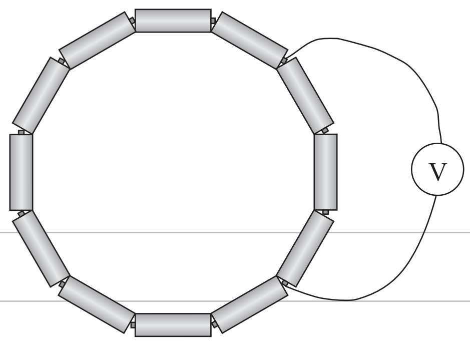
QUESTION FIVE: PHYSICS COMPILATION (8 marks)

(a)



Twelve identical one volt batteries are connected into an electrical circuit as shown in the figure above.

What will be the reading on the voltmeter?

Explain your answer.

Assume each battery has the same internal resistance and the voltmeter has infinite resistance.

(b) The circuit below consists of eight resistors each with resistance r

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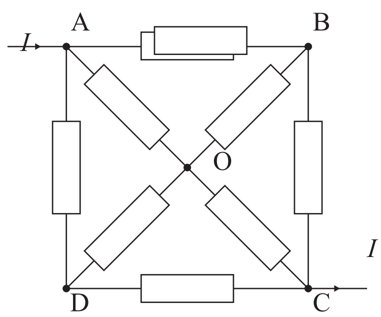

(i) Explain why B and D are at the same potential.

(ii) Calculate the effective resistance between A and C.

ASSESSOR'S USE ONLY

(8)

QUESTION TWO: DC ELECTRICITY (8 marks)

(a) Kirchhoff's Laws are often used in complex circuits and are written as:

- The potential differences around a closed loop sum to zero.
- The currents entering and leaving a junction sum to zero.

(i) Explain the underlying physical meaning of each law.

Kirchhoff's Potential Difference Law

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Kirchhoff's Current Law

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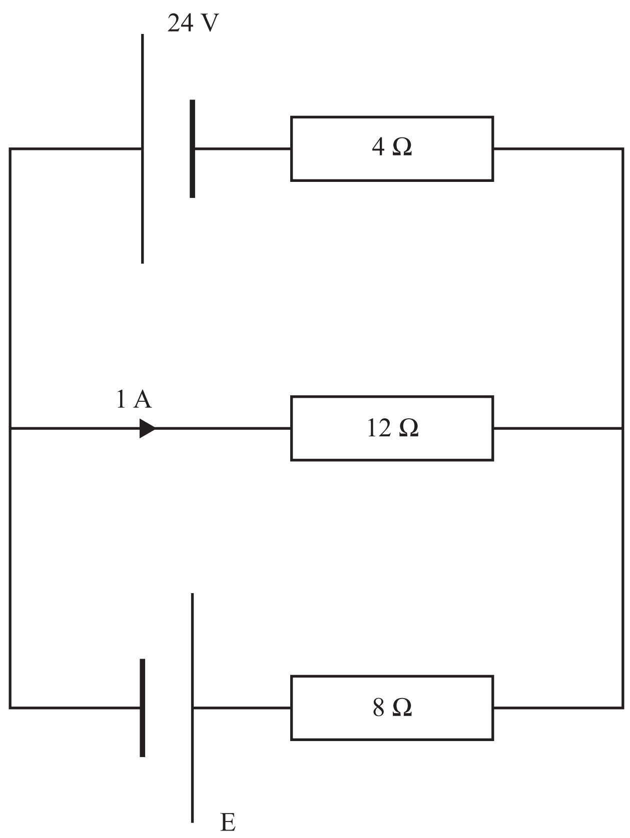
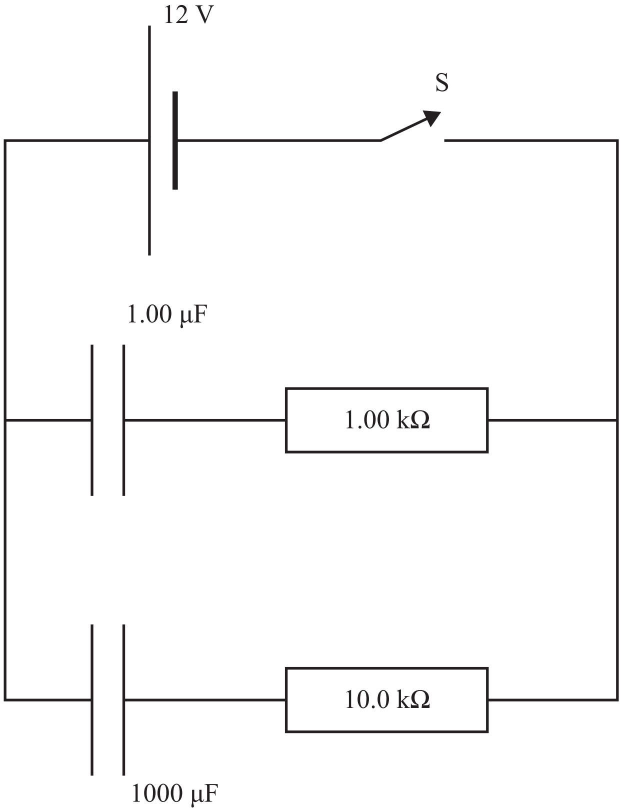
(ii) In the circuit shown below, what is the current in the 8 Ω resistor?



(b) In the circuit below, switch S is initially open and the capacitors are uncharged.



(i) S is closed at $t = 0$.

Discuss how the potential differences across the 1.00 kΩ and the 10.0 kΩ resistors change with time, carefully explaining any differences between them.

(ii) 10.0 seconds after S is closed, it is opened again.

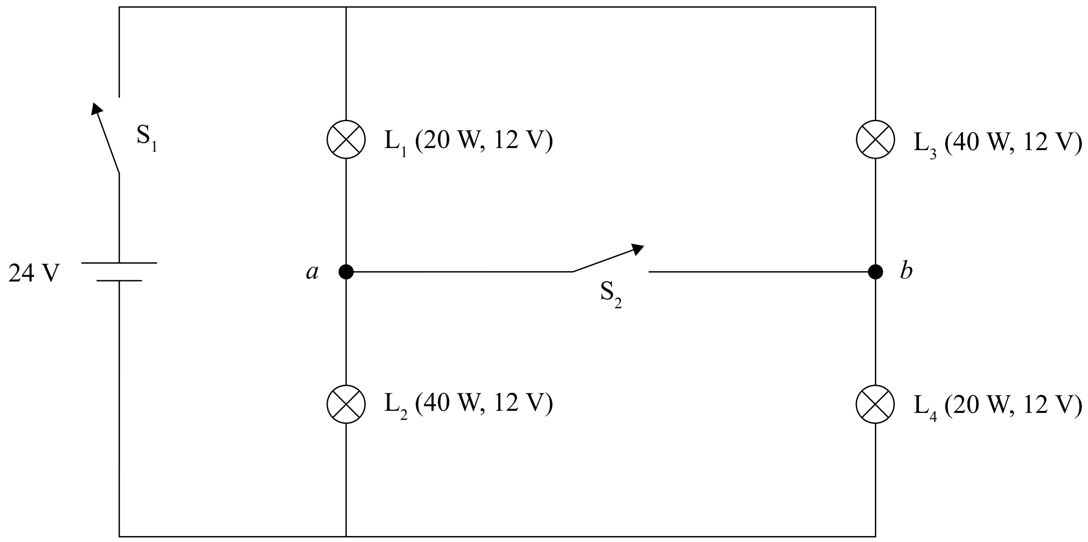
Discuss how the circuit will adjust to this situation, determine the initial current in the resistors when the switch is opened again, and calculate the potential difference across each capacitor when the steady state is reached.

(8)

QUESTION THREE: DC CIRCUITS (6 marks)

Assessor's use only

David and Helen buy four electric lightbulbs from the hardware store. Two of them are labelled 20 W, 12 V and the other two are labelled 40 W, 12 V. They set up the following circuit.



(a) When switches S_1 and S_2 are closed, what is the current through the branch *ab* and in what direction is it?

(b) Switch S_2 is now opened. Explain how the intensities of bulbs L_1 and L_2 change.

(c) David and Helen wish to calculate the potential difference between points a and b, V_{ab}, when switch S_2 is open.

What additional information would they require in order to make this calculation?

(6)

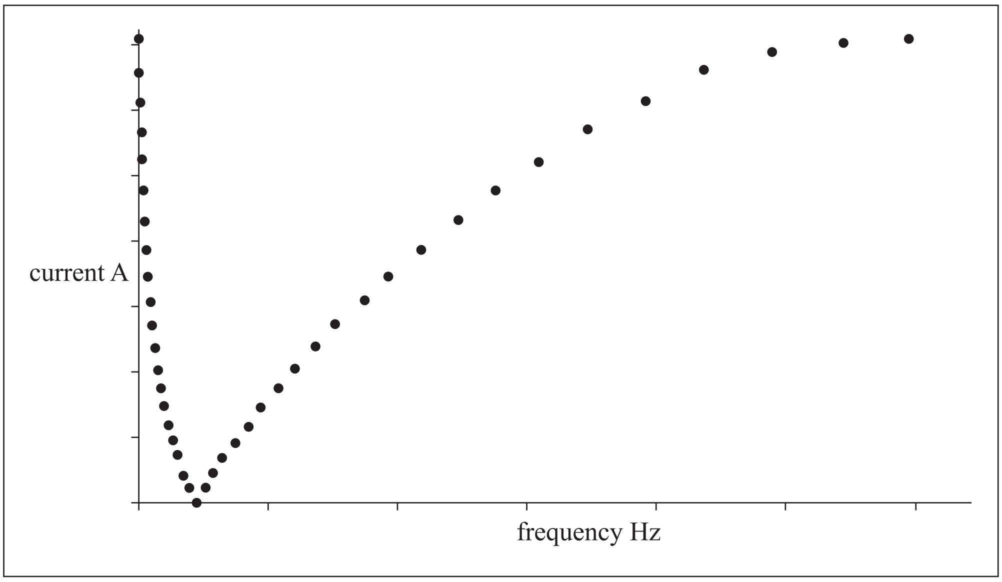
QUESTION FOUR: ELECTRONS EVERYWHERE

Mass of the electron	$= 9.11 \times 10^{-31}$ kg
Charge on the electron	$= -1.60 \times 10^{-19}$ C
Universal gravitational constant	$= 6.67 \times 10^{-11}$ N m^2 kg^{-2}
Coulomb's constant	$= 8.98 \times 10^{9}$ N m^2 C^{-2}

(a) Show that the force of gravitational attraction between a pair of electrons is about 10^{-43} times the force of electrostatic repulsion.

The force of electrostatic repulsion is given by the following equation: $F = \mathrm{k}\dfrac{q_1 q_2}{r^2}$, where k is Coulomb's constant, q is the charge, and r is the separation.

(b) An experimenter is given a black box with two electrical terminals. The experimenter knows that inside the box are exactly one inductor, one capacitor, and one resistor, but does not know the combination of parallel and series connections inside the box. Using an AC generator with variable frequency and fixed voltage, the experimenter measures the magnitude of the AC current as a function of frequency, and obtains the following graph:



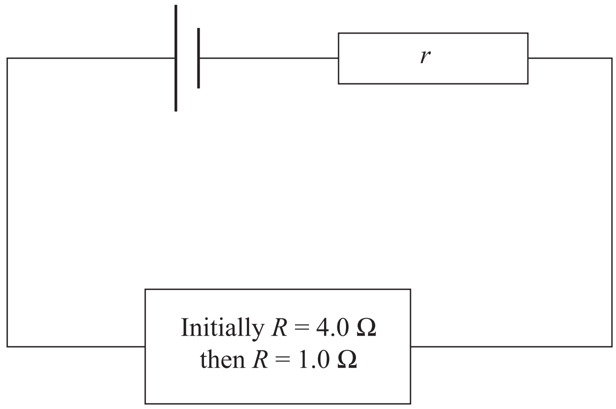
Assuming that the circuit elements are ideal, describe how the three components are connected.

Explain your reasoning.

(c) A resistance of 4.0 Ω is connected across a cell of internal resistance r, as shown below.

The 4.0 Ω resistor dissipates energy at 16 W.

The 4.0 Ω resistor is replaced by a 1.0 Ω resistor, which also dissipates energy at 16 W.



Show that the source voltage must be 12 V.

(d) Explain in detail the key underlying physics of the emission spectra of the hydrogen atom.

(8)

QUESTION FIVE: AC CIRCUITS (8 marks)

In an AC circuit, the RMS current and voltage are related to their peak values by the following two relations:

$$I_{\text{RMS}} = \frac{I_{\text{peak}}}{\sqrt{2}},\ V_{\text{RMS}} = \frac{V_{\text{peak}}}{\sqrt{2}}.$$

(a) Explain why RMS values are needed in AC electricity calculations, but not in DC.

(b) Explain why the expressions connecting RMS and peak values for current and voltage include a factor $\sqrt{2}$.

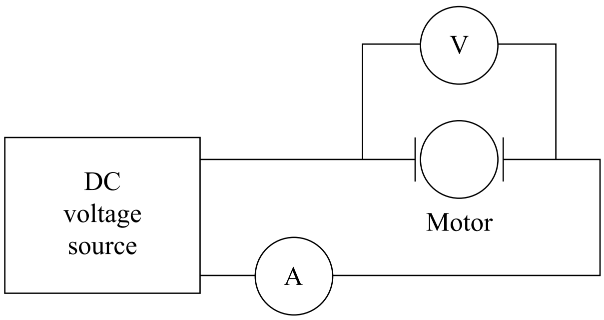
QUESTION SIX: ELECTRIC MOTOR

Shahril has an electric motor. He is intrigued by the similarity between an electric motor and a generator and wonders if his motor generates an emf as well as motion. Shahril devises an experiment to answer this question. His method and results are shown below. Answer the questions to complete his analysis and to reach a conclusion.

Theory

An electric motor consists of a coil of wire rotating in a magnetic field. When the motor is running, the current in the wire interacts with the magnetic field, producing a torque and causing rotation of the coil. If an electric motor is inducing an emf as well as producing motion, then it can be represented by an emf in series with a resistor. Faraday's law states that the induced emf depends on the rate of change of flux.

Method

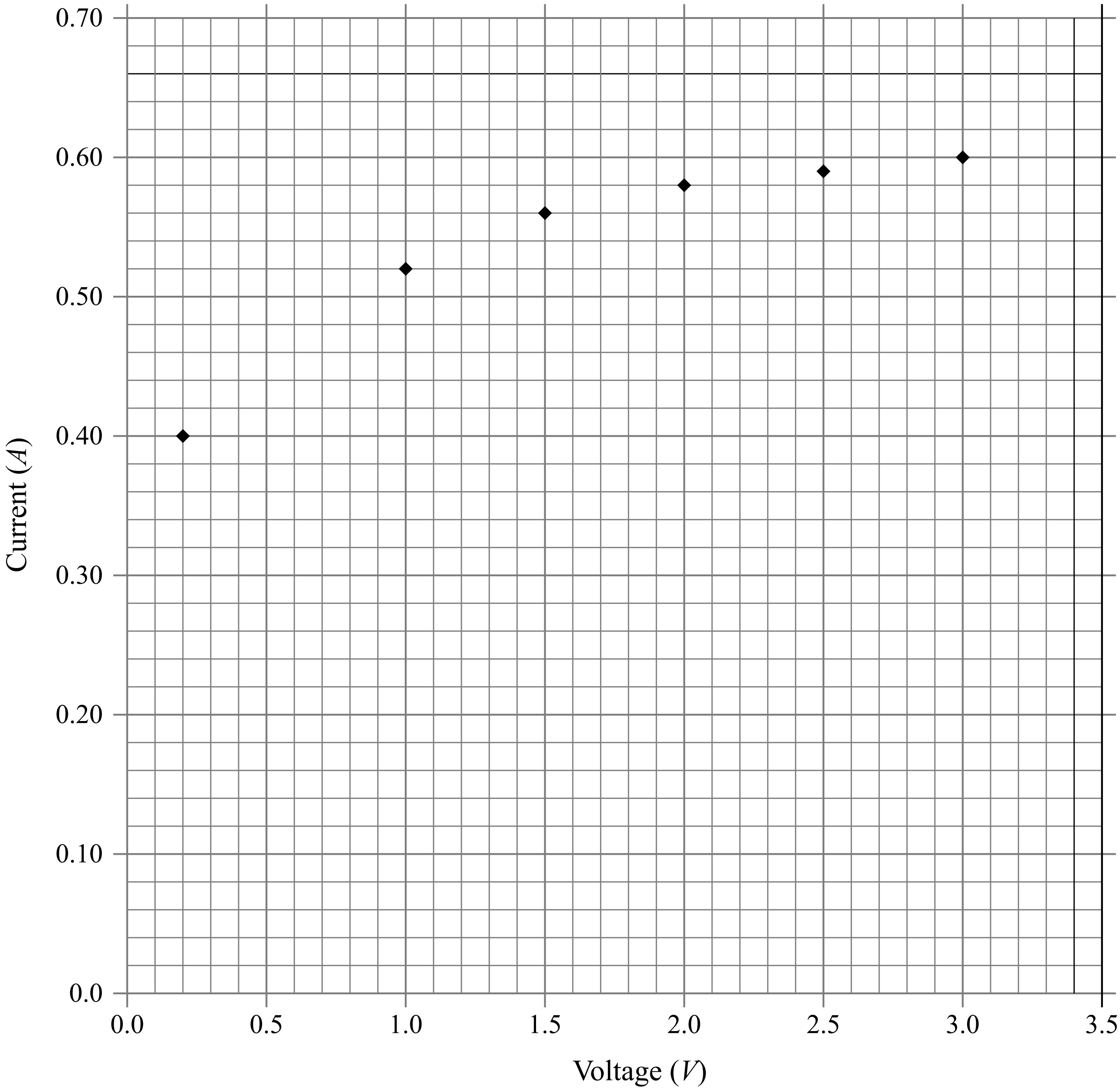


The motor was connected to a variable DC source as shown above. The voltage and current were measured when the coil was stationary and then five values of voltage and current were obtained with the motor turning. The rotation rate was measured using a strobe technique.

Results

Voltage (V)	Current (A)	Rotation rate (rev s^{-1})		
0.2	0.40	0		
1.0	0.52	9		
1.5	0.56	15		
2.0	0.58	21		
2.5	0.59	27		
3.0	0.60	34		

The graph of current plotted against voltage is shown below.



(i) Calculate the resistance, *R*, of the coil when stationary and graph (on the above grid) the relationship that normally exists between I and V for a conductor of resistance, *R*.

resistance = ____________________

(ii) Give an explanation why the voltage and current measurements obtained for the motor are different from the results you would normally expect for a conductor of resistance, R.

(iii) Devise a graphical method that would verify your explanation in part (ii). (*Hint: Are there any variables you would expect to be linearly related?*) Your answer should include a drawn graph.

If you need to redraw this graph, use the spare grid provided on page 28.

(iv) Write a conclusion to summarise and explain your findings.