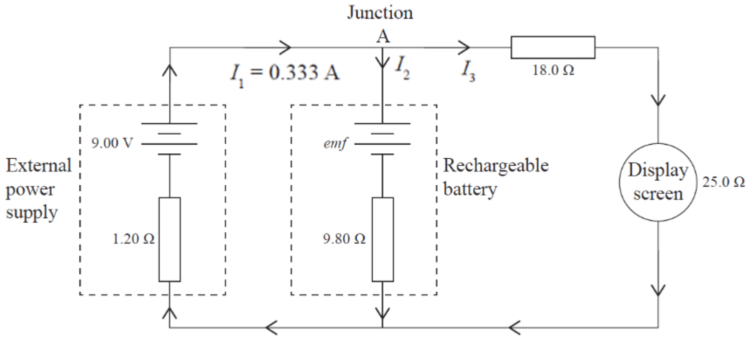
ELECTRICITY: BATTERIES AND KIRCHOFFS LAWS QUESTIONS

QUESTION ONE (2019;1)

Mobile contactless payment systems are used in shops and restaurants throughout New Zealand. The mobile payment machine contains a battery that can be recharged by connecting to an external 9.00 V DC power supply. The terminal voltage of the external power supply drops to 8.60 V DC when the circuit draws 0.333 A of current.

(a) Show that the internal resistance of the external power supply is 1.20 Ω.

While it is recharging, the payment machine displays a charging symbol on its screen. The diagram below shows a simplified model of the charging circuit at one moment in the recharging process.



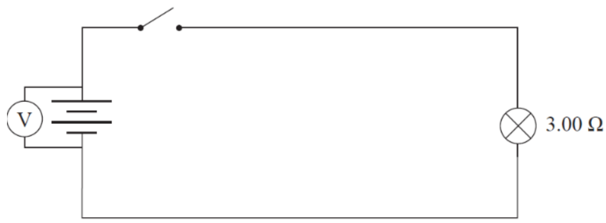
(b) Using Kirchhoff's laws, determine the emf of the rechargeable battery at this moment. Your solution should include:

- an equation showing the relationship between I_1, I_2 and I_3 at Junction A
- a calculation to show that I_3 = 0.200 A.

QUESTION ONE (2018;1)

Casey sets up a battery, a switch, and a 3.00 Ω light bulb in series.

The battery voltage is measured to be 6.02 V when the switch is open. However, when the switch is closed, Casey notices that the battery voltage drops to 5.85 V.

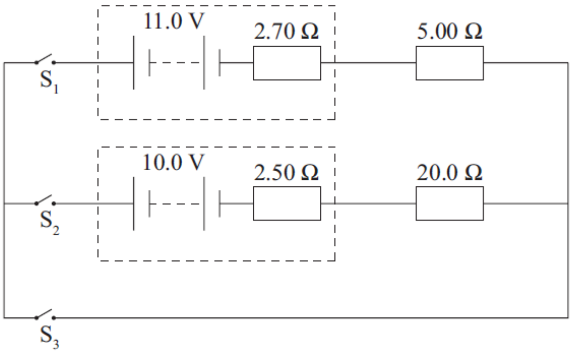


(a) Explain why the battery voltage is less when the switch is closed.

(b) Casey measures the current through the circuit to be 1.89 A. State the EMF, and show that the internal resistance of the battery is approximately 0.09 Ω.

BATTERIES (2014;2)

The circuit diagram shows two batteries connected into a circuit. The internal resistance, r_1, of the 11.0 V battery is 2.70 Ω, and the internal resistance, r_2, of the 10.0 V battery is 2.50 Ω.



(a) Switches S_1 and S_2 are closed and switch S_3 is left open. Show that the current in the circuit is 0.0331 A.

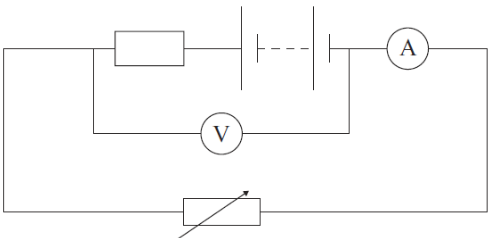
(b) In which direction will the current be flowing through switch S_1? Explain your answer.

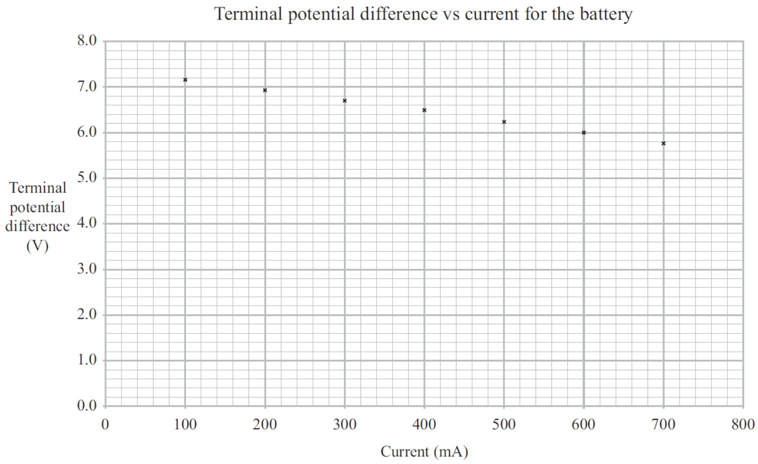
(c) Switch S_3 is now closed so all three switches are closed. Show, using Kirchhoff's laws, that the current through switch S_3 is 1.87 A.

(d) Switch S_1 is now opened, leaving switches S_2 and S_3 closed. After this circuit has been operating for some time, the 10.0 V battery starts to go flat. A student suspects that this is caused by an increase in the internal resistance. Explain what effect a changing internal resistance has on the power delivered to the 20.0 Ω resistor (*A full answer will include some sample calculations).*

THE BATTERY (2012;1)

Hugo has bought a remote-controlled car. He removes the battery from the car and connects it to a variable load that allows him to control the current. Hugo then measures the terminal potential difference using the voltmeter and plots his results on a graph.





(a) Calculate the size of the resistance that Hugo uses to draw a current of 500 mA.

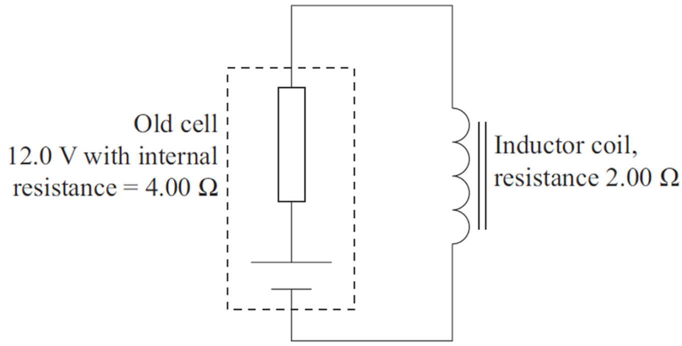
(b) Use the graph to estimate the EMF of the battery. Explain your answer.

(c) Use the graph to calculate the internal resistance of the battery. Explain your answer.

(d) Hugo puts the battery in the car and plays with the car until it is running noticeably slower. He then removes the battery again and repeats the experiment, measuring the terminal potential difference and the current. Draw a line on the graph to show the relationship between the terminal potential difference and current from this used battery. Explain why you have placed the line where you have.

PORTABLE POWER (2010;1)

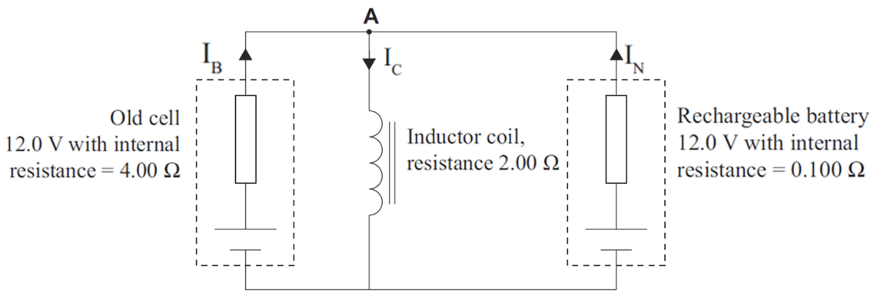
(a) A student connects an old cell to an inductor coil, as shown in the diagram. Calculate the steady current that flows in the circuit.



(b) The student boosts the current by adding a re-chargeable battery with low internal resistance, as shown.

(i) Write an expression for the current at point **A**, in terms of the three currents labelled in the diagram.

(ii) A steady current of 5.58 A flows from the new cell. Using Kirchhoff's Voltage Law, or otherwise, calculate the steady current through the inductor coil.



TORCH INVESTIGATION (2008;1)

Jess is investigating a torch to find out the characteristics of the battery and the lamp. The torch uses a filament lamp. The filament is a long coil of fine wire that heats up and glows when it carries sufficient current. For the purposes of calculation, assume that the resistance of the filament remains constant.

Jess measures the battery voltage when the lamp is switched off and finds the voltage to be 6.12 V. When Jess switches on the lamp, the voltage drops to 5.87 V. The current through the lamp is then 0.743 A.

(a) Name the term used for the potential difference measured when no current is drawn from the battery.

(b) Show that the working resistance of the lamp is 7.90 Ω.

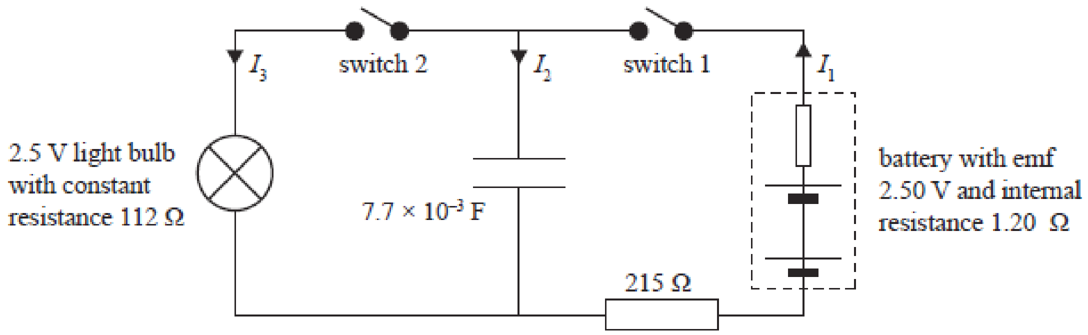
(c) Show that the internal resistance of the battery is 0.336 Ω.

(d) Describe and explain what would be observed if a battery with a higher internal resistance was used in the torch (Assume that the resistance of the lamp remains constant).

(e) Calculate the current that travels through the battery if a second identical lamp is connected in parallel with the first lamp.

CAPACITORS AND LOOPED CIRCUITS (2007;1)

The following circuit was set up to model the operation of a camera flash.



With switch 2 open, switch 1 is closed and the capacitor starts to charge.

(b) Write a Kirchhoff's voltage equation for the closed loop to calculate the initial current in the circuit (the voltage across the capacitor will initially be zero).

The capacitor is then discharged. With switch 2 still closed, switch 1 is now closed to re-charge the capacitor.

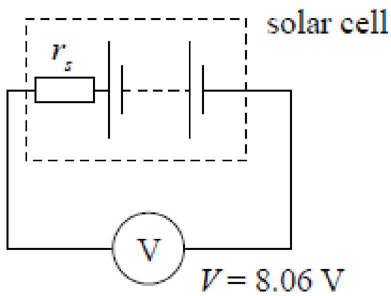
(f) Write a Kirchhoff's current equation for the circuit while the capacitor is charging.

(g) Show that the terminal voltage of the battery, when the capacitor has finished charging, is 2.49 V (the current through the capacitor will now be zero).

(h) When the capacitor is charged, the voltage across the 215 Ω resistor is 1.64 V. Calculate the voltage across the capacitor.

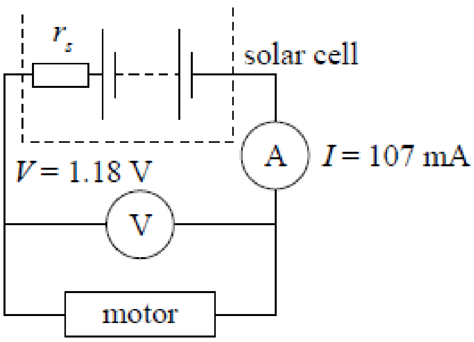
SOLAR RACING (2005;1)

As part of a technology challenge Tui and Richard are building a solar powered model car. They plan to use a solar cell connected to a small motor to drive the car.



They have been told that the internal resistance, r_s, of a solar cell is relatively large and so, before they start, they decide to investigate the electrical properties of the solar cell.

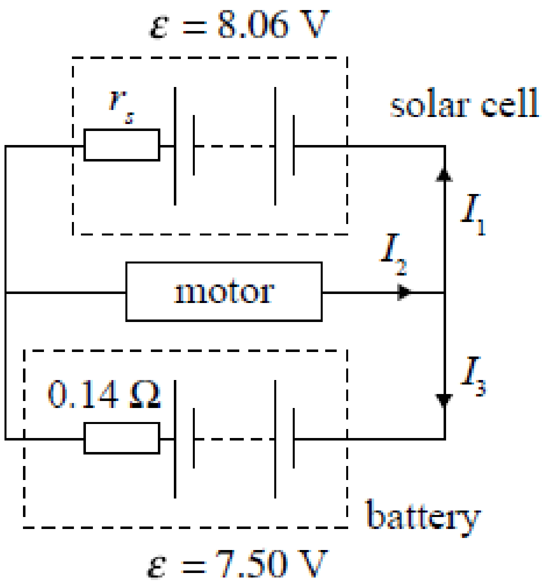
First, they connect the solar cell to a voltmeter with no other components and find the voltage is 8.06 V.



Then they connect the solar cell to the motor. They measure the voltage across the terminals of the cell to be 1.18 V, and the current to be 107 mA.

(a) Show that, in this circuit, the internal resistance of the solar cell is 64.3 Ω.

The arrangement does not make the motor go. Richard suggests they use a battery to drive the motor and then, when the motor isn't going, use the solar cell to charge the battery. A diagram of this arrangement is shown.



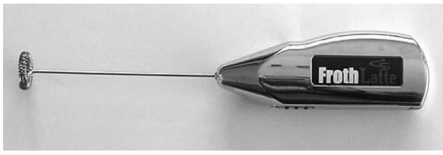
(b) Explain why this arrangement is more likely to make the motor go.
(c) State, in words, Kirchhoff's Voltage Law.

In the circuit, I_1 = 0.029 A, I_2 = 0.674 A and I_3 = 0.645 A.

(d) Calculate the internal resistance, r_s, of the solar cell when connected in this circuit.

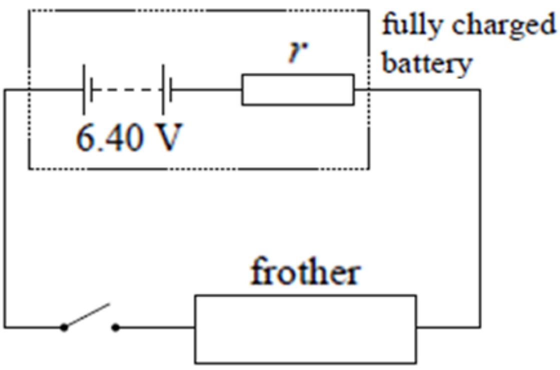
CAPPUCCINO ESSENTIALS (2004;1)

Jodi has a battery-operated rotary whisk that makes frothy milk for her coffee.



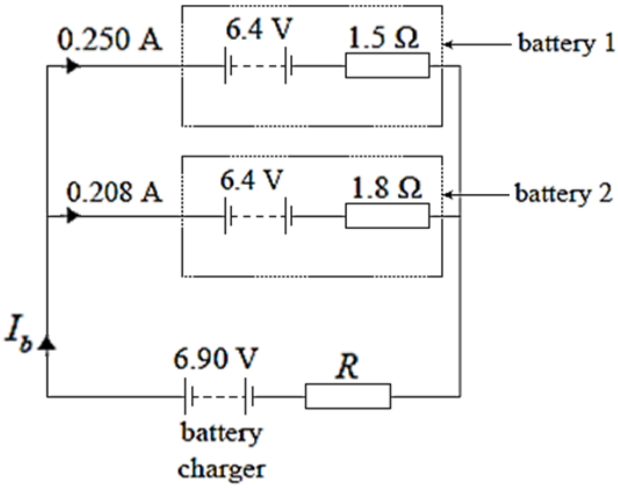
The electrical circuit of the frother is shown below; the motor that drives the frother is shown as a resistor. The battery has an emf of 6.40 V, and when fully charged it has internal resistance r.

At maximum speed the power output of the frother is 4.5 W and this is achieved when the voltage across it is 6.25 V.
(a) Calculate the current through the frother when it is operating at maximum speed.



The frother operates at maximum speed when the battery is fully charged
(b) Calculate the internal resistance, r, of the fully charged battery.

After some time, the frother slows down because the battery is becoming flat. Jodi removes the battery and starts to recharge it, together with another battery that is also flat. The internal resistance of the battery Jodi removed is now 1.5 Ω and the internal resistance of the second flat battery is 1.8 Ω. The battery charger has a voltage of 6.90 V. The initial current through battery 1 is 0.250 A and through battery 2 is 0.208 A. The diagram shows the recharging circuit.



(c) Calculate the current, I_b, through the battery charger.
(d) Calculate the resistance, R, of the resistor.