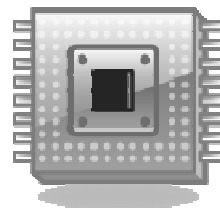
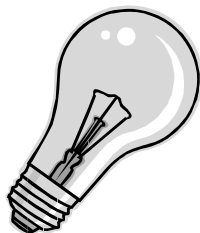


Higher Physics Homework Tutorials

Unit 2

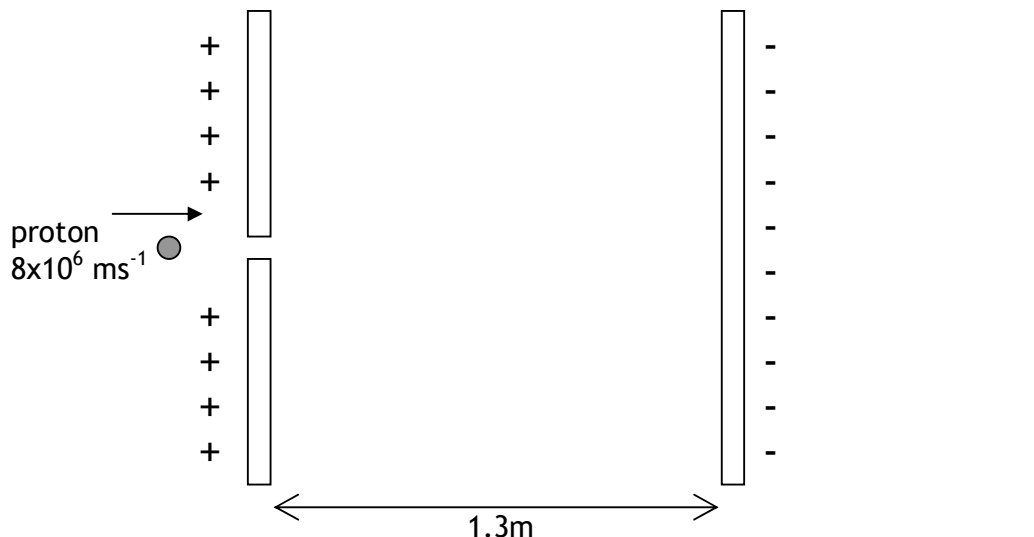
Electricity & Electronics
Version 2.0



Tutorial 1 Charges & Electric Fields

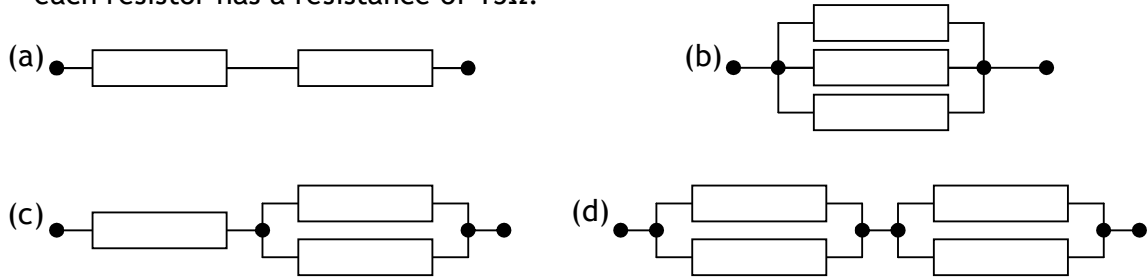
Mass of electron	9.11×10^{-31} kg	Charge on electron	-1.6×10^{-19} C
Mass of proton	1.673×10^{-27} kg	Charge on proton	1.6×10^{-19} C
Mass of neutron	1.675×10^{-27} kg	Charge on neutron	0 C

- Draw a diagram showing the electric field in each of the following:
 - around a positive point charge
 - between a positive point charge and a negative point charge
 - between a positive flat plate and a negative flat plate
- Calculate the work done on a proton which is placed in a 3kV electric field.
- In a particle accelerator, electric fields are used to accelerate sub atomic particles. By equating work done and kinetic energy, find the velocity of each of the following when placed in a 14kV electric field, assuming the particles are initially at rest.
 - a proton
 - an electron
 - an alpha particle (2 protons and two neutrons)
- Calculate the voltage of electric field required to accelerate an electron from rest to 6% of the speed of light in a vacuum.
- Two opposite charged plates are set up as shown and a proton is fired into the field from the left through a small hole in the plate at a velocity of $8 \times 10^6 \text{ ms}^{-1}$. The electric field has a voltage of 6kV. Calculate
 - the work done on the proton by the electric field
 - the initial kinetic energy of the proton when it enters the field
 - the total energy of the proton when it reaches the negative plate
 - the velocity of the proton on reaching the negative plate
 - the average force acting on the proton while in the electric field.

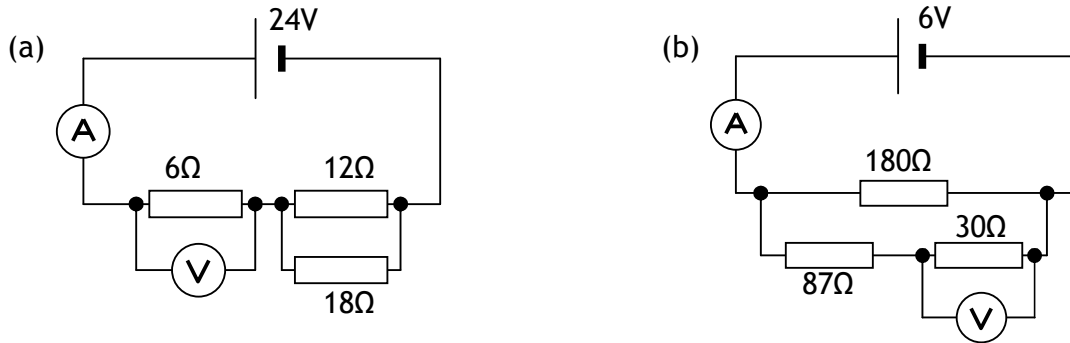


Tutorial 2 Circuits Revision

1. Calculate the total resistance of each of the following combinations of resistors if each resistor has a resistance of 15Ω :



2. Calculate the unknown readings on the voltmeter and ammeter in each circuit:

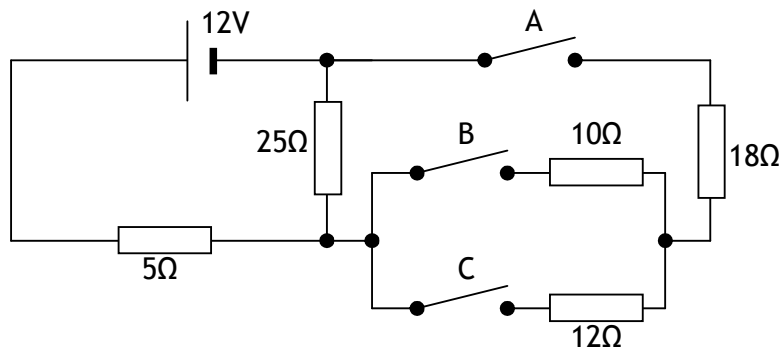


3. Calculate the current drawn by and resistance of the following mains (230V) appliances:

- (a) a 4W phone charger
 (b) a 3kW kettle

4. Calculate the current drawn from the supply in the circuit below when

- (a) all switches are open
 (b) switches A & C are closed, switch B is open
 (c) Switches A, B & C are closed



Tutorial 3 Internal Resistance

1. State what is meant by each of the following
 - (a) the emf of a cell
 - (b) the internal resistance of a cell
 - (c) the 'lost volts' in a circuit
 - (d) the terminal potential difference in a circuit

2. A battery is tested under open circuit conditions with a voltmeter and produces a voltage of 13V. When connected to a 5Ω load resistor, the voltage drops to 12.3V.
 - (a) State the emf of the cell
 - (b) Calculate the internal resistance of the cell

3. An AA cell has an emf of 1.5V and an internal resistance of 1.3Ω . Calculate the following:
 - (a) the short circuit current of the cell
 - (b) the terminal potential difference when connected to a load of 4Ω
 - (c) the current if two identical cells were connected in series to a 6Ω resistor
 - (d) the current if two identical cells were connected in parallel to a 6Ω resistor

4. A battery has an emf of 12V and an internal resistance of 2Ω .
 - (a) Calculate the power output of a 5Ω heater connected to this battery.
 - (b) If a second identical heater is connected in parallel with the first, calculate their total power output.

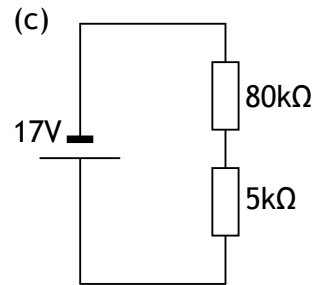
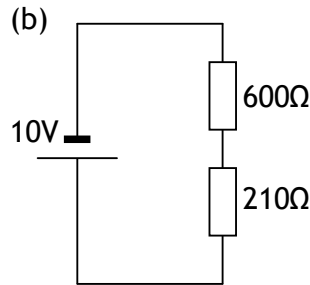
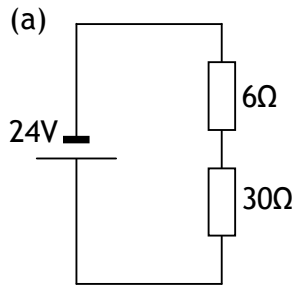
5. Describe in detail an experiment to measure the internal resistance of a cell. Include a circuit diagram, a note of all measurements you would take and a description of any calculations you would perform.

6. Two cells are available. Cell A has an emf of 3V and an internal resistance of 0.6Ω , while cell B has an emf of 5V and an internal resistance of 2.3Ω . Show by calculation which of the two cells will produce the greatest power output when connected to a 3Ω heating element.

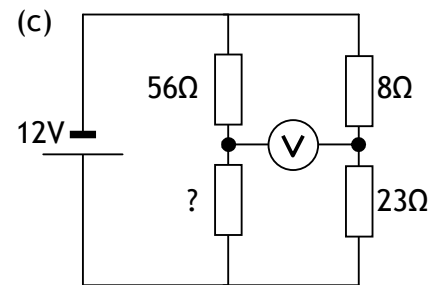
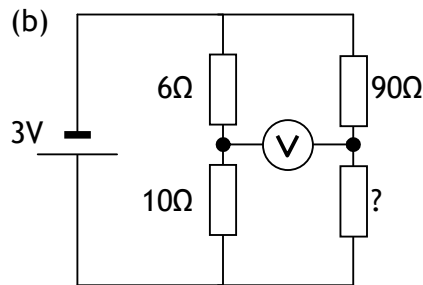
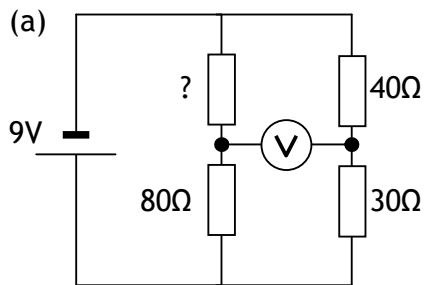
Tutorial 4

Voltage dividers & Wheatstone Bridges

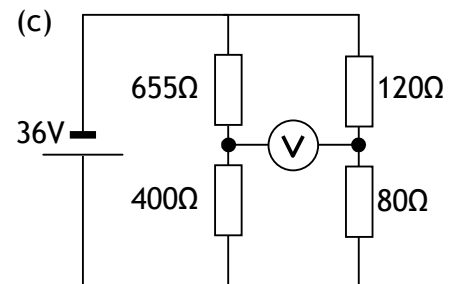
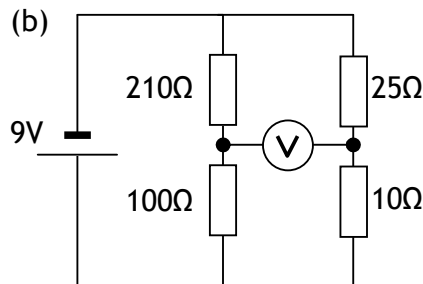
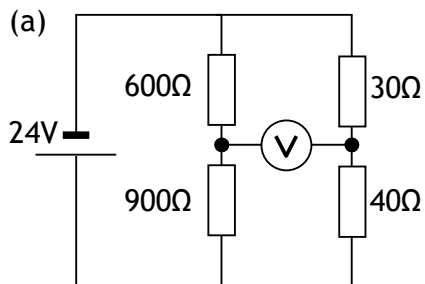
1. In each of the following voltage divider circuits find the voltage across the **larger** resistor.



2. In each of the following Wheatstone bridge circuits, calculate the value of the missing resistor in order to make the reading on the voltmeter zero.

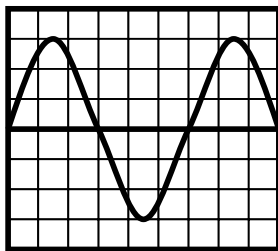


3. By considering the circuits below as two potential dividers, calculate the potential difference across the Wheatstone bridge (the reading on the voltmeter).

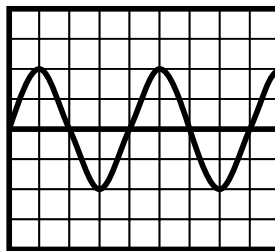


Tutorial 5 AC and DC Voltages & Currents

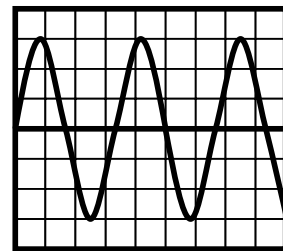
- The following voltages are all given as peak voltages. Calculate the rms equivalent for each:
 - 230 V
 - 11,000 V
 - 50 V
- Using the view on the oscilloscopes shown and the settings noted below each, state the peak value of the voltage and its period, and therefore calculate its frequency.



Time base = 5 ms/div
V Gain = 0.2 V/div



Time base = 50 μ s/div
V Gain = 0.01 V/div



Time base = 0.5 s/div
V Gain = 2 V/div

- The following circuit is supplied with an AC supply which has a peak voltage of 400V. Calculate:
 - the rms voltage
 - the rms current drawn from the supply
 - the peak current drawn from the supply
 - the power dissipated in the load resistor

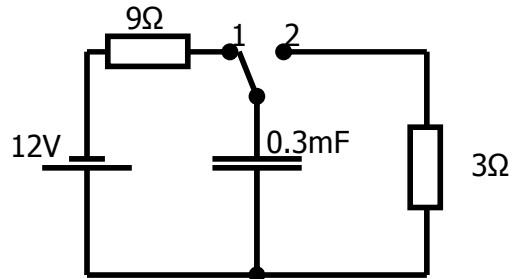


Tutorial 6 Capacitors

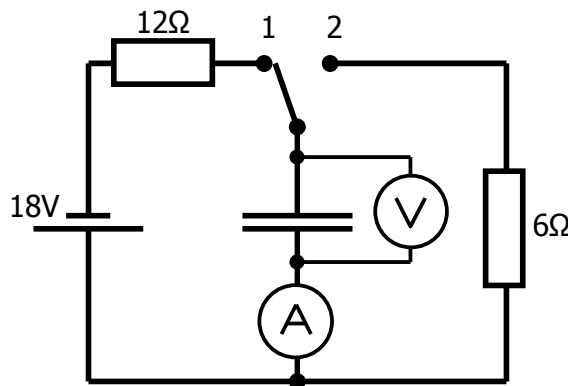
1. A $500\mu\text{F}$ capacitor is charged from a DC supply. Calculate the charge stored on the capacitor when it is charged to:
 - (a) 2V
 - (b) 6V
 - (c) 24V

2. The circuit below is set up to analyse the charging and discharging behaviour of a 0.3mF capacitor. With the two way switch in position 1, the capacitor is allowed to become fully charged. When the switch is moved to position two, the capacitor discharges through the 3Ω load resistor. Calculate:

- (a) The initial charging current
- (b) The current in the 9Ω resistor when the capacitor is fully charged
- (c) The energy stored on the capacitor when fully charged
- (d) The charge stored on the capacitor when fully charged
- (e) The initial discharging current when the switch is moved to position two.



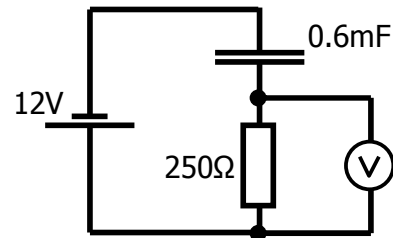
3. A similar charging and discharging circuit to that used in Q2 is used to measure how the voltage across the capacitor and current through it vary with time. The voltage supply is activated at time $t=0$ with the capacitor completely discharged. The capacitor becomes fully charged after 6 seconds. 7s from the start of charging, the switch is moved to position 2 and the capacitor fully discharges in 3 seconds. Calculate numerical values for the voltage and current at $t=0$, $t=6$, $t=7$ and $t=10$ s. Use these values to sketch a graph with numerical values on both axes for
 - (a) the voltage across the capacitor against time
 - (b) the current through the capacitor against time



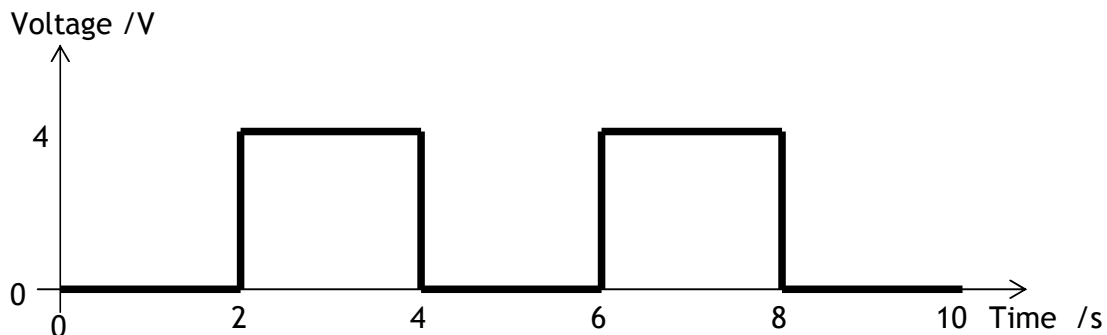
Tutorial 7 Capacitors 2 (extension problem solving)

1. State three common uses for a capacitor in small electrical devices. Describe how it is used in each case.
2. A 400nF capacitor is allowed to fully charge to 9V .
 - (a) Calculate the energy stored on the capacitor at this voltage
 - (b) If the capacitor is allowed to partially discharge such that the energy stored on it is 50% of the energy at full charge, calculate the voltage across the capacitor.
3. To produce the correct level of brightness a camera flash must produce 0.04J of energy. The flash is powered from a $150\mu\text{F}$ capacitor. To what voltage must the capacitor charge in order to provide this much energy?

4. At a point during charging the voltmeter reads 3V in the circuit shown. Calculate:
 - (a) The current in the circuit at this time
 - (b) the charge stored on the capacitor at this time

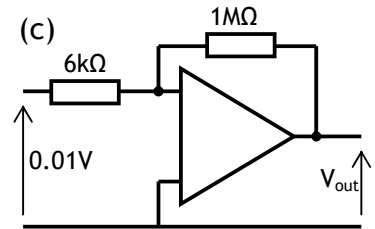
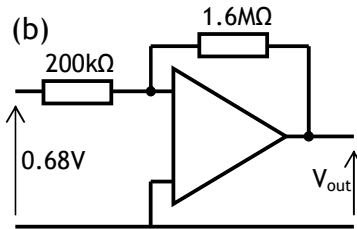
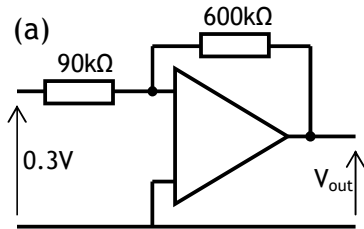


5. A capacitor is charged by a constant current of $20\mu\text{A}$ for 12 seconds and reaches a voltage of 12V . Calculate
 - (a) the charge stored on the capacitor
 - (b) the capacitance of the capacitor
6. The graph below shows the input signal to a circuit from a power supply unit which is connected to a capacitor and resistor in series. Sketch a copy of this graph and add another line to show how the voltage across the capacitor changes with time. Assume that when connected to a 4V DC supply the capacitor takes 1 second to charge and then takes 1.5 seconds to discharge when the power supply is producing no voltage.

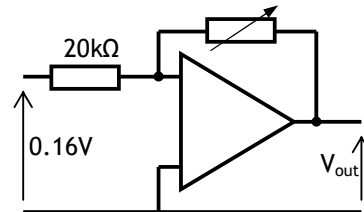


Tutorial 8 Inverting Mode Op-Amps

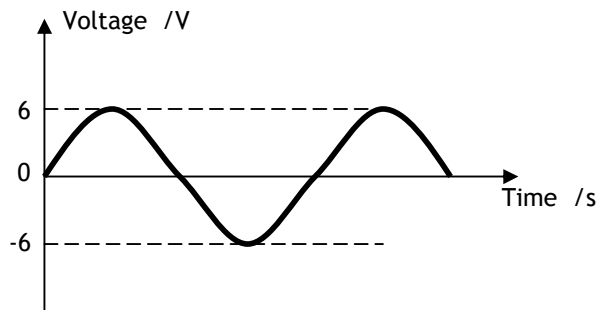
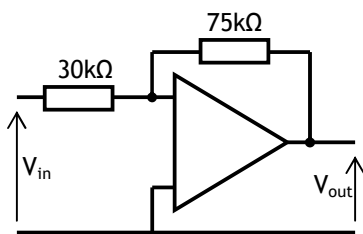
1. For each of the following, calculate the voltage output. Assume that no amplifiers in this question reach saturation.



2. Adjusting the value of the variable resistor in the following circuit will alter the gain of the operational amplifier, which has a saturation voltage of $\pm 13\text{V}$. At what value of resistance will the output voltage of the amplifier become saturated?



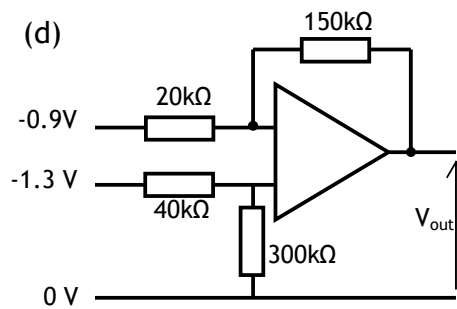
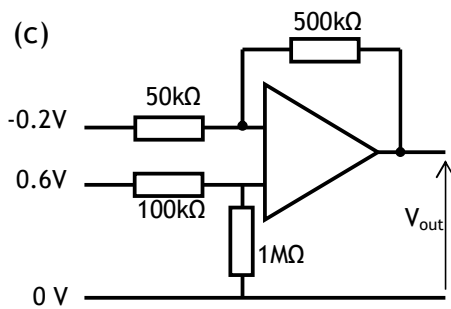
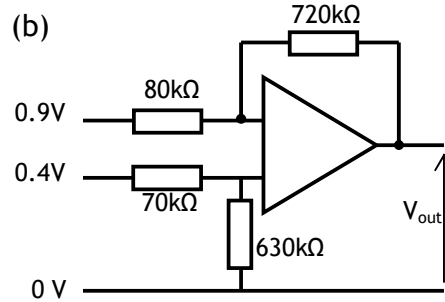
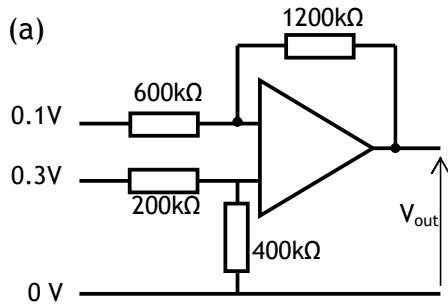
3. The following AC input voltage is applied to the op-amp as shown. Neatly sketch a copy of this graph then add a second line to show how the output voltage varies with time. Numerical values should be included on the voltage axis. Assume that the op-amp saturates at a voltage of $\pm 13\text{V}$.



4. An op-amp is required to produce an output of 9.6V from an input of -0.52V . The saturation voltage of the op-amp is $\pm 12\text{V}$.
- Suggest a combination of feedback and input resistors which would fulfil this requirement.
 - At what input voltage will the op-amp output voltage become saturated?

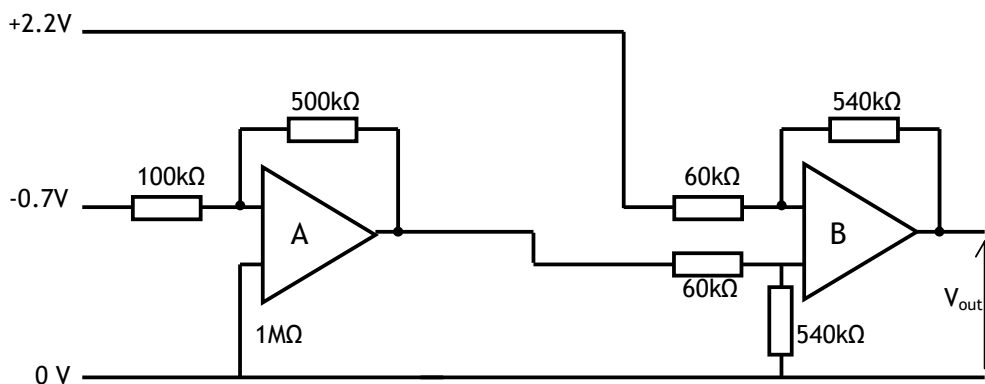
Tutorial 9 Differential Mode Op-Amps

1. Find the output voltage in each of the following differential mode op-amps.



2. An operational amplifier is set up in differential mode fitted with $500\text{k}\Omega$ input resistors and $2\text{M}\Omega$ feedback resistors in their normal positions. The non inverting input has a voltage of 0.4V applied to it. An unknown voltage is applied to the inverting input. The output voltage is measured to be 1.4V .
- Draw the circuit diagram for this op-amp including all the information given in the question.
 - Calculate the unknown voltage.

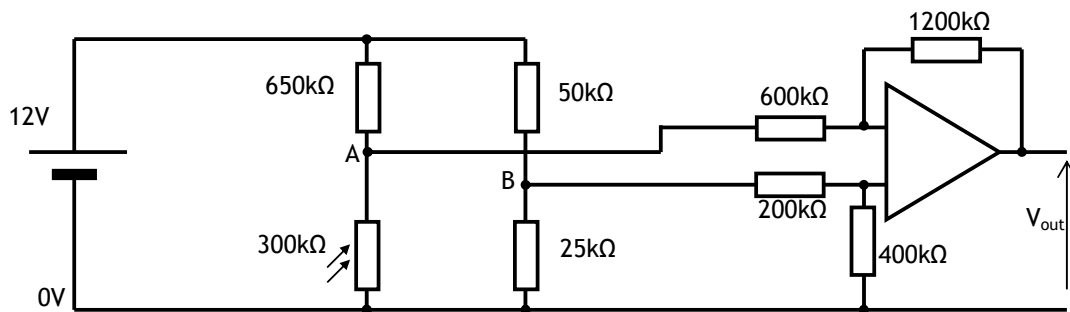
3. Calculate the overall output voltage of the following circuit. Show all your working and state the output voltage after each amplifier.



Tutorial 10 Op-Amp Control Circuits

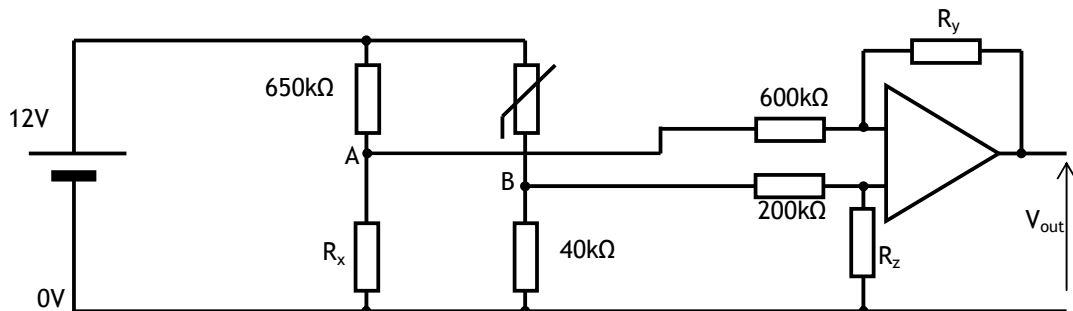
- A wheatstone bridge is setup and is connected to an operational amplifier as shown in the circuit diagram below. The saturation voltage for the op-amp is $\pm 14\text{ V}$. Under current conditions the LDR has a resistance of $300\text{ k}\Omega$.

 - State the mode in which the op-amp is operating
 - Calculate the potential at point A
 - Calculate the potential at point B
 - Calculate the potential difference between point A and point B
 - Calculate the output voltage of the op-amp
 - If the light level changes such that the output voltage is zero, calculate the resistance of the LDR.



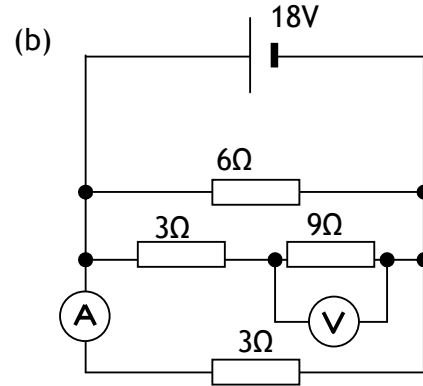
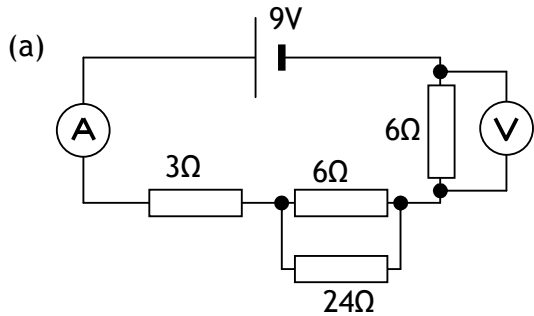
- The circuit below is to be used as a digital thermometer. As the resistance of the thermistor changes, the voltage output will also change and his reading can be converted to a temperature. In order to calibrate the system, you must choose appropriate values of resistor for R_x , R_y , and R_z . You test the resistance of the thermistor at 0°C and 100°C and find the resistances to be $34\text{ k}\Omega$ and $30\text{ k}\Omega$ respectively.

 - Calculate the value of R_x such that the Wheatstone bridge is balanced at 0°C
 - Calculate the potential difference across AB at 100°C
 - Choose values for R_y and R_z such that at 100°C , the output voltage is exactly 1 V



Tutorial 11 Summary

1. Calculate the readings on the voltmeter and ammeter in each of the following circuits



2. An AA cell has an emf of 1.55V. Its internal resistance is 0.9Ω. The cell is connected to a heater which has a resistance of 1.1Ω. Calculate:
- the current in the circuit
 - the terminal potential difference
 - the power generated by the heater
 - the energy supplied by the cell in one minute
 - the total power which would be generated by two identical heaters connected to the same cell in parallel

3. A 120μF capacitor is charged to 23V. It is then allowed to discharge through a 3kΩ resistor. Calculate:
- the energy stored on the capacitor when fully charged
 - the charge stored on the capacitor when fully charged
 - the initial discharge current through the resistor

4. For each of the following op-amp circuits, state which mode the op-am is operating in and calculate the values of any missing voltages or resistances marked with a question mark.

