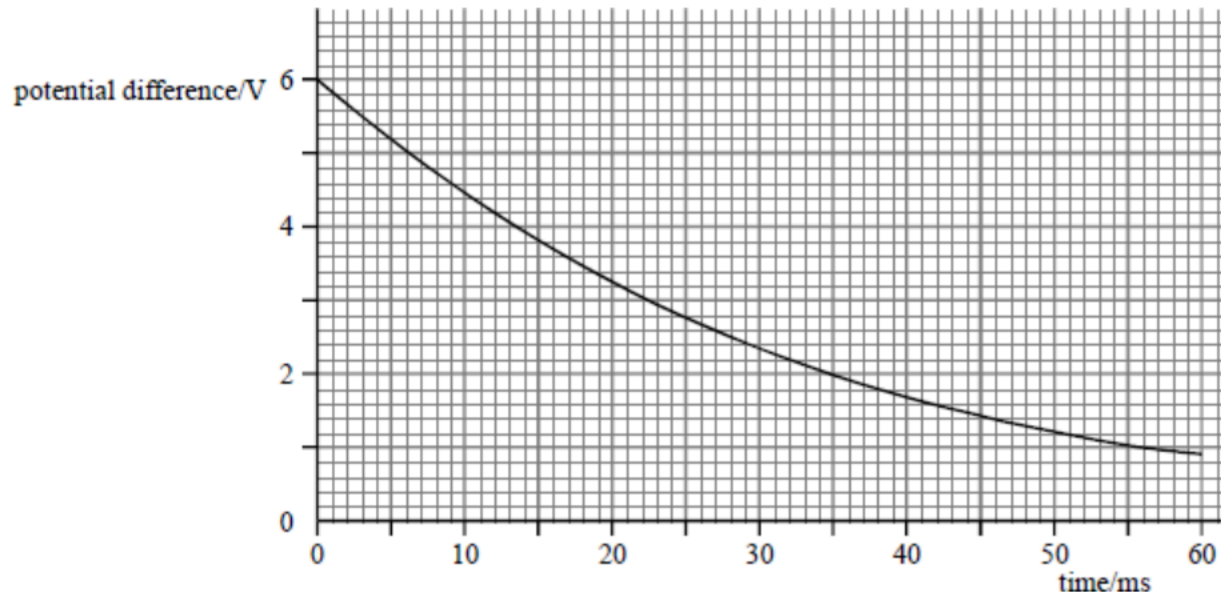
- (c) the p.d. across the capacitor $60\ \text{s}$ after the discharge has begun.

(3)

(Total 6 marks)

4

A student used a voltage sensor connected to a datalogger to plot the discharge curve for a $4.7\ \mu\text{F}$ capacitor. She obtained the following graph.



Use data from the graph to calculate

- (a) the initial charge stored,

(2)

- (b) the energy stored when the capacitor had been discharging for 35 ms,

(3)

- (c) the time constant for the circuit,

(3)

- (d) the resistance of the circuit through which the capacitor was discharging.

(2)

(Total 10 marks)

5

- (a) Explain what is meant by a capacitance of 1 farad (F).

(1)

- (b) A parallel plate capacitor was made from two circular metal plates with air between them. The distance between the plates was 1.8 mm. The capacitance of this capacitor was found to be 2.3×10^{-11} F.

The permittivity of free space $\epsilon_0 = 8.9 \times 10^{-12} \text{ F m}^{-1}$

The relative permittivity of air = 1.0

Calculate:

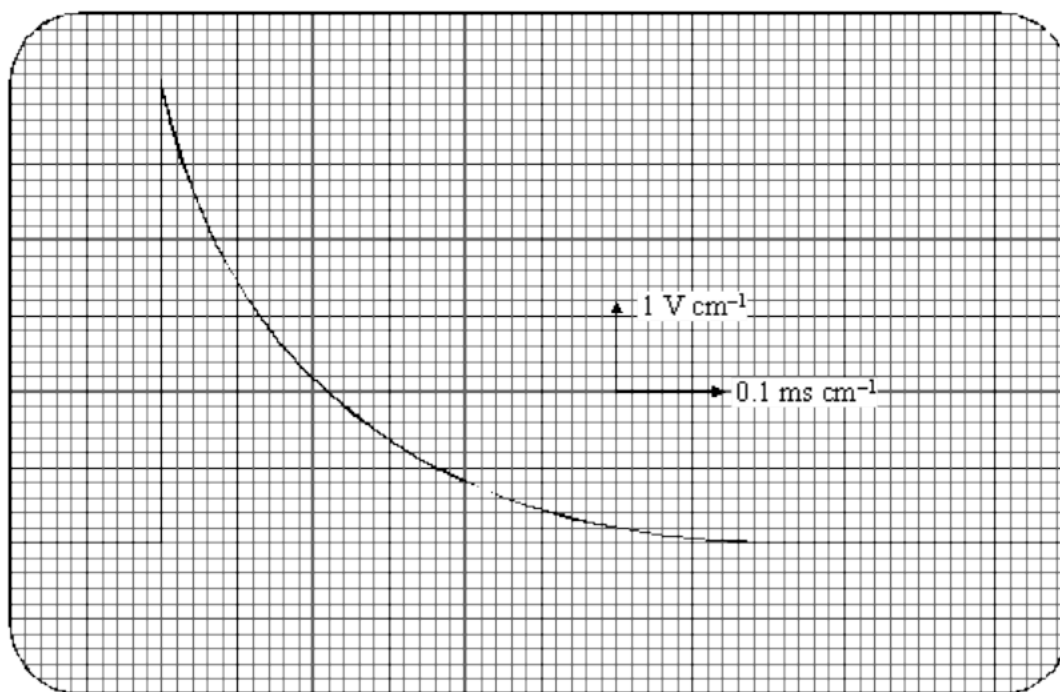
- (i) the radius of the plates used in the capacitor;

(3)

- (ii) the energy stored when the potential difference between the capacitor plates is 6.0 V.

(2)

- (c) A student charged the capacitor and then tried to measure the potential difference between the plates using an oscilloscope. The student observed the trace shown in the diagram below and concluded that the capacitor was discharging through the oscilloscope.



Calculate the resistance of the oscilloscope.

(3)

(Total 9 marks)

6

- (a) (i) A label on a capacitor shows it to have a capacitance of 0.020 F. Explain what this tells you about the capacitor.

(1)

- (ii) Sketch on **Figure 1** the graph that shows how the charge on the 0.020 F capacitor varies with the potential difference across it over the voltage range given. Insert an appropriate scale on the charge axis.

(2)

- (iii) Explain how your graph could be used to obtain the energy stored for a given potential difference.

(2)

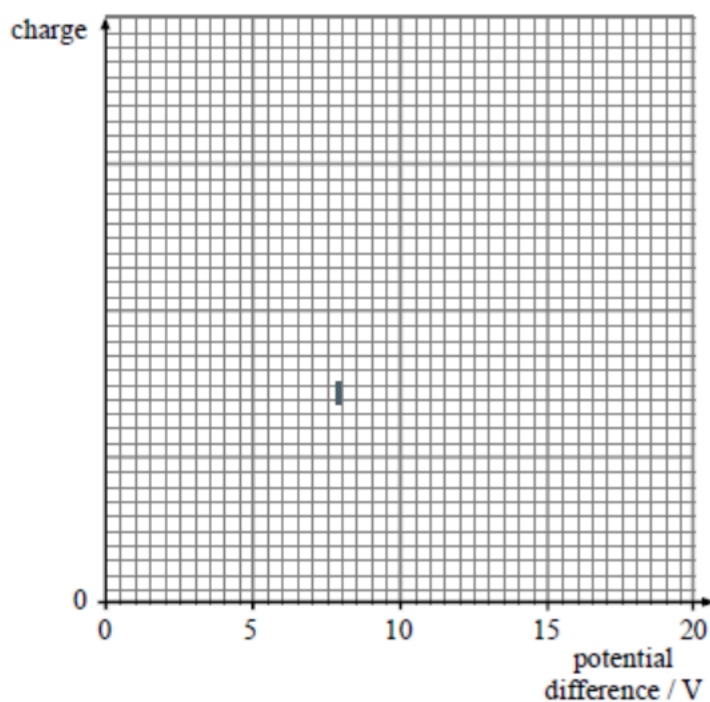


Figure 1

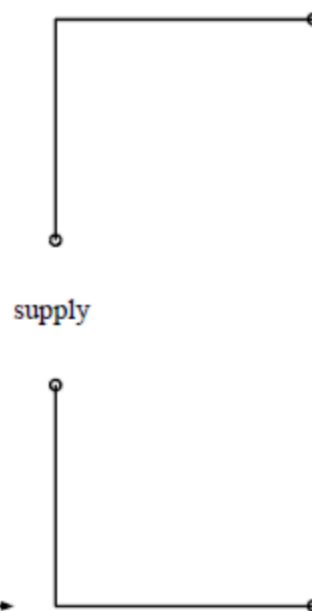


Figure 2

- (iv) Show on **Figure 2** how **two** similar capacitors could be connected to a supply to store more energy for the same potential difference.

(1)

- (b) **Figure 3** shows one 0.020 F capacitor connected to a 20 V supply. By means of the changeover switch **S**, the capacitor is disconnected from the supply and connected to a small motor. The motor lifts an object of mass 0.15 kg through a height of 0.80 m , after which the energy left in the capacitor is negligible.

acceleration of free fall, $g = 9.8\text{ m s}^{-2}$

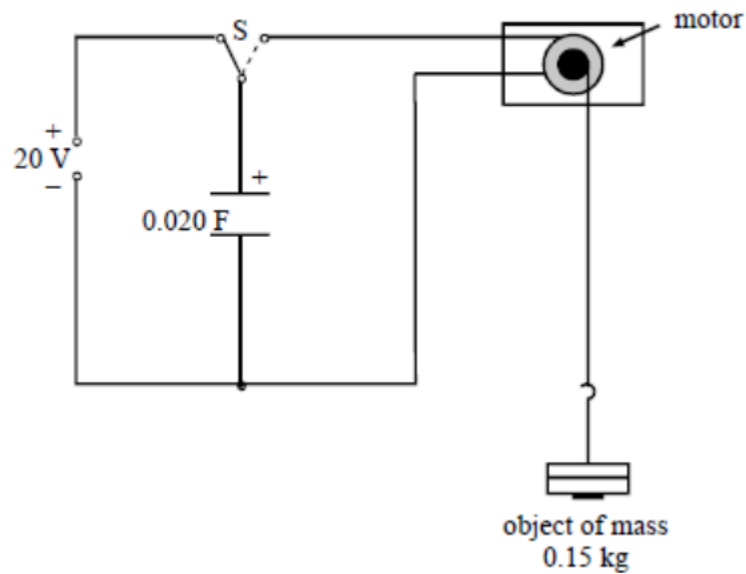


Figure 3

Calculate:

- (i) the initial energy stored by the capacitor;

(2)

- (ii) the efficiency of the energy conversion.

(3)

(Total 11 marks)

Mark schemes

1	B	[1]
2	(a) $E \propto V^2$ (or $E = \frac{1}{2}CV^2$) (1) pd after 25 s = 6 V (1)	
	2	
	(b) (i) use of $Q = Q_0 e^{-t/RC}$ or $V = V_0 e^{-t/RC}$ (1) (e.g. $6 = 12e^{-25/RC}$) gives $e^{\frac{25}{RC}} = \frac{12}{6}$ and $\frac{25}{RC} = \ln 2$ (1) ($RC = 36(.1)$ s) [alternatives for (i): $V = 12 e^{-25/36}$ gives $V = 6.0$ V (1) (5.99 V) or time for pd to halve is $0.69RC$ $\therefore RC = \frac{25}{0.69}$ (1) = 36(.2) s] (ii) $R = \frac{36.1}{680 \times 10^{-6}}$ (1) = $5.3(0) \times 10^4 \Omega$ (1)	[6]
3	(a) $Q (= CV = 330 \times 9.0) = 2970$ (μC) (1) $E (= \frac{1}{2}QV) = \frac{1}{2} \times 2.97 \times 10^{-3} \times 9.0 = 1.34 \times 10^{-2}\text{J}$ (1) [or $E (= \frac{1}{2}CV^2) = \frac{1}{2} \times 300 \times 10^{-6} \times 9.0^2$ (1) = $1.34 \times 10^{-2}\text{J}$ (1)] (b) time constant ($= RC$) = $470 \times 10^3 \times 330 \times 10^{-6} = 155$ s (1) (c) $Q (= Q_0 e^{-t/RC}) = 2970 \times e^{-60/155}$ = 2020 (μC) (allow C.E. for time constant from (b)) $V = \left(\frac{Q}{C}\right) = \frac{2020}{330} = 6.11$ V (1) (allow C.E. for Q) [or $V = V_0 e^{-t/RC}$ (1) = $9.0 e^{-60/155}$ (1) = 6.11 V (1)]	
	2	
	1	
	3	

4

(a) $Q = CV$ (1)
 $(= 4.7 \times 10^{-6} \times 6.0) = 28 \times 10^{-6} \text{ C or } 28 \mu\text{C}$ (1)

2

(b) $E = \frac{1}{2}CV^2$ (1)
 $= \frac{1}{2} \times 4.7 \times 10^{-6} \times 2.0^2$ (1)
 $= 9.4 \times 10^{-6} \text{ J}$ (1)
 [or $E = \frac{1}{2}QV$ (1)
 $= \frac{1}{2} \times 28 \times 10^{-6} \times 2.0$ (1)
 $= 9.4 \times 10^{-6} \text{ J}$ (1)]

3

(c) time constant is time taken for V to fall to $\frac{V_0}{e}$ (1)
 $\therefore V$ must fall to 2.2 V (1)
 time constant = 32 ms (1)
 [or draw tangent at $t = 0$ (1)
 intercept of tangent on t axis is time constant (1)
 accept value 30 - 35 ms (1)]
 [or $V = V_0 \exp(-t / RC)$ or $Q = Q_0 \exp(-t / RC)$ (1)
 correct substitution (1)
 time constant = 32 ms (1)]

3

(d) time constant = RC (1)

$$R = \frac{32 \times 10^{-3}}{4.7 \times 10^{-3}} = 6800 \Omega$$
 (1)

(allow C.E. for value of time constant from (c))

2

[10]**5**

- (a) 1 coulomb of charge is stored for a p.d. of 1 V between the plates
 (or equivalent statement) Condense 1 coulomb per volt

B1

1

- (b) (i) Correct substitution in $C = \frac{\epsilon_0 \epsilon_r A}{d}$ (ignore powers of 10)

C1

Plate area = $4.65 \times 10^{-3} \text{ m}^2$ or $C = \frac{\epsilon_0 \epsilon_r \pi r^2}{d}$ with correct data

A1

Radius = (their area / 3.14)^{1/2}; 0.038(4 or 5) m if correct

B1

3

- (ii) $E = \frac{1}{2} CV^2$ or correct numerical substitution or
 $E = \frac{1}{2} QV$ & $Q = VC$

C1

$4.1(4) \times 10^{-10} \text{ J}$

A1

2

- (c) Time constant = RC or Time to halve = $0.69 RC$
or $V = V_0 e^{-t/RC}$

C1

Time to fall to 1/e (0. 19 ms) or time to halve (0. 13 ms)
or $V_0 = 6 \text{ V}$ and correct coordinates of point on line
(0.6 ms max)

C1

8.1 - 8.6 M Ω

A1

3

[9]

6

- (a) (i) 0.02 C of charge produce a p.d. of 1 V between the two terminals
or 0.02 C of charge per unit p.d.

B1

(2)

(ii) straight line through the origin

M1

correct gradient (possible check point 0.2 C at 10 V)

and graph line up to 20 V

A1

(2)

(iii) area between graph line and charge axis

(allow area under graph)

not area of the graph

not area under graph / 2

M1

from 0 to the required voltage or up to the required voltage

A1

or energy = $\frac{1}{2}QV$ or $\frac{1}{2}CV^2$

M1

read corresponding Q from the graph

A1

(only allow second mark if graph is straight line through the origin)

or C determined from gradient of graph and V given

(2)

(iv) sketch showing two capacitors in parallel connected to a supply

B1

(1)

(b) (i) energy stored = $0.5 CV^2$

C1

4.0 J (condone 1 sf answer)

A1

(2)

(ii) (useful) energy output = mgh

or

efficiency = useful energy out / energy input (in same time)

or

efficiency = useful power out / power input

C1

energy output = $0.15 \times 9.8 \times 0.8 = 1.18 \text{ J}$

C1

efficiency = 0.294 or 29.4% e.c.f. from (b)(i)

A1

(allow 29% – 30%)

(3)

[11]