Capacitors Past Questions + Markscheme

Jan 2005

9 This question is about capacitor discharge.

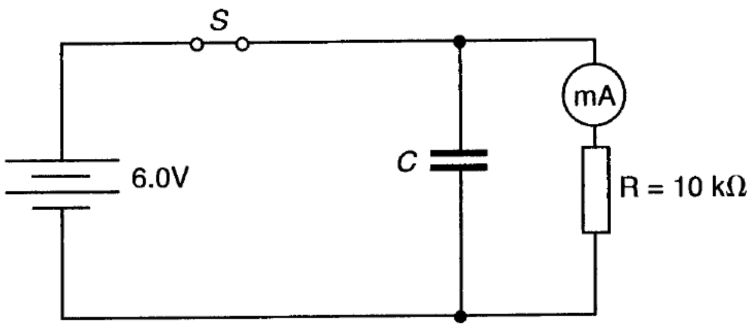


Fig. 9.1

The circuit is set up as shown in Fig. 9.1. Switch S is then opened and the capacitor discharges through the resistor. The variation of discharge current I with time t is shown in Fig. 9.2.

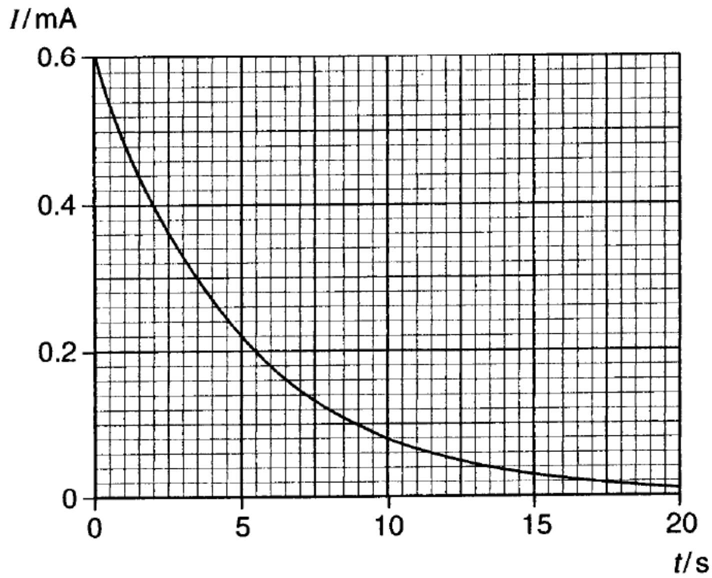


Fig. 9.2

(a) **(i)** Explain why the area under the curve represents the initial charge on the capacitor.

[1]

(ii) Show that the initial charge on the capacitor is about 3 mC.

[2]

(iii) Calculate the value of the capacitance used in the experiment.

value of capacitance = ... unit .... [3]

(b) Calculate the energy stored on the capacitor when the switch is closed.

energy stored = ...J [2]

(c) The experiment is repeated. The 10 kΩ resistor is removed and replaced with a 20 kΩ resistor. No other changes are made to the circuit.

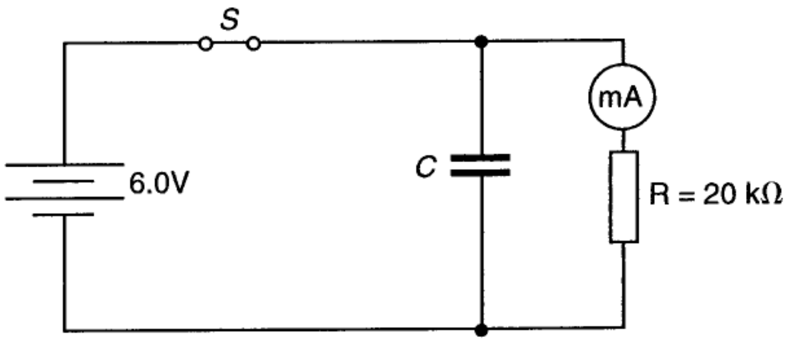
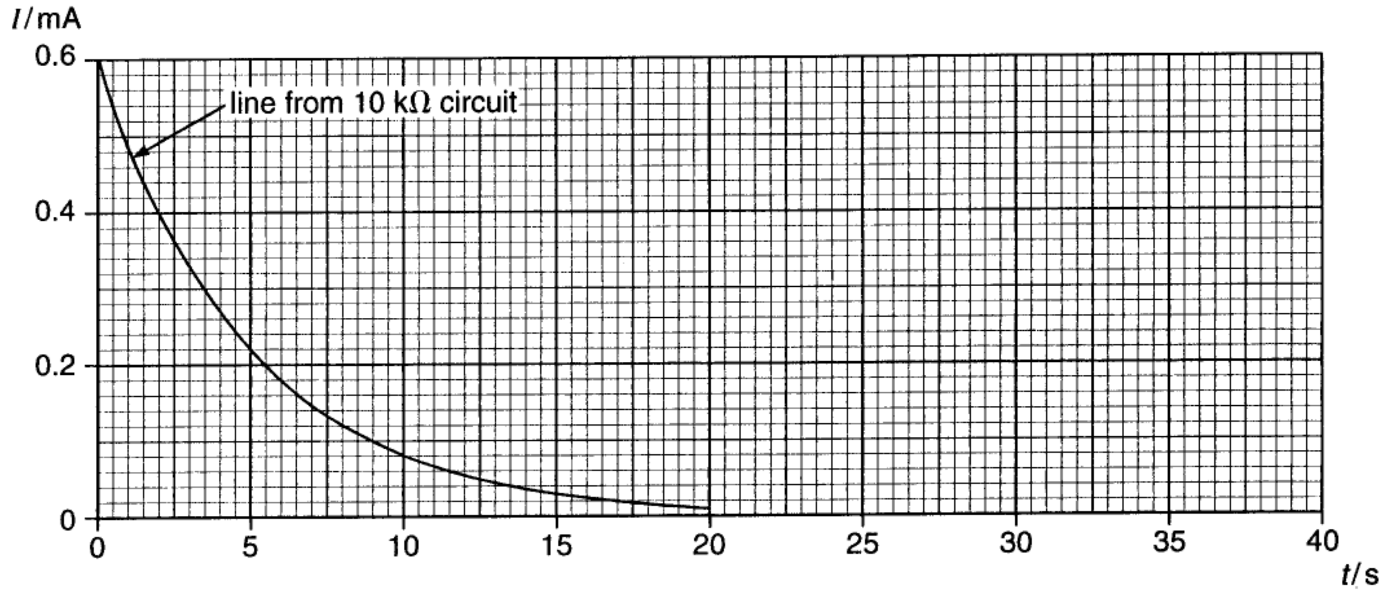


Fig. 9.3

Use the axes on Fig. 9.4 to sketch the graph of current against time for the new circuit.



[3]

Fig. 9.4

[Total: 11]

June 2005

2 The flash unit of a disposable camera contains a 470 μF capacitor. The potential difference across the charged capacitor is 270 V.

(a) Calculate the charge on the capacitor.

charge on capacitor = ... unit ....[3]

(b) Calculate the energy stored on the capacitor.

energy stored on capacitor = ... J [2]

Jan 2007

7 A capacitor stores a charge of 5.6 mC at a p.d. of 12 V.

Calculate the value of the capacitance.

capacitance = ... F [2]

7 The 4700 μF capacitor shown in Fig. 7.1 is used as a part of a timing circuit.

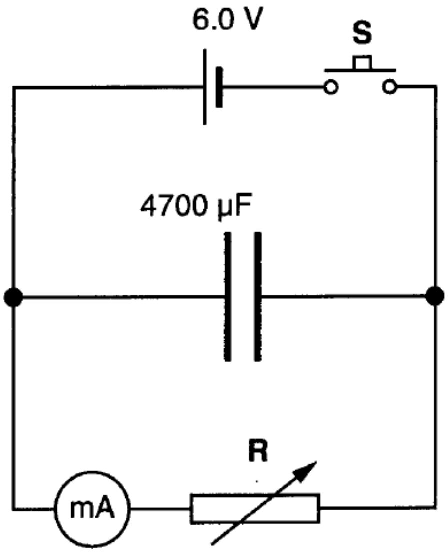


Fig. 7.1

The variable resistor **R** is initially set to a value of 12 kΩ.
The timing sequence is started by closing and opening the switch **S**.

(a) Whilst the switch **S** is closed, calculate

(i) the charge stored by the capacitor

charge = ...C [1]

(ii) the energy stored by the capacitor

energy = ...J [2]

(iii) the current in **R**.

current = ...unit .... [2]

(b) **(i)** Explain why the current will start to decrease as soon as **S** is opened.

[2]

(ii) Show that the time constant τ for this circuit is about 60 s.

[1]

(c) The experiment is repeated with the value of **R** reduced to 6.0 kΩ from its previous value of 12 kΩ.

State the new values of

(i) the current whilst the switch is closed

current = ... [1]

(ii) the time constant.

time constant = ...[1]

(d) With **R** set at 6.0 kΩ, a student briefly closes the switch **S** every 10 seconds. The voltage across the capacitor varies as shown in Fig. 7.2.

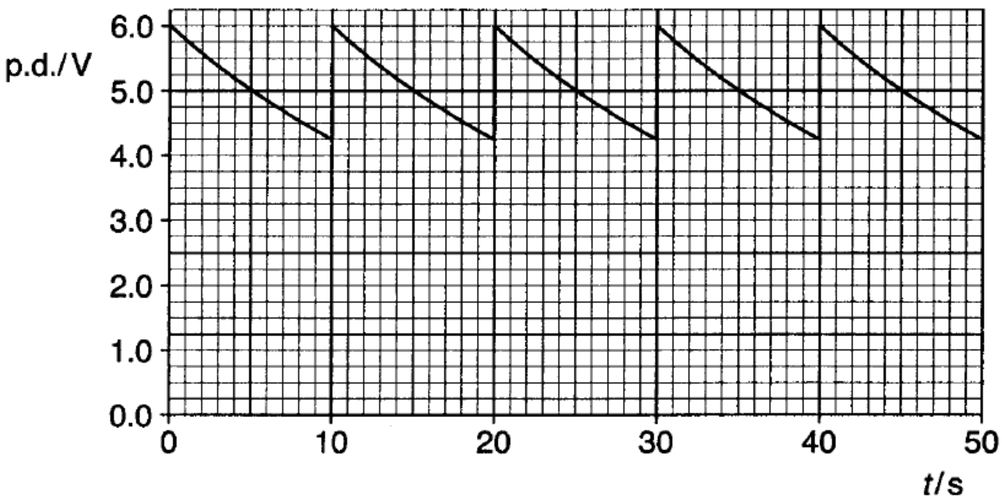


Fig. 7.2

State and explain **two** features of the graph.

feature 1:

explanation:

feature 2:

explanation:

[4]

1 Study the circuit in Fig. 1.1.

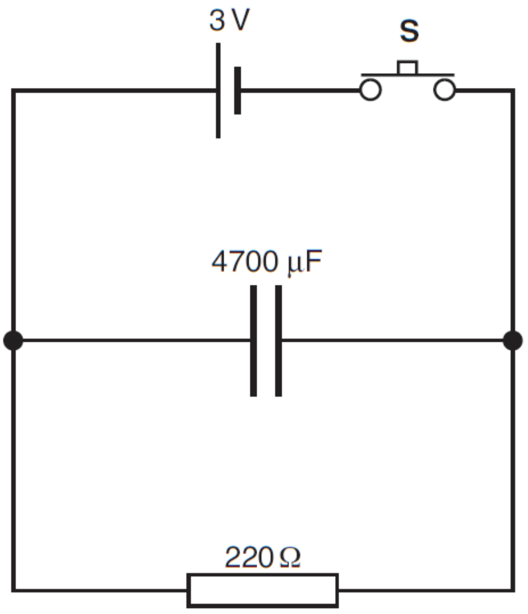


Fig. 1.1

The switch **S** is closed to charge the capacitor. When the switch is opened the capacitor discharges through the resistor.

Here is a list of values:

1.4×10^{-2} 2.1×10^{-2} 1.0 1.4 2.1

Choose from the list the value that is closest to

(a) the time constant τ of the circuit in seconds

value .... s

(b) the charge in coulombs on the capacitor when at a p.d. of 3.0 V

value C

(c) the energy stored on the capacitor in joules when at a p.d. of 3.0 V

value .... J

(d) the initial value of the current in ampere when the fully charged capacitor discharges through the resistor.

value .... A

[4]

11 This question is about capacitor discharge in the circuit shown in Fig. 11.1.

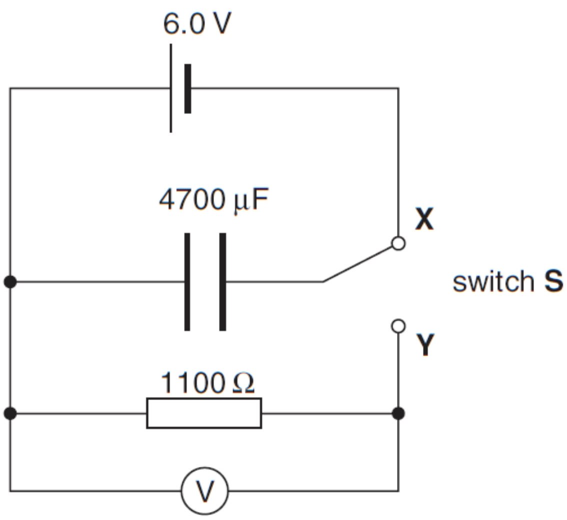


Fig. 11.1

The switch **S** is moved from **X** to **Y**. The capacitor discharges through the 1100 Ω resistor. Fig. 11.2 shows the graph of p.d. against time.

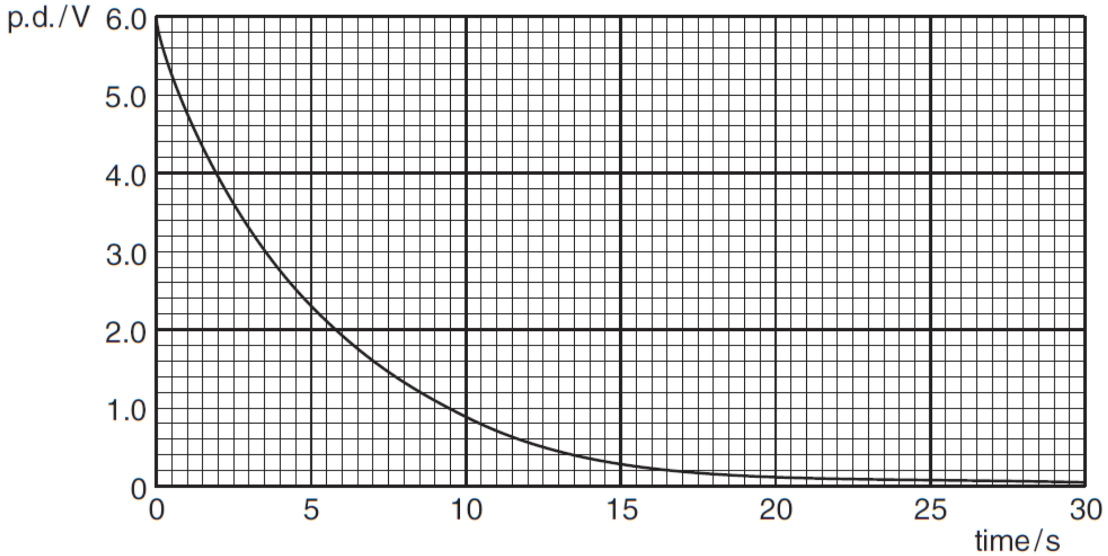


Fig. 11.2

(a) Use information from the diagram and the graph to show that

(i) the initial charge on the capacitor is about 0.03 C

[1]

(ii) the initial rate of discharge is about 5 mA

[1]

(iii) the time constant of the circuit is about 5 s.

[1]

(b) Explain why the rate of fall of voltage is proportional to the rate of fall of charge and hence proportional to the current in the circuit.

[2]

(c) A series of models of the discharge are considered.

(i) In the simplest model the current is assumed to remain constant at its initial value throughout the discharge. Show that this model predicts that the capacitor would fully discharge in time *RC*.

[2]

(ii) A better model calculates the change of charge ΔQ in successive time intervals Δt using the equation $\Delta Q = -\frac{Q}{RC}\Delta t$.

Fig. 11.3 shows the graph produced when Δt is set at 4.0 s.

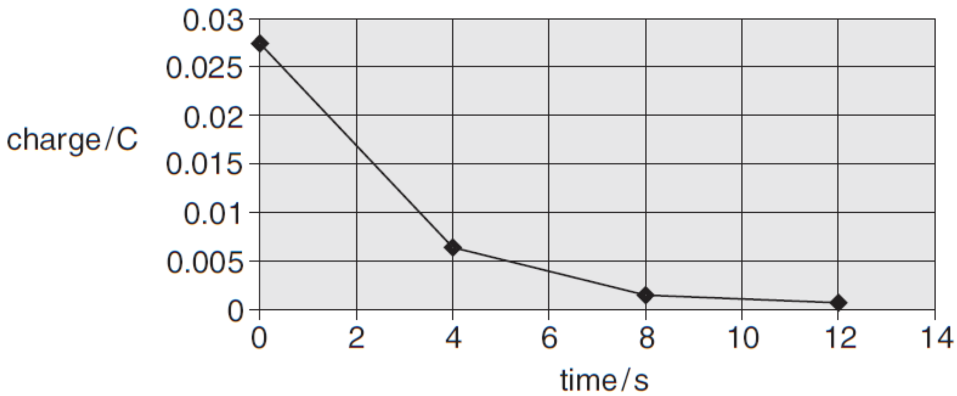


Fig. 11.3

To improve the model Δt is reduced to 2.0 s. This graph gives the charge remaining at 2.0 s as 0.017 C. Use this value to show that the loss of charge during the next two seconds will be about 6.5×10^{-3} C.

[1]

(iii) Draw a line on the graph in Fig. 11.3 to represent the loss of charge from the capacitor between 2.0 s and 4.0 s.

[1]

(iv) Explain why reducing the time interval Δt leads to a more accurate model of the discharge.

[1]

June 2008

3 Here are some data about a capacitor

capacitance = 470 μF

p.d. across fully charged capacitor = 12 V.

(a) Show that the charge on the capacitor is about 5.6 mC.

[1]

The capacitor is discharged through a resistor. After three seconds the p.d. across the capacitor has fallen to 10 V.

(b) Show that a charge of about 0.9 mC passes through the resistor as the p.d. across the capacitor falls to 10 V.

[2]

(c) The average current in the resistor as the p.d. across the capacitor falls from 12 V to 10 V is about 0.3 mA.

Explain why 0.3 mA is an **average** value.

[1]

Jan 2010

9 Calculate the energy stored on a 4700 μF capacitor when a p.d. of 9.0 V is applied across it.

energy stored = ……………………..J **[2]**

11 A student is experimenting with capacitors. He has two capacitors available, one of capacitance 1000 μF and one of unknown value. He connects the circuit shown in Fig 11.1 and closes the switch **S**.

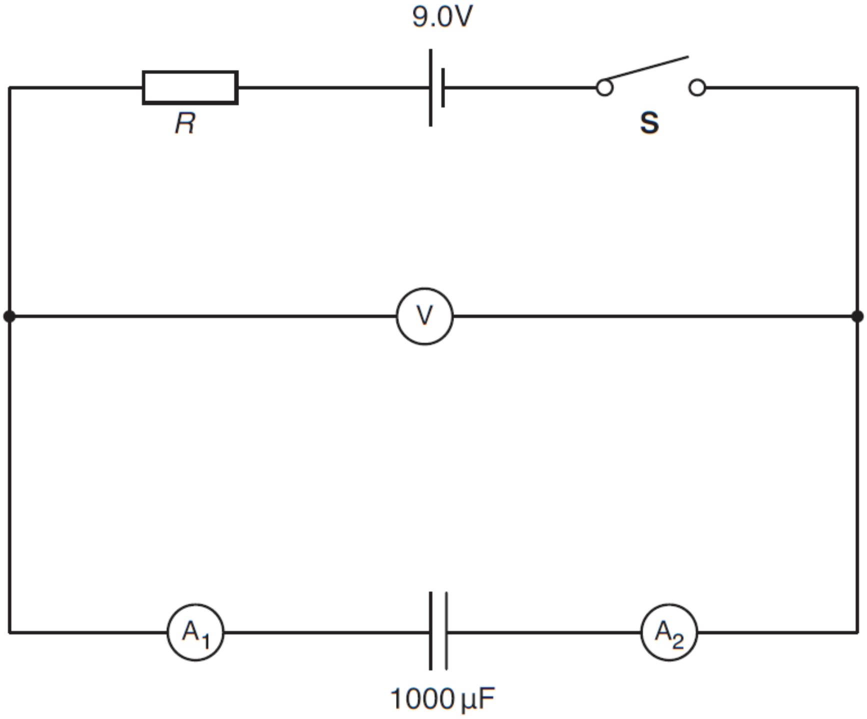


Fig. 11.1

(a) **(i)** State the current in ammeter A_1 when the current in ammeter A_2 is + 0.5 mA.

sign and magnitude of current = ………………….. mA **[1]**

(ii) Calculate the charge on the 1000 μF capacitor when the potential difference across the capacitor is 9.0 V.

charge = …………… C **[2]**

(b) The switch **S** is now opened again. The high-resistance voltmeter reading remains at 9.0 V. The student connects the uncharged capacitor of unknown value in parallel with the charged 1000 μF capacitor.

(i) Draw on Fig. 11.1 to show the second capacitor connected in the circuit. **[1]**

When the second capacitor has been connected the student notices that the voltmeter reading has dropped to half its previous value.

(ii) Deduce the capacitance of the second capacitor explaining your reasoning carefully.

Reasoning:

capacitance = ………………….. μF **[2]**

(c) The student now connects the 1000 μF capacitor into the circuit shown in Fig. 11.2. Switch **S** is closed briefly and then opened again.

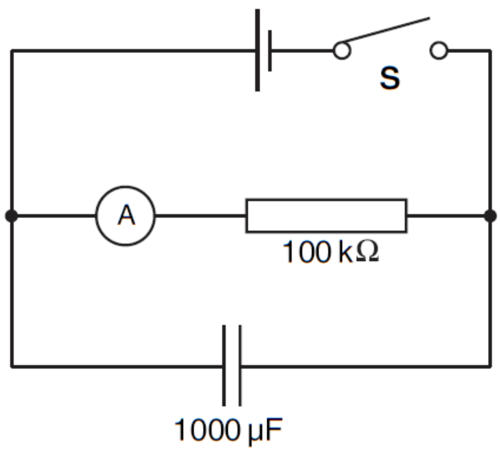


Fig. 11.2

(i) Show that when the switch is opened the initial current in the resistor is 9×10^{-5} A.

[1]

(ii) Show that the current in the resistor falls to less than 3.5×10^{-5} A after the switch has been opened for 100 s.

[2]

[Total: 9]

10 This question is about capacitor discharge.

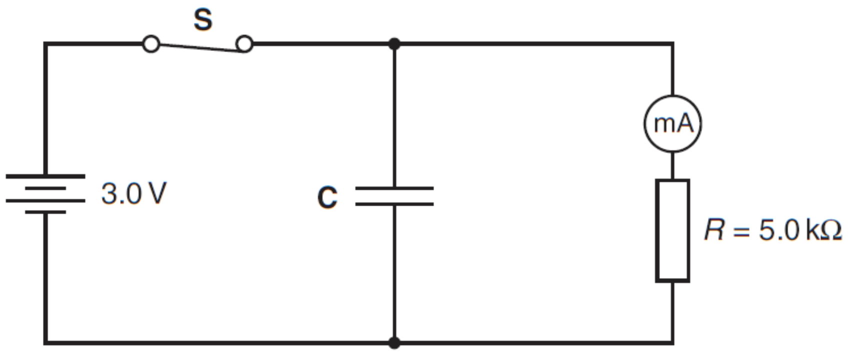


Fig. 10.1

The circuit is set up as shown in Fig. 10.1. Switch **S** is then opened and the capacitor discharges through the resistor. The variation of discharge current I with time t is shown in Fig. 10.2.

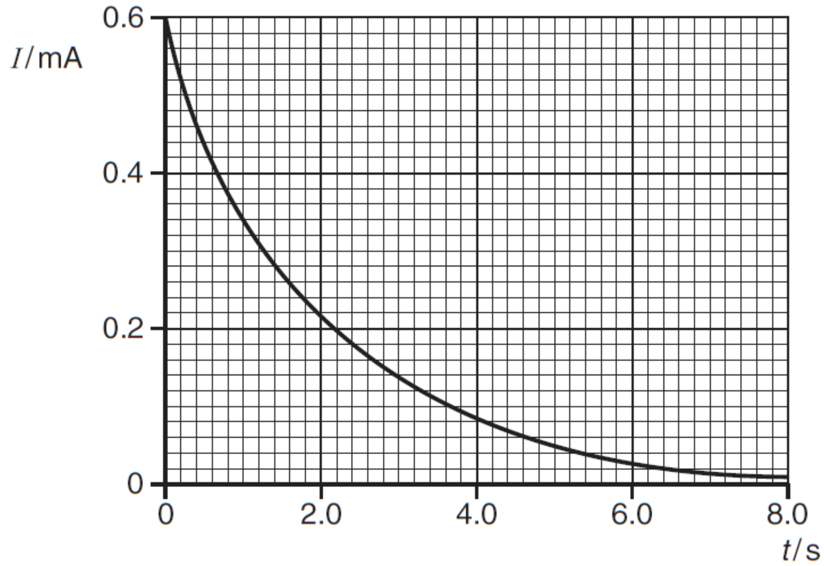


Fig. 10.2

(a) **(i)** Explain why the area under the curve represents the **initial** charge on the capacitor.

[2]

(ii) Show that the initial charge on the capacitor is about 1 mC.

[2]

(iii) Calculate the value of the capacitance used in the experiment.

value of capacitance = ... unit .... **[3]**

(b) Calculate the energy stored on the capacitor when the switch is closed.

energy stored = ... J **[2]**

(c) The experiment is repeated. The 5.0 kΩ resistor is replaced with a 10 kΩ resistor. No other changes are made to the circuit.

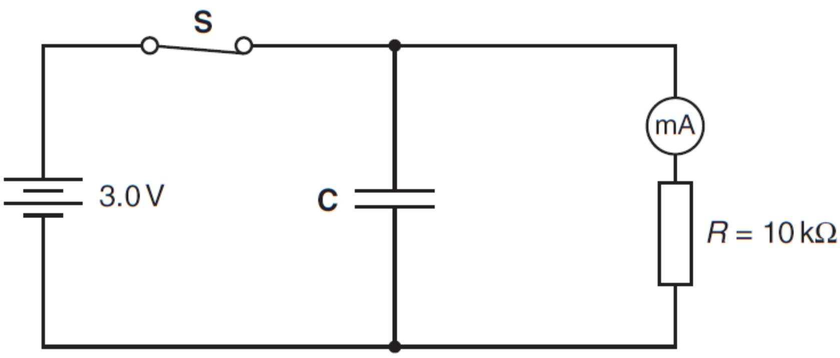


Fig. 10.3

Use the axes on Fig. 10.4 to sketch the graph of current against time for the circuit of Fig. 10.3.

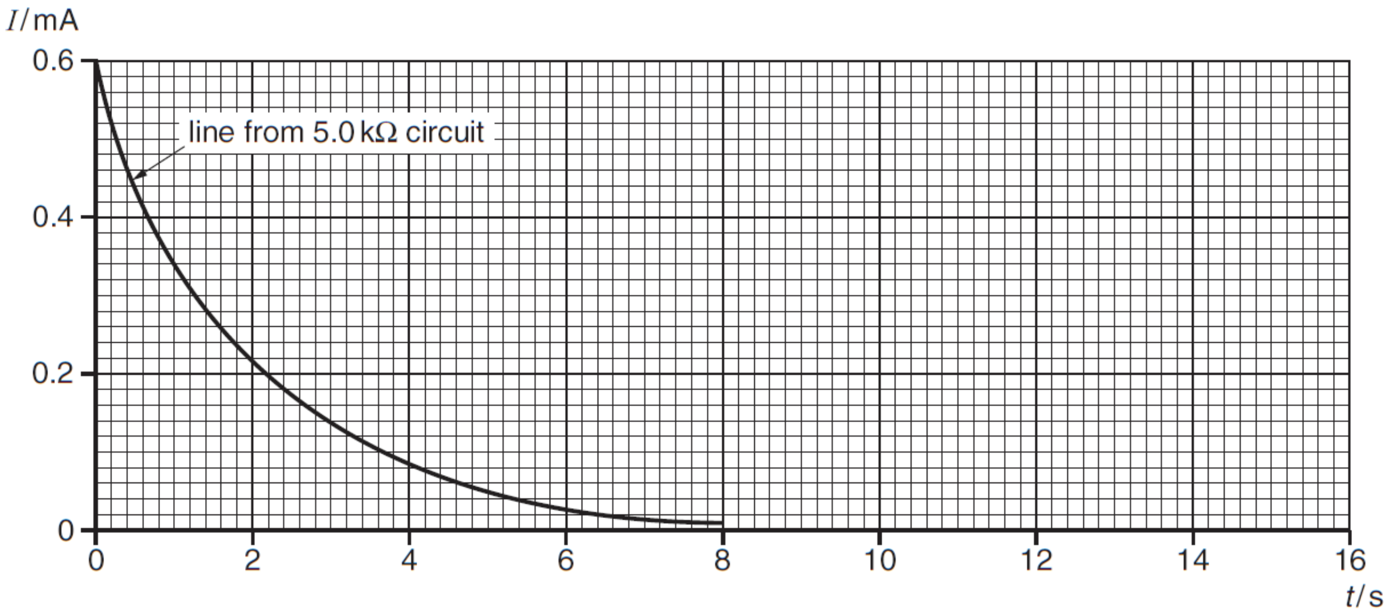


Fig. 10.4

[3]

[Total: 12]

9a (I)	Q = I t argument ✓/ dimensions argument	1	
a(ii)	Counting squares ✓gives answer in range 2.5 – 3.5 mC✓	2	Other methods acceptable
a(iii)	C =Q/V = 2.8 x 10^{-3}/6✓ = 4.7 x 10^{-4} ✓F✓ 5 x10^{-4} F if paper value used. (If 1/3 used for RC proportion answer is 5.5 x10^{-4} F)	3	μF fine. Other methods acceptable
b	E = ½ Q V = ½ x 2.8 x 10^{-3} x 6 ✓= 8.4 x 10^{-3} J ✓ (ecf)	2	Other methods acceptable.
c	y intercept 0.3 mA ✓ time constant✓ shallower curve✓ (valid method)	3	0.11 mA at 10 s or 0.15 at 7 s. accept displaced curve.

2 a	Q = CV = 470 x 10^{-6} x 270 ✓ = 0.13 ✓ C ✓	3	Lose one mark (over whole question) for power of ten error in capacitance. Bare answer for calculation worth two marks if correct.
2b	E = ½ QV = ½ x 0.13 x 270 ✓ = 18 J ✓ (or 17 if 0.127 C used)	2	Or E = ½ CV^2 = 17 J

7		C = 5.6 x 10^{-3}/ 12 ✓ = 4.7 x 10^{-4}✓ F	2	No sf penalty Don't accept 4.6

7a (i) (ii)	Q = 4700 x 10^{-6} x 6 = 0.028 C ✓ E = ½ x 0.028 x 6 ✓= 0.084 J ✓ ecf	1 2	0.085 to 2sf
(iii)	I = 6/ 12 000 ✓ = 0.5 mA ✓	2	Or 5 x 10^{-4} A (0.5 A gains one mark)
b (i)	As charge leaves, V on capacitor decreases ✓. Therefore, lower V across resistor✓ and lower I through resistor. AW	2	Can gain second mark through V = IR
(ii)	Time constant = 12000 x 4700 x 10^{-6} ✓ = 56 s	1	
c (i) (ii)	1 mA or ecf ✓ 28 s ✓ UNIT PENALTY once in c(i) and (ii)	1 1	UNIT PENALTY once in c(i) and (ii)
(d)	Sensible feature✓ linked to correct explanation ✓ Sensible feature✓ linked to correct explanation✓ (Look for following features: sudden rise, slow fall, peak pd of 6V, 10 s period, curved discharge, minimum 4.2/4.25/4.4 V.) Accept exponential nature of <u>discharge</u> as an explanation. Look at feature and explanation together.	2 2	e.g. falling to given value of charge linked to time constant. Vertical line at 10 s intervals linked to recharging through low resistance.

1 a b c d	1.0 ✓ 1.4 x 10^{-2}✓ 2.1 x 10^{-2}✓ 1.4 x 10^{-2}✓	1 1 1 1	Accept 1.03 Accept 0.014(1) Accept 0.021(15) Accept 0.0136

11 (a) (i) (a) (ii) (a) (iii)	Q = 4700 x 10^{-6} x 6✓ = 0.028 C I = V/R = 6/1100✓ = 5.5 mA T = 4700 x 10^{-6} x 1100✓ = 5.2 s	1 1 1	Own answer or method Or by clear graphical method

(b)	V is proportional to Q ✓, rate of fall of charge = current✓	2	Other arguments possible
c(i) (ii) (iii) (iv)	Use of *t* = *Q*/*I* (or rearranged) ✓ Correct substitution of *Q* = *CV* and *R* = *V*/*I*✓ Loss of charge = (-0.017/5.2) x 2.0✓ = 6.5(4) x 10^{-3} C Line from (2.0, 0.017) to (4.0, 0.01) by eye ✓ Holds rate of decay constant for smaller time period /closer to continuous change ✓	2 1 1 1	Accept numerical arguments No ecf

3(a)	Q = 470 x 10^{-6} x 12 ✓ = 5.6(4) mC	**1**	Check correct power of ten
3(b)	Q = 470 x 10^{-6} x 10 = 4.7 mC ✓	**1**	Or ΔQ =CΔV or implicit✓
	ΔQ = 5.6 – 4.7 ✓ mC = 0.9 mC	**1**	Correct evaluation✓
3(c)	**Rate** of flow of charge/discharge or current **falls** (with time) ✓ AW	**1**	Beware experimental error explanations Accept *I* =*V*/*R* and V falls *I* =ΔQ/Δt not sufficient

9	*E* = ½ x 4700 x 10^{-6} x 9.0^2 ✓= 0.19 J✓	2	1.9 x 10^5 one mark 1.9 x 10^2 one mark

11(a)i (ii)	+0.5 ✓ Q = 1000 x 10^{-6} x 9.0✓ = 9 x 10^{-3} C. ✓	1 2	
(b)(i) (ii)	Correctly connected in parallel ✓ Half the charge has left original capacitor✓ (therefore) both capacitors have same value (as p.d. across each is the same in parallel) AW✓	1 2	Many ways to explain this. Use of total capacitance = 2000 μF is a valid method.
c(i) (ii)	I = V/R = 9/100 000 ✓= 9 x 10^{-5} A RC = 100 s. ✓After 100s I = 0.37 x 9 x 10^{-5} = 3.3 x 10^{-5} ✓	1 2	(100 kΩ OK) Need full argument Or use $I = I_o e^{-t/RC}$ M ✓E✓

10	**(a)**	**(i)**	Idea of charge = current x time ✓ Area under curve gives charge, and the area shows (almost) complete discharge ✓	2	
		(ii)	Counting squares/ other clear method✓. Answer in range 1.1 – 1.5 mC✓	2	
		(iii)	1.5 x 10^{-3} / 3.0✓ = 500✓ μF✓	3	Ecf. Using 1 mC gives 330 μF. CV^{-1} acceptable for unit if correct.
	(b)		E = ½ 500 x 10^{-6} x 3^2 ✓=2.3 x 10^{-3} ✓J	2	Ecf, range at standardisation
	(c)		Line starts at 0.3 mA✓, τ twice original (by eye) ✓, smooth curve✓	3 **Total 12**	Starting at 0.6 mA but everything else correct worth 2