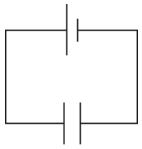
Capacitance *[54 marks]*

1. A parallel plate capacitor is connected to a cell of negligible internal resistance. *[1 mark]*



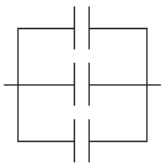
The energy stored in the capacitor is 4 J and the electric field in between the plates is 100 N C^{-1}. The distance between the plates of the capacitor is doubled. What are the energy stored and the electric field strength?

	Energy / J	Electric field strength / N C^{-1}
A.	2	50
B.	8	50
C.	2	200
D.	8	200

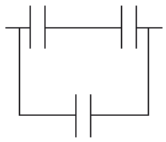
2. Three capacitors, each one with a capacitance C, are connected such that their combined capacitance is $1.5C$. How are they connected? *[1 mark]*

A.

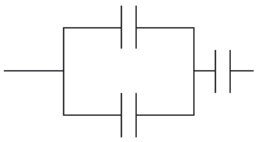
B.



C.



D.

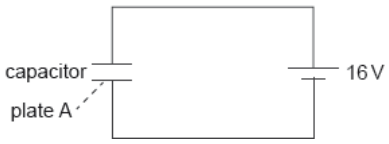


A capacitor consists of two parallel square plates separated by a vacuum. The plates are 2.5 cm × 2.5 cm squares. The capacitance of the capacitor is 4.3 pF.

3a. Calculate the distance between the plates. *[1 mark]*

3b. The capacitor is connected to a 16 V cell as shown. *[2 marks]*

diagram not to scale

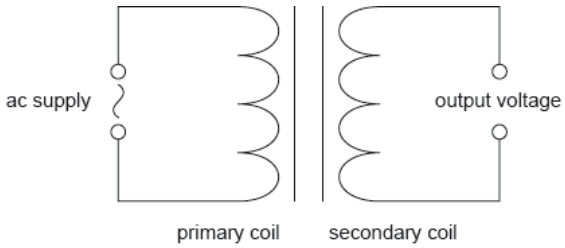


Calculate the magnitude and the sign of the charge on plate A when the capacitor is fully charged.

3c. The capacitor is fully charged and the space between the plates is then filled with a dielectric of permittivity $\varepsilon = 3.0\varepsilon_0$. *[2 marks]*

Explain whether the magnitude of the charge on plate A increases, decreases or stays constant.

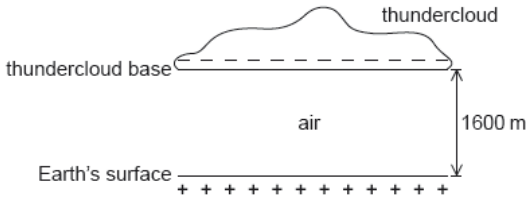
3d. In a different circuit, a transformer is connected to an alternating current (ac) supply. *[3 marks]*



The transformer has 100 turns in the primary coil and 1200 turns in the secondary coil. The peak value of the voltage of the ac supply is 220 V. Determine the root mean square (rms) value of the output voltage.

3e. Describe the use of transformers in electrical power distribution. *[3 marks]*

A negatively charged thundercloud above the Earth's surface may be modelled by a parallel plate capacitor.



The lower plate of the capacitor is the Earth's surface and the upper plate is the base of the thundercloud.

The following data are available.

Area of thundercloud base	$= 1.2 \times 10^{8}\ \text{m}^2$
Charge on thundercloud base	$= -25\ \text{C}$
Distance of thundercloud base from Earth's surface	$= 1600\ \text{m}$
Permittivity of air	$= 8.8 \times 10^{-12}\ \text{F m}^{-1}$

4a. Show that the capacitance of this arrangement is $C = 6.6 \times 10^{-7}$ F. *[1 mark]*

4b. Calculate in V, the potential difference between the thundercloud and the Earth's surface. *[2 marks]*

4c. Calculate in J, the energy stored in the system. *[2 marks]*

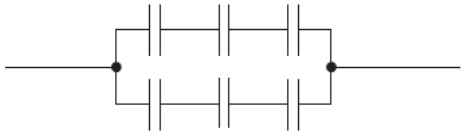
Lightning takes place when the capacitor discharges through the air between the thundercloud and the Earth's surface. The time constant of the system is 32 ms. A lightning strike lasts for 18 ms.

4d. Show that about –11 C of charge is delivered to the Earth's surface. *[3 marks]*

4e. Calculate, in A, the average current during the discharge. *[1 mark]*

4f. State **one** assumption that needs to be made so that the Earth-thundercloud system may be modelled by a parallel plate capacitor. *[1 mark]*

5. Six identical capacitors, each of value C, are connected as shown. *[1 mark]*



What is the total capacitance?

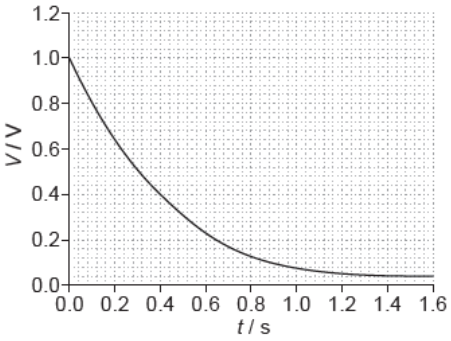
A. $\frac{C}{6}$

B. $\frac{2C}{3}$

C. $\frac{3C}{3}$

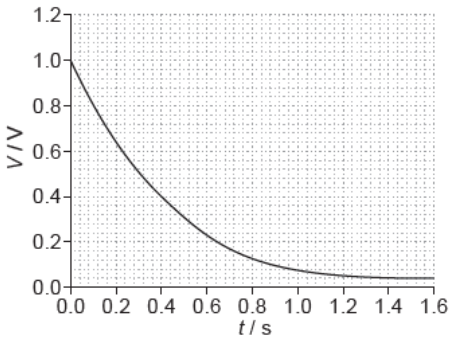
D. $6C$

6. A capacitor of capacitance C discharges through a resistor of resistance R. The graph shows the variation with time t of the voltage V across the capacitor. *[1 mark]*

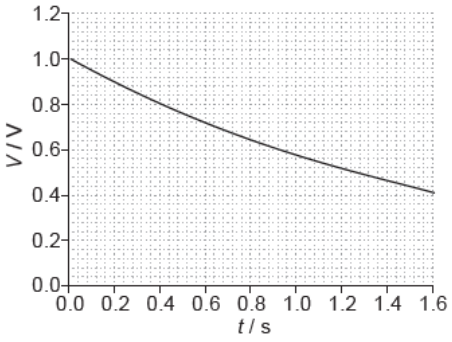


The capacitor is changed to one of value $2C$ and the resistor is changed to one of value $2R$. Which graph shows the variation with t of V when the new combination is discharged?

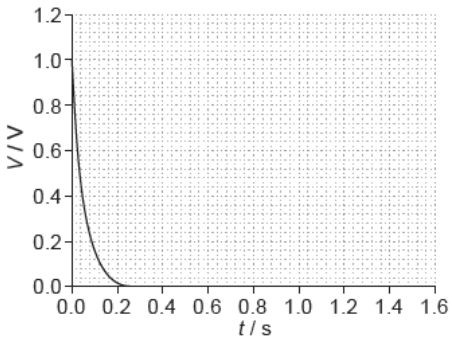
A.



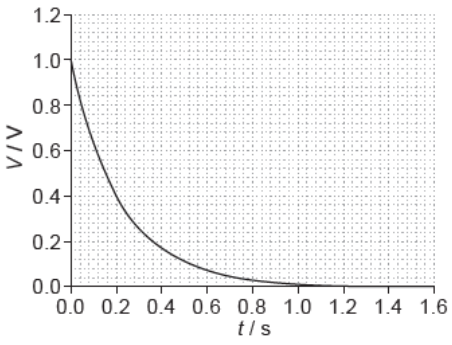
B.



C.



D.



7. A battery is used to charge a capacitor fully through a resistor of resistance R. The energy supplied by the battery is E_b. The energy stored by the capacitor is E_c. *[1 mark]*

What is the relationship between E_b and E_c?

A. $E_b < E_c$

B. $E_b = E_c$

C. $E_b > E_c$

D. The relationship depends on R.

8. A capacitor is charged by a constant current of 2.5 μA for 100 s. As a result the potential difference across the capacitor increases by 5.0 V. *[1 mark]*

What is the capacitance of the capacitor?

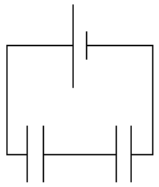
A. 20 μF

B. 50 μF

C. 20 mF

D. 50 mF

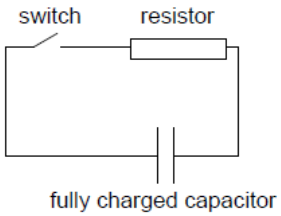
9. Two capacitors of different capacitance are connected in series to a source of emf of negligible internal resistance. *[1 mark]*



What is correct about the potential difference across each capacitor and the charge on each capacitor?

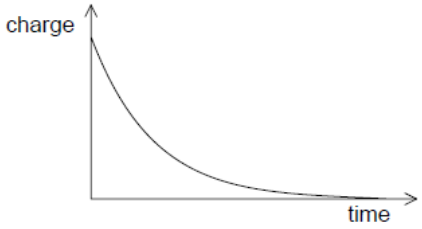
	Potential difference	Charge
A.	same	same
B.	same	different
C.	different	same
D.	different	different

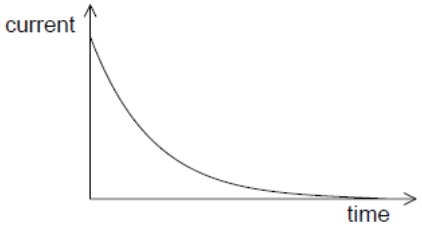
10. A fully charged capacitor is connected to a resistor. When the switch is closed the capacitor will discharge through the resistor. *[1 mark]*



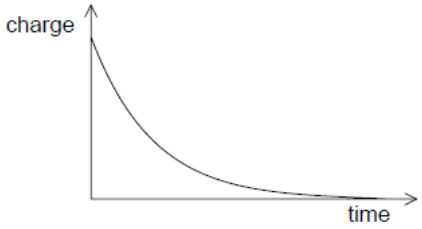
Which graphs correctly show how the charge on the capacitor and the current in the circuit vary with time during the discharging of the capacitor?

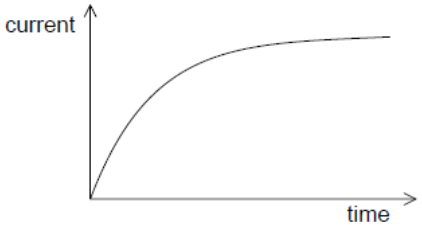
A.



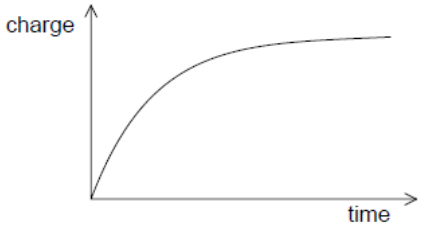


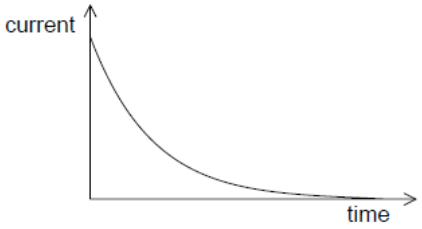
B.



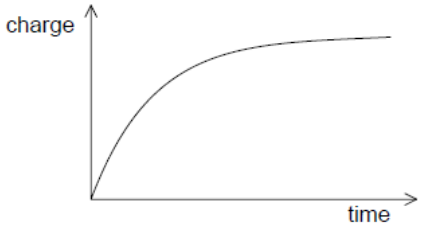


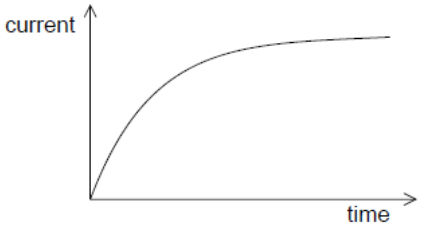
C.



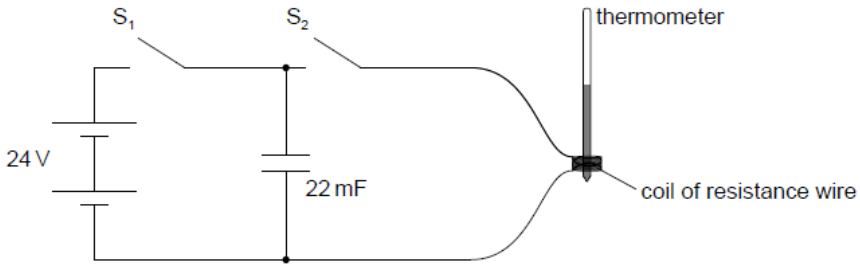


D.





The electrical circuit shown is used to investigate the temperature change in a wire that is wrapped around a mercury-in-glass thermometer.



A power supply of emf (electromotive force) 24 V and of negligible internal resistance is connected to a capacitor and to a coil of resistance wire using an arrangement of two switches. Switch S_1 is closed and, a few seconds later, opened. Then switch S_2 is closed.

11a. The capacitance of the capacitor is 22 mF. Calculate the energy stored in the capacitor when it is fully charged. *[1 mark]*

11b. The resistance of the wire is 8.0 Ω. Determine the time taken for the capacitor to discharge through the resistance wire. Assume that the capacitor is completely discharged when the potential difference across it has fallen to 0.24 V. *[3 marks]*

11c. The mass of the resistance wire is 0.61 g and its observed temperature rise is 28 K. Estimate the specific heat capacity of the wire. Include an appropriate unit for your answer. *[2 marks]*

11d. Suggest **one** other energy loss in the experiment and the effect it will have on the value for the specific heat capacity of the wire. *[2 marks]*

12. A parallel-plate capacitor is connected to a battery. What happens when a sheet of dielectric material is inserted between the plates without disconnecting the battery? *[1 mark]*

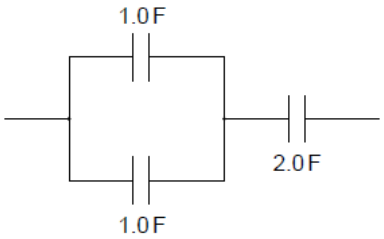
A. The capacitance is unchanged.

B. The charge stored decreases.

C. The energy stored increases.

D. The potential difference between the plates decreases.

13. Three capacitors are arranged as shown. *[1 mark]*



What is the total capacitance of the arrangement?

A. 1.0F

B. 2.5F

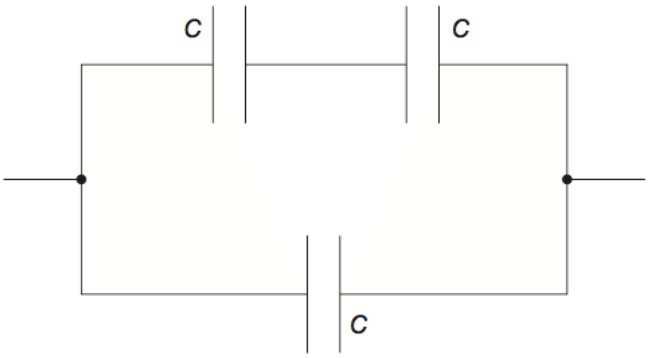
C. 3.0F

D. 4.0F

14. A parallel-plate capacitor is connected to a cell of constant emf. The capacitor plates are then moved further apart without disconnecting the cell. What are the changes in the magnitude of the electric field between the plates and in the capacitance of the capacitor? *[1 mark]*

	Magnitude of the electric field	Capacitance
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

15. Three identical capacitors, each of capacitance *C*, are connected as shown. *[1 mark]*



What is the total capacitance of the combination?

A. $\frac{2}{3}C$

B. *C*

C. $\frac{3}{2}C$

D. 3*C*

16. Which of the following experiments provides evidence for the existence of matter waves? *[1 mark]*

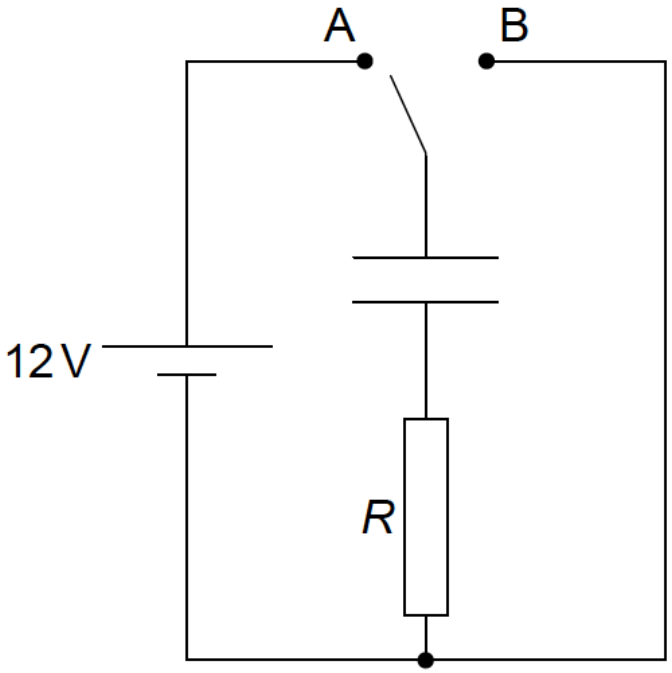
A. Scattering of alpha particles

B. Electron diffraction

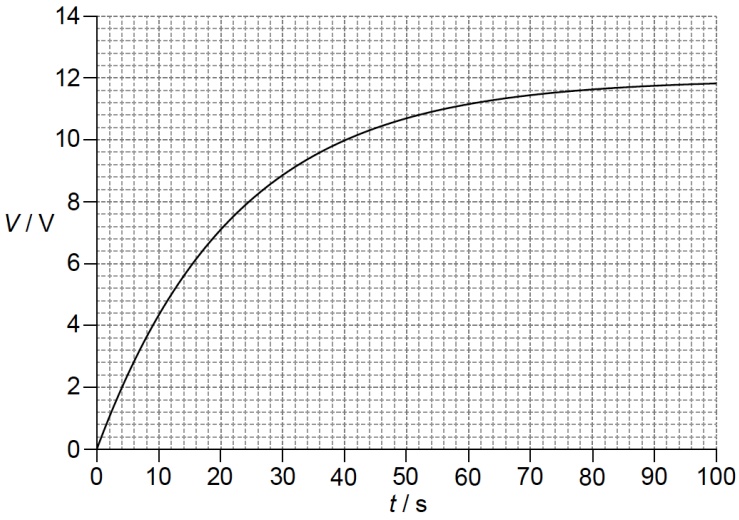
C. Gamma decay

D. Photoelectric effect

An uncharged capacitor in a vacuum is connected to a cell of emf 12V and negligible internal resistance. A resistor of resistance *R* is also connected.



At *t*=0 the switch is placed at position A. The graph shows the variation with time *t* of the voltage *V* across the capacitor. The capacitor has capacitance 4.5μF in a vacuum.



17a. On the axes, draw a graph to show the variation with time of the voltage across the resistor. *[2 marks]*

17b. (i) The time constant of this circuit is 22s. State what is meant by the time constant. *[2 marks]*

(ii) Calculate the resistance *R*.

17c. A dielectric material is now inserted between the plates of the fully charged capacitor. State the effect, if any, on *[2 marks]*

(i) the potential difference across the capacitor.

(ii) the charge on one of the capacitor plates.

17d. (i) The permittivity of the dielectric material in (c) is twice that of a vacuum. Calculate the energy stored in the capacitor when it is fully charged. *[3 marks]*

(ii) The switch in the circuit is now moved to position B and the fully charged capacitor discharges. Describe what happens to the energy in (d)(i).

18. Capacitance of a capacitor is defined as the *[1 mark]*

A. ability to store electrical charge.
B. ratio of charge stored to potential difference.
C. ratio of potential difference to charge stored.
D. ratio of work done to charged stored.

19. The capacitance of a device is defined as the *[1 mark]*

A. charge stored by the device.
B. energy stored by the device.
C. charge stored by the device for a potential difference of 1V across the device.
D. energy stored by the device for a potential difference of 1V across the device.

20. The capacitance of a pixel of a CCD is 3.2 pF. A pulse of light is incident on the pixel and as a result, 10^4 electrons are ejected from the pixel. The magnitude of the change in potential of the pixel is *[1 mark]*

A. $5.0 \times 10^{-16}\ \text{V}$
B. $5.0 \times 10^{-4}\ \text{V}$
C. $2.0 \times 10^{3}\ \text{V}$
D. $2.0 \times 10^{15}\ \text{V}$