QUESTION 1 [Marks 8]

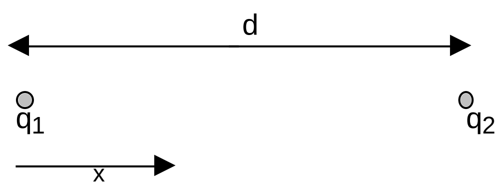
Two vectors are given by:

$$\mathbf{a} = \mathbf{i} + \mathbf{j} + \mathbf{k}$$
$$\mathbf{b} = \mathbf{j} - \mathbf{k}$$

Calculate:
(a) $2\mathbf{a} - \mathbf{b}$
(b) $\mathbf{a} \times \mathbf{b}$
(c) The angle between **a** and **b**.

QUESTION 2 [Marks 10]

A point charge $q_1 = -2C$ is placed at the origin and another point charge $q_2 = +6$ C is placed d = 1 m away along the x-axis. Determine where the electric field is zero.



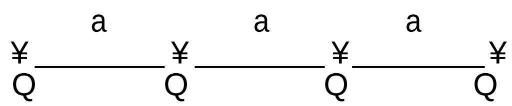
QUESTION 3 [Marks 10]

(a) What does it mean when we say that the electrostatic force is conservative?

(b) The electric potential of a point charge q is given by

$$V(r) = \frac{kq}{r}$$

at a distance r away from it.



Calculate the energy required to assemble four point charges of magnitude Q in a straight line, each separated by distance a from the next, as shown in the diagram.

QUESTION 4 **[Marks 14]**

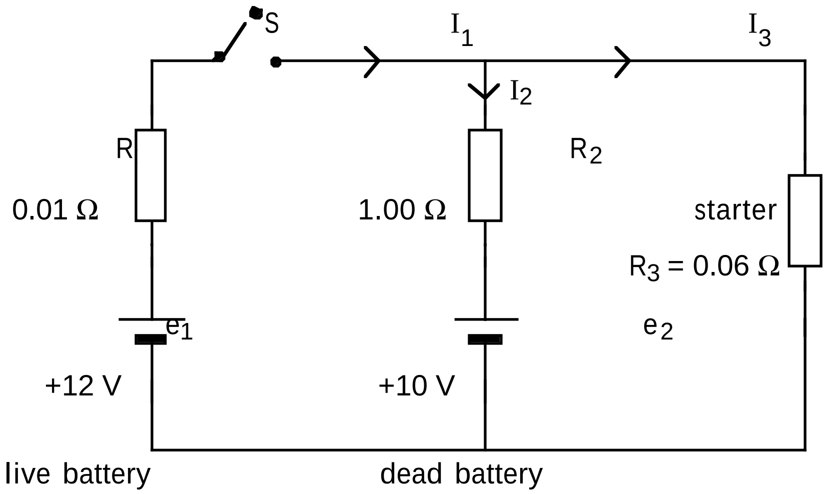
(a) Show that 3 capacitors placed in series in a circuit, with capacitances C_1, C_2 and C_3 respectively, may be replaced by a single capacitor with capacitance C given by

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

(b) A potential difference of 100 V is applied across a 2 C and a 4 C capacitor connected in series. Calculate the charge on each capacitor and the voltage across each capacitor.

(c) The two capacitors are now re-connected, with their positively charged and their negatively charged plates placed together. No external potential difference is applied. For this situation calculate the charge on each capacitor and the voltage across each capacitor.

QUESTION 5 **[Marks 12]**



(a) State and name Kirchhoffs two rules for determining the currents in a circuit containing batteries and resistors. What conservation laws are they derived from?

(b) A dead battery (i.e. one with low charge) is charged by connecting it to the live battery (i.e. of high charge) of another car by jumper cables, as in the diagram. Determine the current in the starter and in the dead battery, when the switch S is closed.

QUESTION 6 **[Marks 14]**

(a) From the magnetic force on a moving charged particle $\underset{\sim}{F} = q\underset{\sim}{v} \times \underset{\sim}{B}$ show that the force in a length L of a current carrying conductor is given by $\underset{\sim}{F} = I\underset{\sim}{L} \times \underset{\sim}{B}$ where I is the current, $\underset{\sim}{B}$ the magnetic induction and $\underset{\sim}{L}$ is in the direction of the current.

(b) Use Amperes law $\oint \underset{\sim}{B}.\underset{\sim}{ds} = {}_{o} I$ to show that the magnetic induction at a distance r from long, straight wire is given by B = $\frac{\mu_o I}{2\pi r}$. In what direction is the field?

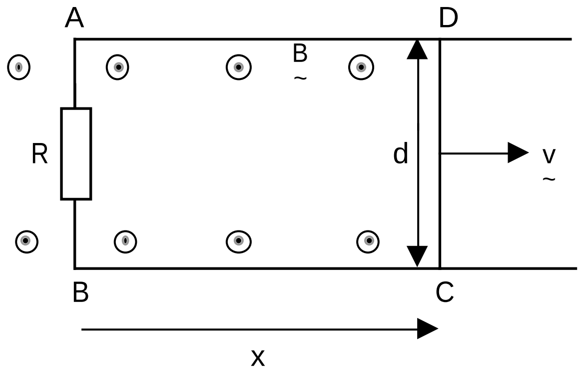
(c) Hence show that the force per unit length between two long, straight, parallel conductors a distance d apart, carrying currents I_1 and I_2, is given by $\frac{\mu_o I_1 I_2}{2\pi d}$.

If the currents are in the same direction is the force attractive or repulsive? Why?

QUESTION 7 **[Marks 12]**

(a) State Faradays law of electromagnetic induction.

(b) In the diagram a conducting rod CD makes contact with parallel metal plates BC and AD, a distance d apart, each with negligible internal resistance. The rails are connected at AB by a resistor R. A uniform magnetic field comes out of the paper, with magnetic induction B. The rod moves to the right at speed v.



Showing your reasoning, derive an expression for the magnitude and direction of the current in loop ABCD.

(c) What force needs to be applied to keep the rod moving at a steady speed?