

## Questions on Capacitors MS

1. Exponential shape (1)  
 Value at  $RC > 1.5 V$  [only if shape correct] (1)  
 Levels off at 3 V (1) 3  
 Why movement of diaphragm causes p.d:  
 No movement, no change in C, no signal (1)  
 OR moving diaphragm changes C  
 As C changes so V changes (1)  
 $V_C + IR$  is constant (1)  
 Hence IR changes – signal (1) 4  
 OR for last 3 marks  
 As C changes Q changes  
 Q flows through R  
 hence  $V = IR$  for resistor as signal 7
2. Calculation of charge  
 $Q = CV$  ) Equation or substitution (1)  
 $= 0.22 \times 95 \times 10^{-3} C$  )  
 $= 0.021 C$  (1) 2
- What voltmeter reading tells about voltmeter  
 Very high resistance (1) 1
- Table  
 3.83, 3.50, 3.09 (1) 1
- Graph  
 Points 1, 2 correctly plotted (1)  
 Points 3, 4, 5 correctly plotted (1)  
 Joined with straight line (1) 3
- Explanation  
 Straight line ( $\rightarrow$  exponential) (1)  
 Negative gradient ( $\rightarrow$  decreases) (1) 2
- Value for resistance of second voltmeter  
 $95 \text{ mV} \div e = 35 \text{ mV}$  )  
 OR  $95 \text{ mV} \div 3 = 32 \text{ mV}$  ) (1)
- Time to fall to 32/35 mV  
 $\approx 55 - 60 \text{ s}$  (1)  
 This time =  $RC$  (1)  
 [OR Gradient of graph method  $\rightarrow RC$  2 marks]  
 $\therefore R = 240 - 280 \Omega$  (1) Max 3

[OR  $V = V_0 e^{-t/RC}$  method:

Correct substitution (any consistent values) 1 mark  
Taking ln (maths) 1 mark  
Answer 1 mark]

[12]

3. Explanation of what has happened in circuit

Charging process (1)

Plates oppositely charged OR charge moves from one plate to another (1)

Charge flows anticlockwise OR electrons flow clockwise OR left plate becomes positive OR right plate becomes negative (1)

Build up of  $Q/V$  reduces flow rate (1)

Max 3

Explanation of what would have been seen

Same as ammeter 1 (1)

Reason: Same  $I$  everywhere OR series circuit OR same  $I/Q$  in each component (1)

2

Estimate of charge

Attempt to find area under correct region of graph (1)

= 52  $\mu\text{C}$  (1)

2

[Allow 45 – 65  $\mu\text{C}$ ]

Estimate of capacitance

p.d. across resistor at  $t = 10 \text{ s} = 100 \times 10^3 \Omega \times 3 \times 10^{-6} \text{ A} = 0.3 \text{ V}$  (1)

(hence p.d. across capacitor =  $1.5 \text{ V} - 0.3 \text{ V} = 1.2 \text{ V}$ )

$$C = \frac{Q}{V} = \frac{5 \times 10^{-5} \text{ C}}{1.2 \text{ V}} \text{ (equation or sub) [ecf] (1)}$$

$C = 42 \mu\text{F}$  [If 1.5 V is used to obtain  $C = 33 \mu\text{F}$ , then 2/3] (1)

3

Alternative method using  $e^{-t/RC}$

Correct answer appropriate to set of values (1)

Correct ln line (1)

Correct answer (40–44 $\mu\text{F}$ ) (1)

Alternative method using  $T = RC$

Using  $T = RC$  (1)

Appropriate  $T$  value (1)

$\Rightarrow$  correct answer (1)

Observations

Same picture as before (1)

since same  $\Delta V$  (1)

2

[OR  $C$  now carries twice the previous charge]

[12]

4. What happens in circuit after switch closed then opened again

Any seven from:

S closed → C charges (1)

up to  $V_s$  (1)

Instantly/very quickly (1)

S open: discharge starts (1)

Exponential discharge (1)

$$(V_c = V_s e^{-t/RC})$$

$$\frac{3}{4} V_s = V_s e^{-t/RC} \text{ (1)}$$

$$\Rightarrow \ln \frac{3}{4} = -t/RC \text{ (1)}$$

$$\Rightarrow t = 29.7 \text{ s OR } RC = 103 \text{ s [if no other calculation] (1)}$$

Buzzer sounds for 29.7 s [ecf] (1)

Max 7

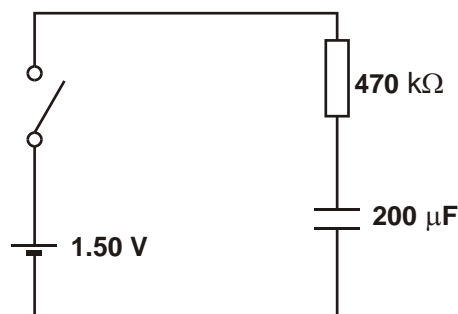
[Marks 1-5 and mark 9 are available via appropriate graph. For mark 5 graph must have axes labelled with a  $V/Q/I$  and same  $t$ , and a recognisable exponential curve.]

5. Define capacitance

**Capacitance = Charge / Potential difference.**

(2 marks)

An uncharged capacitor of  $200 \mu\text{F}$  is connected in series with a  $470 \text{ k}\Omega$  resistor, a  $1.50 \text{ V}$  cell and a switch. Draw a circuit diagram of this arrangement.



(1 mark)

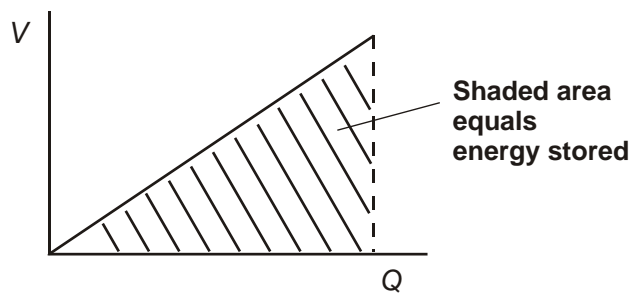
Calculate the maximum current that flows.

$$\text{Current} = 1.5 \text{ V} / 470 \text{ k}\Omega$$

$$\text{Current} = 3.2 \mu\text{A}$$

(2 marks)

Sketch a graph of voltage against charge for your capacitor as it charges. Indicate on the graph the energy stored when the capacitor is fully charged.



(4 marks)

Calculate the energy stored in the fully-charged capacitor.

$$\frac{1}{2}CV^2 = \frac{1}{2} (200 \mu\text{F}) (1.5 \text{ V})^2$$

$$\text{Energy} = 2.25 \mu\text{J}$$

(2 marks)

[Total 11 marks]

6. Slope of graph:

Capacitance

Shaded area of graph:

Energy/work done

2

Energy stored 3.1 J:

$$CV^2/2$$

$$= 100 \times 10^{-6} \times 250^2/2 \text{ [formula + correct substitution]}$$

$$(= 3.125) = 3.1 \text{ J [Must have previous mark]}$$

2

Power from cell, and minimum time for cell to recharge capacitor:

$$\text{Cell power} = 1.5 \text{ V} \times 0.20 \text{ A}$$

$$= 0.30 \text{ W [allow } 3/10 \text{ W here]}$$

$$\text{Time} = 3.1 \text{ J}/0.30 \text{ W(e.c.f.)}$$

$$= 10 \text{ s}$$

3

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7. Calculation of charge

$$6000 \text{ V} \times 20 \times 10^{-6} \text{ F} \quad (1)$$

$$= 0.12 \text{ C} \quad (1)$$

2

Energy stored in capacitor

$$\left( \frac{CV^2}{2} \right) \frac{20 \times 10^{-6} \text{ C} \times (6000 \text{ V})^2}{2} \quad (1)$$

$$= 360 \text{ J} \quad (1)$$

2

Resistance

$$\frac{6000 \text{ V}}{40 \text{ A}} = 150 \Omega \quad (1)$$

1

Time to discharge capacitor

$$\text{Time} = \frac{0.12 \text{ C}}{40 \text{ A}} \text{ /their } Q \quad (1)$$

$= 0.0030 \text{ s} / 3.0 \times 10^{-3} \text{ s}$  [e.c.f.] (1)

2

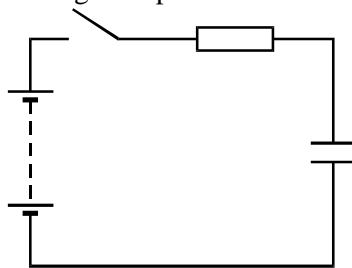
Reason

Time is longer because the rate of discharge decreases/ current decreases with time (1)

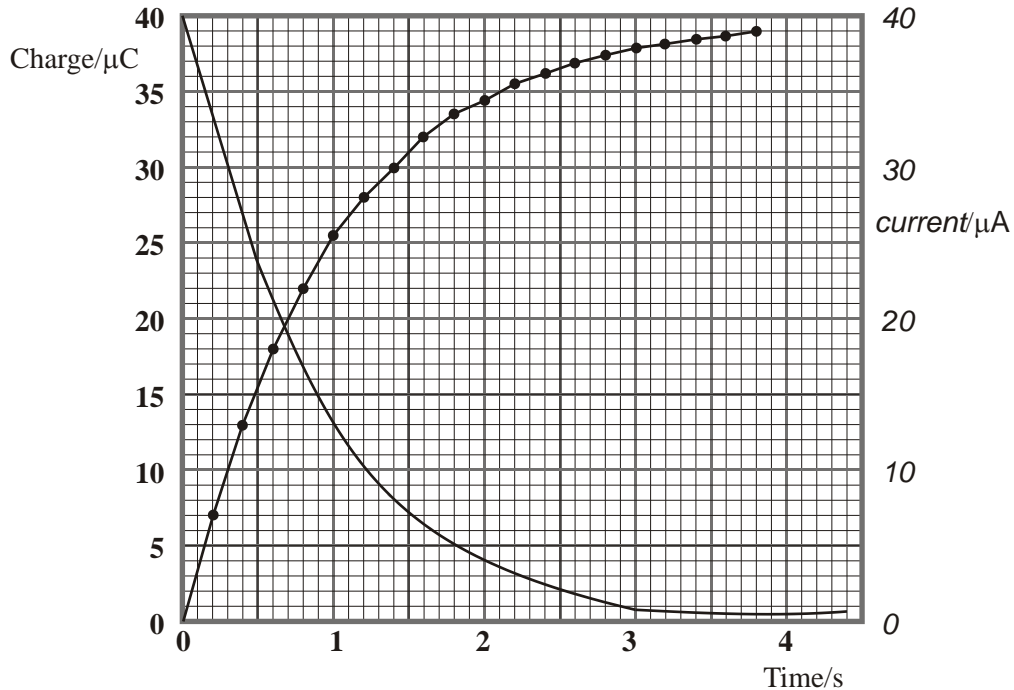
1

[8]

8. The circuit shown is used to charge a capacitor.



The graph shows the charge stored on the capacitor whilst it is being charged.



On the same axes, sketch as accurately as you can a graph of current against time. Label the current axis with an appropriate scale.

**Label current axis (1)**

**Current at  $t = 0$  within range  $30 - 45 \mu\text{A}$  (1)**

**Current graph right shape (1)**

**Exponential decay (1)**

**(4 marks)**

The power supply is 3 V. Calculate the resistance of the charging circuit.

**Resistance =  $3 \text{ V} / 40 \mu\text{A}$  (1)**

**=  $75 \text{ k}\Omega$  (1)**

**Resistance = Allow  $66 \text{ k}\Omega \rightarrow 100 \text{ k}\Omega$**

**(2 marks)**

**[Total 6 marks]**

9. Calculation of charge

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$= 0.021 \text{ C}$  (1) 2

What voltmeter reading tells about voltmeter

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OR  $95 \text{ mV} \div 3 = 32 \text{ mV}$  ) (1)

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$\approx 55 - 60 \text{ s}$  (1)

This time =  $RC$  (1)

[OR Gradient of graph method  $\rightarrow RC$  2 marks]

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[12]

10. Energy stored in a capacitor

Justify area:  $W = QV$

OR

work/area of thin strip =  $V \times \Delta Q$  (1)

Area under graph (1) 2

Energy stored when capacitor charged to 5000 V

$W = \frac{1}{2} QV = \frac{1}{2} \times 0.35 \times 5000 \text{ J}$

$= 875 \text{ J}$  (1) 1

Time constant for circuit

$5000/e$  or  $3 = 1840/1667 \text{ V}$  (1)

$\Rightarrow \text{T.C} = 3.3 \text{ m s}$  [3.1 – 3.6 m s] (1)

OR

Initial tangent  $\rightarrow t$ -axis (1)

Accept between 3.5 and 4.0 m s (1) 2

[Also allow use of exponential formula with appropriate substitution of correct  $V$  and  $t$ , e.g. 2000 and 3 ms]

Capacitance

$$C = \frac{T}{R} \text{ or as numbers (1)}$$

3.3 m s  $\rightarrow 7.0 \times 10^{-5}$  F [Allow e.c.fs.]

4.0 m s  $\rightarrow 8.5 \times 10^{-5}$  F (1) 2

[OR using graph:  $C = Q/V$  (1)  
 $= 0.35/5000 = 7.0 \times 10^{-5}$  F (1)]

Energy left in capacitor

At 2 ms,  $V = 2700$  V [2600 – 2800] (1)

$$\Rightarrow E = \frac{1}{2} CV^2 \text{ OR } \frac{1}{2} QV$$

$= 255$  J [e.c.f, depends on method] (1) 2

Energy setting

Energy leaving capacitor  $= (875 - 255)$  J

$= 620$  J [e.c.f.] (1)

Energy delivered  $= 620 \times 60/100$  J

$= 372$  J

$\Rightarrow 380$  J setting [Allow e.c.f.] (1) 2

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11. Estimation of charge delivered:

Charge = area under graph (1)

= a number of squares  $\times$  correct calculation for charge of one square i.e. correct attempt at area e.g. single triangle (1)

=  $(3.5 \text{ to } 4.8) \times 10^{-3}$  C (A s,  $\mu$ A s) (1)

[Limit = triangle from 41  $\mu$ A  $\rightarrow$  300 s]

OR

Charge = average current  $\times$  time (1)

= (something between 10 and 20  $\mu$ A)  $\times$  300 s (1)

=  $(3.5 \text{ to } 4.8) \times 10^{-3}$  C (1) 3

[But  $Q = It \rightarrow 0/3$ , e.g. 41  $\mu$ A  $\times$  300 s]

Estimation of capacitance

C = calculated charge/9.0V time constant  $\approx 100$  s (1)

= 390 to 533  $\mu$ F  $C = 100 \text{ s}/220 \text{ k}\Omega = 450 \mu\text{F}$  (1) 2

[5]

12. Charge on capacitor

$$220 \mu\text{F} \times 5 \text{ V} \text{ [use of CV ignore powers of 10] (1)}$$
$$= 1100 \mu\text{C (1)}$$

2

Energy on capacitor

$$\frac{220}{2} \mu\text{F} \times (5 \text{ V})^2 / \frac{1100}{2} \mu\text{C} \times 5 \text{ V} / \frac{1100^2 \mu\text{C}^2}{2 \times 220 \mu\text{F}} \text{ [ignore powers of 10] (1)}$$
$$= 2750 \mu\text{J} (2.8 \times 10^{-3} \text{ J}) (1)$$

2

Experiment

Method 1 (constant current method):

- Circuit (1)
- For a given  $V$  record time to charge capacitor at a constant rate (1)
- for a range of values of  $V$  (1)
- Use  $Q = It$  to calculate  $Q$  (1)
- Plot  $Q \rightarrow V$ – straight line graph through origin / sketch graph / divide  $Q/V$  and obtain constant value (1)

Method 2:

- Circuit (1)
- For a given value  $V$  measure  $I$  and  $t$  (1)
- Plot  $I \rightarrow t$  find area under graph  $Q$  (1)
- Repeat for a range of values of  $V$  (1)
- Plot  $Q \rightarrow V$  for straight line graph through origin/ sketch graph / divide  $Q/V$  and obtain constant value (1)

Method 3 (joulemeter method):

- Circuit (1)
- Record  $V$  and energy stored (1)
- For range of  $V$  (1)
- Determine  $Q$  from  $\frac{1}{2} QV$  or  $\frac{Q^2}{2C}$  (1)
- Plot  $Q \rightarrow V$ – straight line graph through origin / sketch graph / divide  $Q/V$  and obtain constant value (1)

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[Coulombmeter (will not work with this value of capacitor) circuit (1) ; record charge  $Q$  on coulombmeter (1); for a range of values of  $V$  (1); Plot  $Q \rightarrow V$  for straight line through origin (1) – Max 3]

[9]