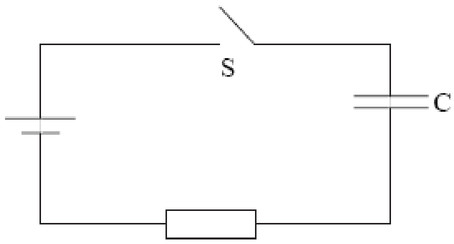
A2 Physics

Test on Capacitors

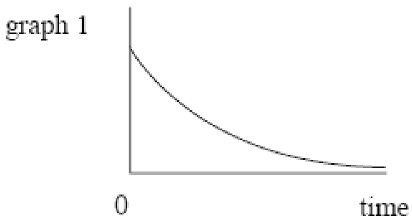
Examination Time - 45 minutes

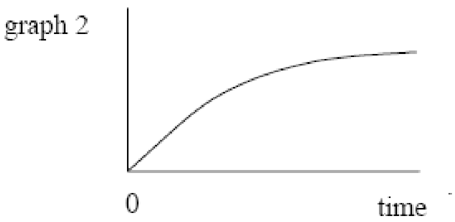
1.

In the circuit shown, the capacitor C is charged to a potential difference V when the switch S is closed.



Which line, **A** to **D**, in the table gives a correct pair of graphs showing how the charge and current change with time after S is closed?





	charge	current
A	graph 1	graph 1
B	graph 1	graph 2
C	graph 2	graph 2
D	graph 2	graph 1

Charge rises exponentially (Graph 2) while the current falls exponentially (Graph 1).

D is the correct answer ✓

2.

A 400 μF capacitor is charged so that the voltage across its plates rises at a constant rate from 0 V to 4.0 V in 20 s. What current is being used to charge the capacitor?

A 5 μA
B 20 μA
C 40 μA
D 80 μA

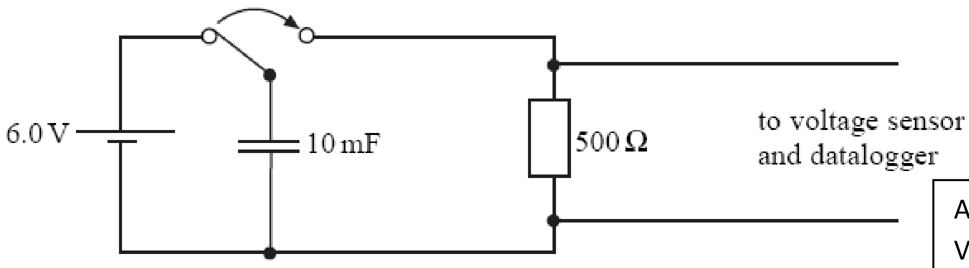
$Q = CV = 400 \times 10^{-6} \times 4.0 = 1.6 \times 10^{-3}$ C

$I = Q/t = 1.6 \times 10^{-3}$ C × 20 s = 8×10^{-5} A = 80 mA

Answer D is correct ✓

3.

A voltage sensor and a datalogger are used to record the discharge of a 10 mF capacitor in series with a 500 Ω resistor from an initial pd of 6.0 V. The datalogger is capable of recording 1000 readings in 10 s. Which line, **A** to **D**, in the table gives the pd and the number of readings made after a time equal to the time constant of the discharge circuit?



	potential difference/V	number of readings
A	2.2	50
B	3.8	50
C	2.2	500
D	3.8	500

At the time constant:
$V = 6.0 \times e^{-1} = 2.21$ V

$RC = 10 \times 10^{-3} \times 500 = 5$ s

The number of readings = 500

Answer C is correct. ✓

4.

The relationship between two physical quantities may be inverse, inverse square or exponential. Which line, **A** to **D**, in the table shows correct relationships for

(i) pd and time in capacitor discharge,
(ii) electric field strength and distance in a radial field, and
(iii) gravitational potential and distance in a radial field?

	(i) **capacitor discharge**	(ii) **electric field strength**	(iii) **gravitational potential**
A	exponential	inverse	inverse square
B	inverse	inverse square	exponential
C	inverse square	exponential	inverse
D	exponential	inverse square	inverse

Capacitor discharge is exponential

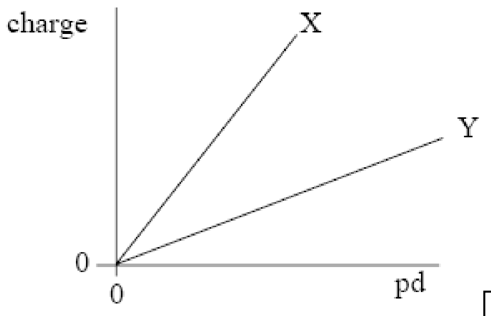
Electric field is inverse square.

Gravitation potential is inverse.

Line D is correct. ✓

5.

The graph shows how the charge stored by each of two capacitors, X and Y, increases as the pd across them increases.



Which one of the following statements is correct?

A The capacitance of X is equal to that of Y.
B The capacitance of Y is greater than that of X.
C The capacitance of Y is less than that of X.
D The capacitances of both X and Y are increasing.

Capacitance is the gradient of the charge-voltage graph.

X has a higher gradient than Y, so X has a higher capacitance.

C is the correct line ✓

6.

A 1000 μF capacitor and a 10 μF capacitor are charged so that the potential difference across each of them is the same. The charge stored in the 1000 μF capacitor is Q_1 and the charge stored in the 10 μF capacitor is Q_2.

What is the ratio $\frac{Q_1}{Q_2}$?

A 100
B 10
C 1
D $\frac{1}{100}$

V = Q/C

$\frac{Q1}{1000} = \frac{Q2}{10}$

Q1/Q2 = 1000/10 = 100

A is correct ✓

7.

A 1000 μF capacitor, initially uncharged, is charged by a steady current of 50 μA. How long will it take for the potential difference across the capacitor to reach 2.5 V?

A 20 s
B 50 s
C 100 s
D 400 s

$Q = 1000 \times 10^{-6} \times 2.5 = 2.5 \times 10^{-3}$ C

$t = Q/I = 2.5 \times 10^{-3}$ C $\div 50 \times 10^{-6} = 50$ s

B is correct ✓

8.

In experiments to pass a very high current through a gas, a bank of capacitors of total capacitance 50 μF is charged to 30 kV. If the bank of capacitors could be discharged completely in 5.0 ms what would be the mean power delivered?

A 22 kW
B 110 kW
C 4.5 MW
D 9.0 MW

$E = ½ CV^2 = ½ \times 50 \times 10^{-6} \times 30\,000^2 = 22500$ J
$P = E/t = 22500 \div 5.0 \times 10^{-3} = 4.5 \times 10^{6}$ W

C is correct. ✓

9.

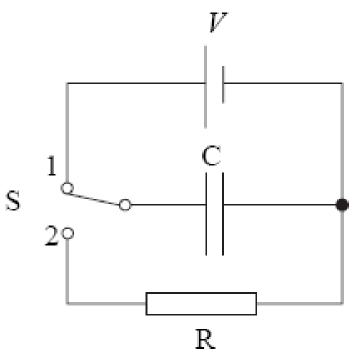
A capacitor of capacitance 2500 μF is charged by a **constant** current of 200 μA. What is the pd across the capacitor 25 s after starting to charge?

A 0.50 V
B 1.0 V
C 2.0 V
D 4.0 V

$Q = 200 \times 10^{6} \times 25 = 5 \times 10^{-3}$ C

$V = Q/C = 5 \times 10^{-3}$ C $\div 2500 \times 10^{-6} = 2.0$ V
C is correct ✓

10.



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 $\frac{V}{2}$.
After the switch has been moved to position 2, how long does it take before the energy stored by C has fallen to $\frac{E}{16}$?

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

$E = ½ CV^2$. When V falls to V/2, E will fall to E/4. Similarly, when, after 2 half-lives, V falls to V/4, E falls to E/16.

The half life is 36 ms, so 2 half lives take 72 ms.

Answer B is correct. ✓

11.

A 680 μF capacitor is charged fully from a 12 V battery. At time $t = 0$ the capacitor begins to discharge through a resistor. When $t = 25$ 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 $t = 25$ s.

$E = \frac{1}{2} CV^2$ Therefore if V is halved, E will be ¼ ✓

Half-life is 25 s, therefore the voltage = 6.0 V ✓

(2 marks)

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

$t_{1/2} = \ln 1/2 \times RC$ ✓

$RC = 25 \div \ln 0.5$ ✓

= 36.1 s = 36 s (QED)

(ii) Calculate the resistance of the resistor.

$t = RC \Rightarrow R = 36 \div 680 \times 10^{-6}$ ✓

$R = 53000\ \Omega = 53\ k\Omega$ ✓

(4 marks)

12.

Figure 2 shows a circuit used to determine the capacitance of a capacitor C. Switch S is held in position **X** until C is fully charged. It is then switched to position **Y**, so that C discharges through the microammeter and the variable resistor R. While discharging, R is adjusted continuously to keep the current constant until C has been fully discharged. Measurements taken during the discharge allow the initial charge stored by C to be determined.

Figure 2

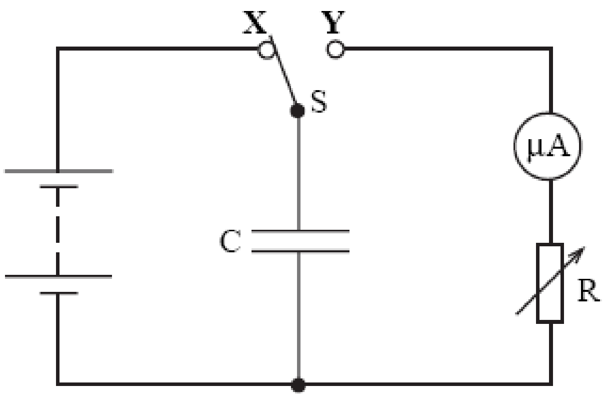


Figure 3 shows a graph of current, *I*, against time, *t*, obtained in such an experiment.

Figure 3

(a) Calculate

(i) the initial charge stored by the capacitor,

$Q = It = 35 \times 10^{-6} \times 24$

$= 8.4 \times 10^{-4}$ C

(ii) the capacitance of the capacitor, if the emf of the battery used was 6.0 V.

$C = Q/V = 8.4 \times 10^{-4} \div 6.0$

$= 1.4 \times 10^{-4}$ F = 140 μF

(2 marks)

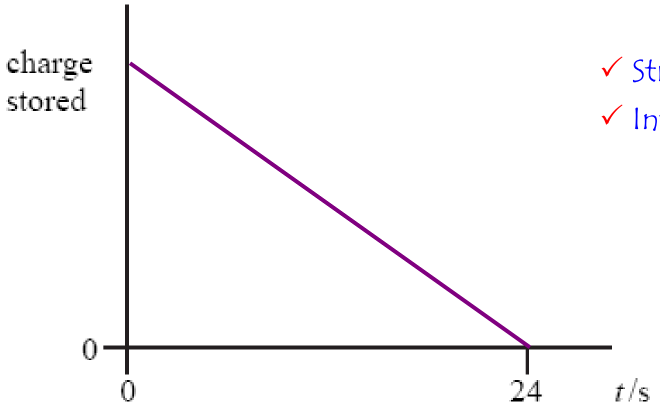
(b) Sketch graphs on the axes below to show, for the capacitor, how

(i) the charge stored
(ii) the energy stored

varied with time during the experiment.

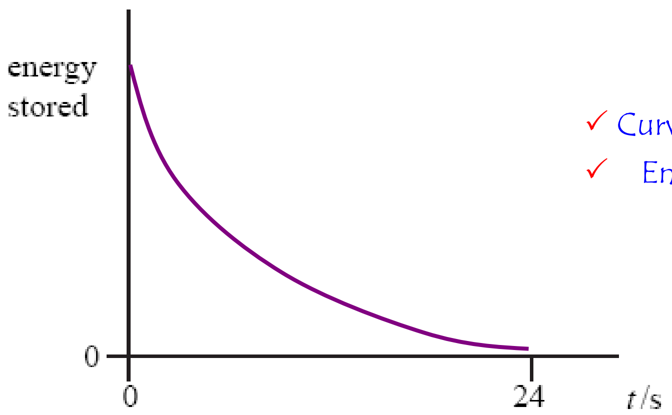
You do not need to show any values on the vertical axes.

(i)



✓ Straight line (as $\Delta Q/\Delta t$ is constant)
✓ Intercept

(ii)



✓ Curve ($\propto \sqrt{E}$)
✓ Energy 0 at 24 s

(4 marks)

13 (*3 marks*)

(a) An experiment is to be carried out to determine the capacitance of a capacitor by measuring the potential difference V across it at various times t as it discharges through a resistor. The timing is to be carried out using a stopwatch. If the capacitance is known to be about 30 μF, suggest a suitable value for the resistance of the resistor, and explain why you have chosen this value.

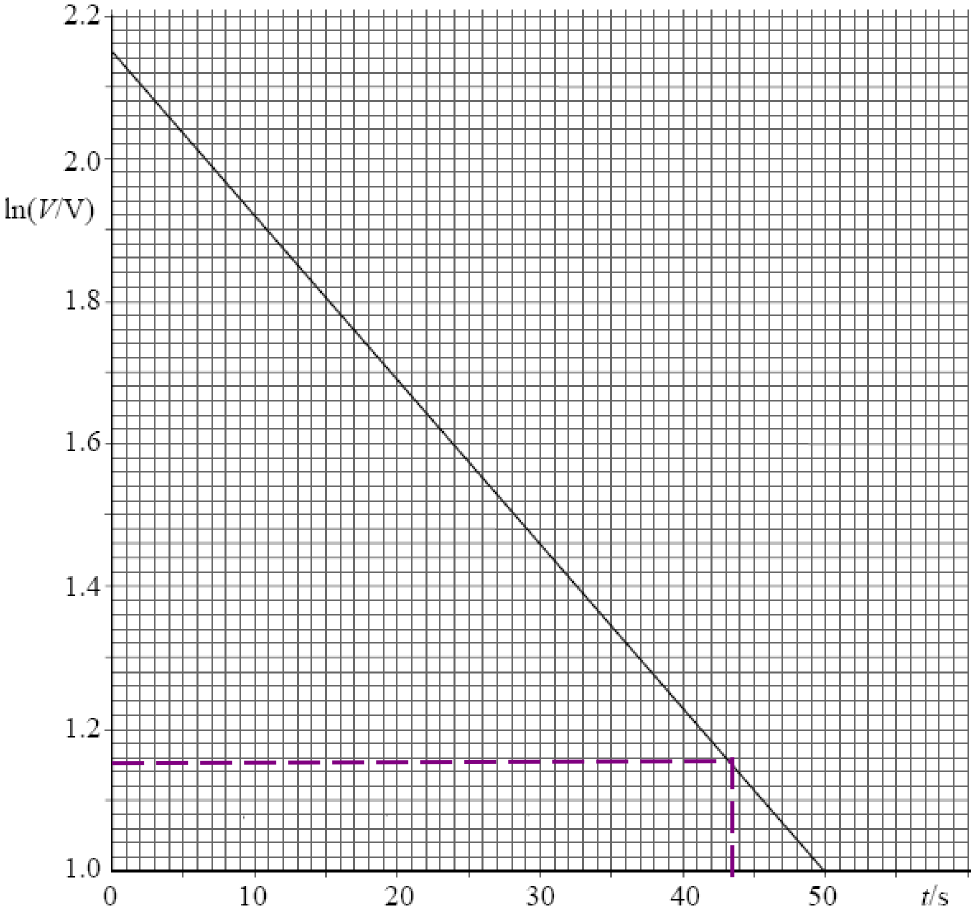
You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

RC needs to be about 100 s ✓

RC is the time taken for the voltage to fall to 37 % of its original value. ✓

$R = t/C = 100\ \text{s} \div 30 \times 10^{-6} = 3.3 \times 10^{6}\ \Omega$ ✓

(b) A similar experiment, in which the resistor had a resistance of 91 kΩ, gave the graph of ln V against t shown on the opposite page.



Use this graph to calculate

(i) the pd across the capacitor when $t = 0$,

$V_0 = e^{2.15} = 8.6$ V ✓

(ii) the time constant for the discharging circuit,

RC is time taken for V0 to fall to V0 × e^{-1} ✓

V = 8.6 × e^{-1} = 3.16 V. ln 3.16 = 1.15 ✓

Read from the graph: RC = 43 s ✓

(iii) the capacitance of the capacitor used in this experiment.

C = t/R = 43 × 91 × 10^3 = 4.7 × 10^{-4} = 470 μF ✓

(5 marks)

Total = 30 marks