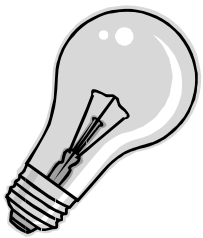
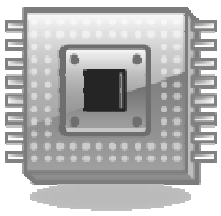
Higher Physics Homework Tutorials

Unit 2

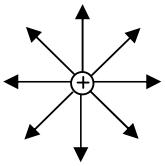
Electricity & Electronics
Version 2.0
Solutions

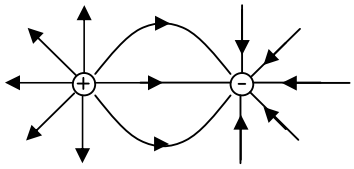


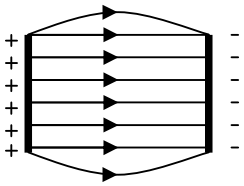


Tutorial 1
Charges & Electric Fields

1. *Draw a diagram showing the electric field in each of the following:*

(a) 

(b) 

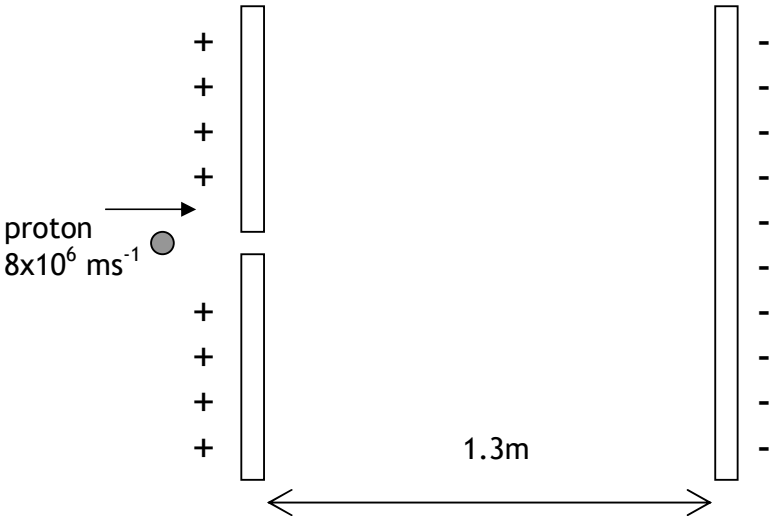
(c) 

2. *Calculate the work done on a proton which is placed in a 3kV electric field.*
   E_w=QV = 1.6×10^{19} x 3000 = 4.8×10^{-16} J

3. *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) 1.6×10^{6} ms^{-1}
   (b) 7.0×10^{7} ms^{-1}
   (c) 1.2×10^{6} ms^{-1}

4. *Calculate the voltage of electric field required to accelerate an electron from rest to 6% of the speed of light in a vacuum.*
   922 V

5. *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 8×10^{6} ms^{-1}. The electric field has a voltage of 6kV. Calculate*
   (a) $E_w = Q\ V = 9.6\times10^{-16}$ J
   (b) $E_k = \frac{1}{2}mv^2 = 5.35\times10^{-14}$ J
   (c) Initial $E_k + E_w = 5.45\times10^{-14}$ J
   (d) 8.1×10^{6} ms^{-1}
   (e) 7.37×10^{-16} N



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:*

   (a) $R_T = 15+15 = 30\ \Omega$
   (b) $R_T = 15/3 = 5\ \Omega$
   (c) $R_T = 15 + (15/2) = 22.5\ \Omega$
   (d) $R_T = (15/2) + (15/2) = 15\ \Omega$

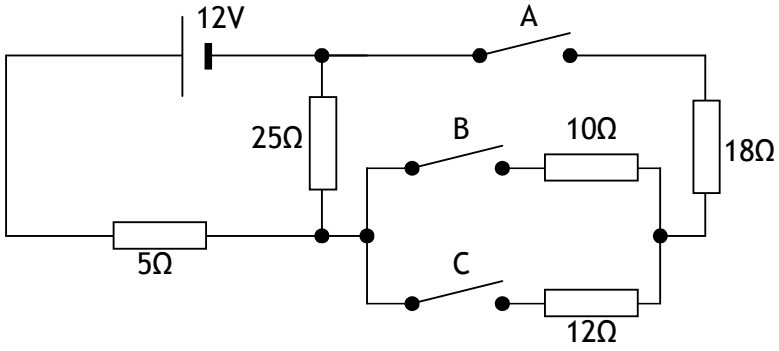
2. *Calculate the unknown readings on the voltmeter and ammeter in each circuit:*

   (a) $R_p=7.2\ \Omega$, $R_t=13.2\ \Omega$, Ammeter reading = 1.82 A
   Voltmeter reading = IR = 10.9 V

   (b) $R_t=70.91\ \Omega$, Ammeter reading = 0.085 A
   Voltmeter reading = voltage divider = 1.54 V

3. *Calculate the current drawn by and resistance of the following mains (230V) appliances:*
   (a) 0.017A
   (b) 13.04 A

4. *Calculate the current drawn from the supply in the circuit below when*
   (a) $R_t=25+5=30\ \Omega$, I=0.4A
   (b) (18+12)Ω in parallel with 25 Ω $R_t=5+13.64=18.64\ \Omega$, I=0.64 A
   (c) (10+12 in par = 5.45 Ω)+18=23.45 Ω
   (23.45 in par with 25)+5 $R_t=17.1\ \Omega$, I=0.70 A



Tutorial 3
Internal Resistance

1. *State what is meant by each of the following*
   (a) energy given to each coulomb of charge
   (b) a resistance caused by the chemicals in the call results in terminal voltage drop
   (c) difference between the emf and tpd, voltage across internal resistance
   (d) the measured voltage across the terminals of the cell

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) 13V
   (b) r=0.28 Ω

3. *An AA cell has an emf of 1.5V and an internal resistance of 1.3Ω. Calculate the following:*
   (a) I_{sc}=1.15 A
   (b) V_{tpd}=1.13 V
   (c) I=0.35 A
   (d) I=0.22 A

4. *A battery has an emf of 12V and an internal resistance of 2Ω.*
   (a) P = 14.7 W
   (b) P = 17.8 W

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.*
   There are a couple of options but basically
   Measure emf by connecting a voltmeter to the cell – no current flowing
   Connect external resistor of known resistance, measure current and tpd
   Use these in $E=V_{tpd}+Ir$

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.

   Cell A - P=2.08 W
   Cell B - P=2.66 W

Tutorial 4
Voltage dividers & Wheatstone Bridges

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

   (a) 20V (b) 7.4V (c) 16V

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.*

   (a) 106.7 Ω (b) 150 Ω (c) 161 Ω

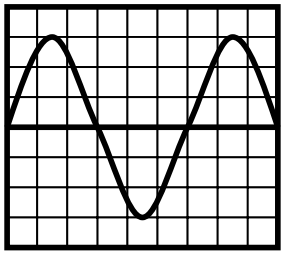
3. *By considering the circuits below as two potential dividers, calculate the potential difference across the Wheatstone bridge (the reading on the voltmeter).*

   (a) 0.69 V (b) 0.33V (c) 0.75V

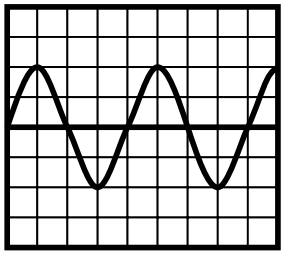
Tutorial 5
AC and DC Voltages & Currents

1. *The following voltages are all given as peak voltages. Calculate the rms equivalent for each:*
   (a) 230 V_{peak} = 162.6 V_{rms}
   (b) 11,000 V_{peak} = 7778 V_{rms}
   (c) 50 V_{peak} = 35.3 V_{rms}

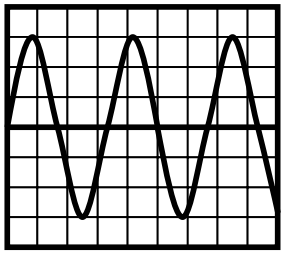
2. *Using the view on the oscilloscopes shown and the settings noted below each, state the peak value of the voltage and its period, and therefore calculate its frequency.*



Time base = 5 ms/div
V Gain = 0.2 V/div
V_{peak} = 0.6V
Period = 30ms
f= 33Hz



Time base = 50 µs/div
V Gain = 0.01 V/div
V_{peak} = 0.02 V
Period = 200 µs
f= 5000 Hz



Time base = 0.5 s/div
V Gain = 2 V/div
V_{peak} = 6 V
Period = 1.67 s
f= 0.6 Hz

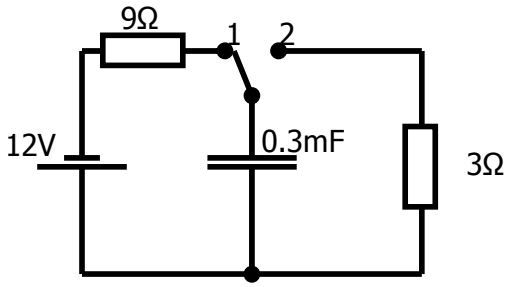
3. *The following circuit is supplied with an AC supply which has a peak voltage of 400V. Calculate:*
   (a) V_{rms}=282.8 V
   (b) I_{rms}=11.3 A
   (c) I_{peak}=16 A
   (d) P = 3192 W

Tutorial 6
Capacitors

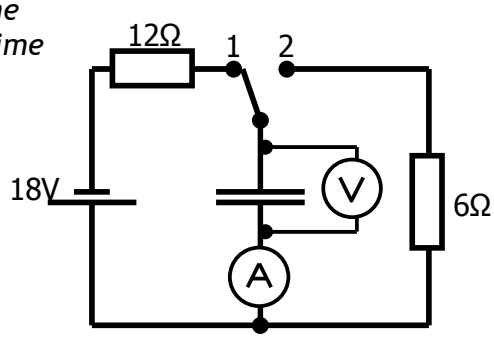
1. *A 500μF capacitor is charged from a DC supply. Calculate the charge stored on the capacitor when it is charged to:*
   (a) 1 mC
   (b) 3 mC
   (c) 0.012 C

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:*

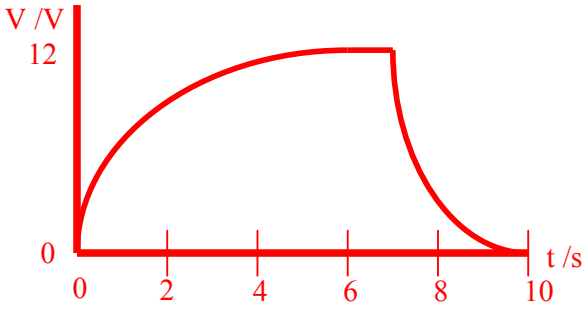
   (a) I = 1.33 A
   (b) Fully charged current = 0 A
   (c) E = 0.036 J
   (d) Q = 3×10^{-3} C
   (e) I = 4 A

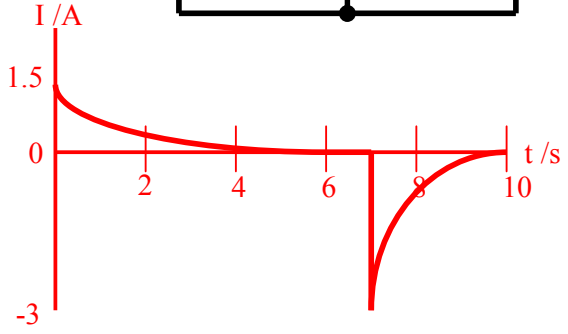


3. *A similar charging and discharging circuit to that used in Q2 is used to measure how the voltage across the capacitor and current through it vary with time.*
   The voltage supply is activated at time=0 with the capacitor completely discharged.
   The capacitor becomes fully charged after 6 seconds.
   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=10s.
   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



		(a)		(b)
t=0	-	0	-	1.5A
t=6	-	12V	-	0A
t=7	-	12V	-	-3A
t=10	-	0V	-	0A





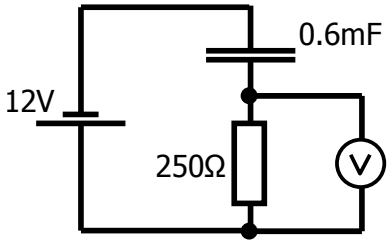
Tutorial 7
Capacitors 2 (extension problem solving)

1. *State three common uses for a capacitor in small electrical devices. Describe how it is used in each case.*
   Camera – store energy for quick release in flash
   Tuning – Filter out low or high frequency
   Time delay lights (interior in cars) – keeps lights on for a few seconds after power supply is removed

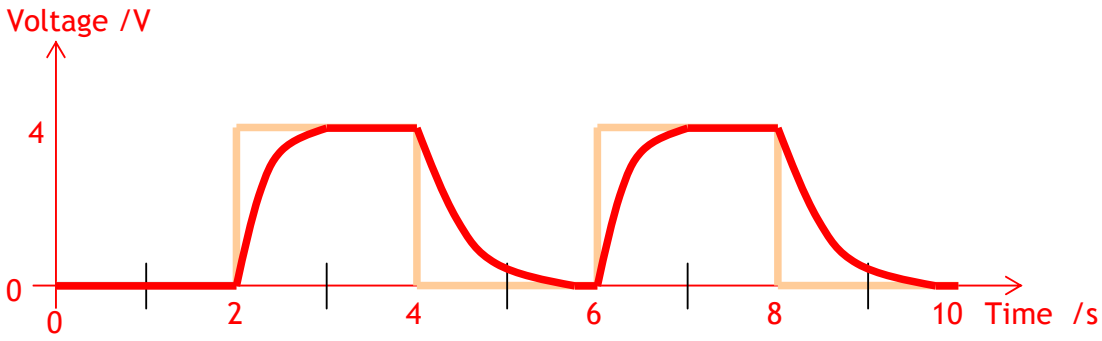
2. *A 400nF capacitor is allowed to fully charge to 9V.*
   (a) 1.62×10^{-5} J
   (b) 6.63 V

3. *To produce the correct level of brightness a camera flash must produce 0.04J of energy. The flash is powered from a 150μF capacitor. To what voltage must the capacitor charge in order to provide this much energy?*
   23 V

4. *At a point during charging the voltmeter reads 3V in the circuit shown. Calculate:*
   (a) 0.012 A
   (b) 5.4×10^{-3} C

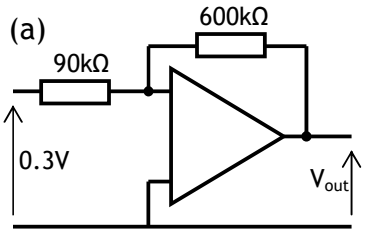


5. *A capacitor is charged by a constant current of 20μA for 12 seconds and reaches a voltage of 12V. Calculate*
   (a) $Q=It=2.4 \times 10^{-4}$ C
   (b) 20 μF

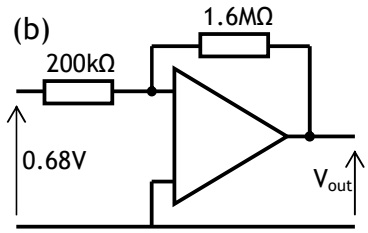
6. 

Tutorial 8
Inverting Mode Op-Amps

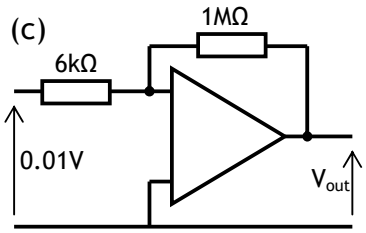
1. *For each of the following, calculate the voltage output. Assume that no amplifiers in this question reach saturation.*



$V_{out} = -2V$

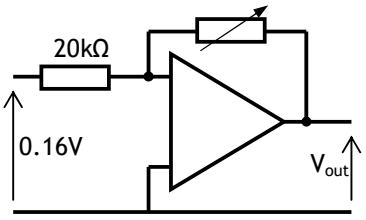


$V_{out} = -5.44V$



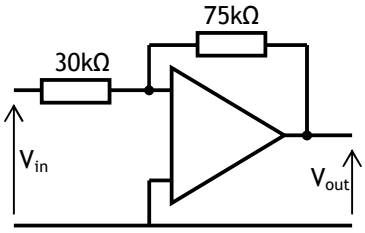
$V_{out} = -1.67V$

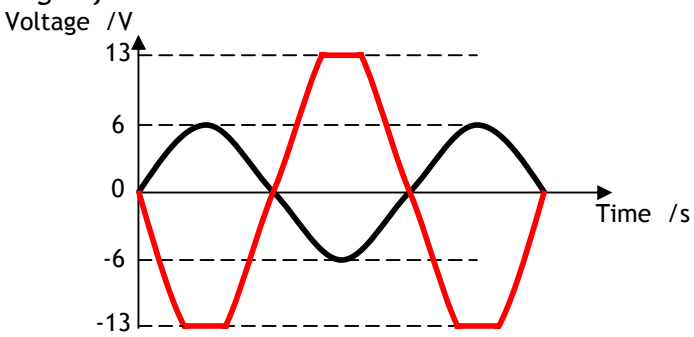
2. *Adjusting the value of the variable resistor in the following circuit will alter the gain of the operational amplifier, which has a saturation voltage of ±13V. At what value of resistance will the output voltage of the amplifier become saturated?*



$R_f = 1.625\ M\Omega$

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 ±13V.*

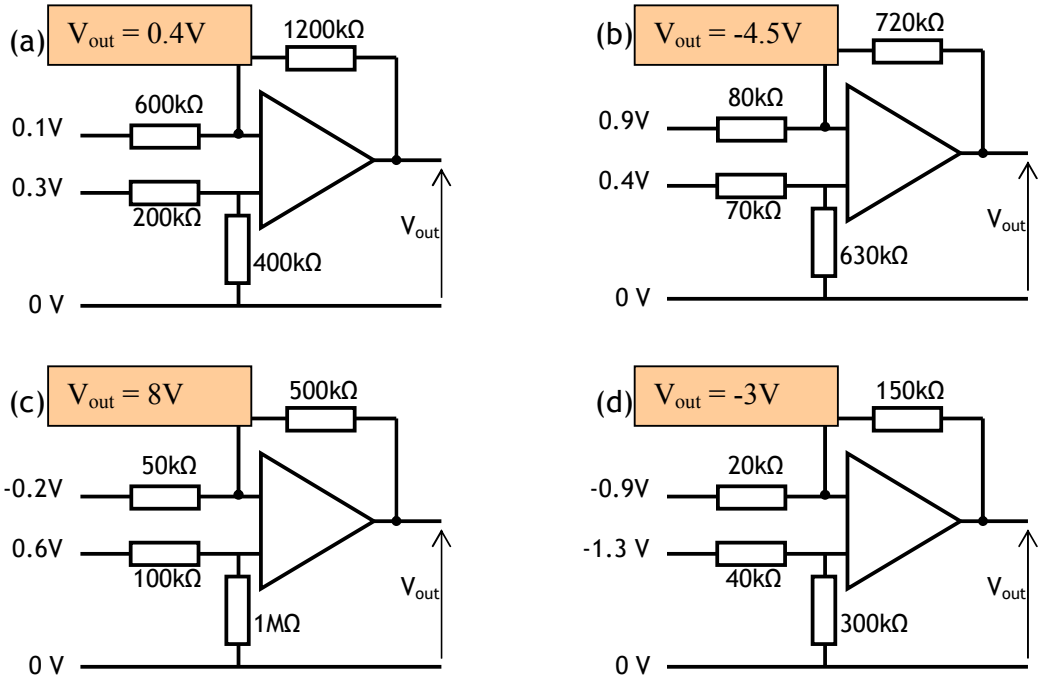




4. *An op-amp is required to produce an output of 9.6volts from an input of -0.52V. The saturation voltage of the op-amp is ±12V.*
   (a) Suggest a combination of feedback and input resistors which would fulfil this requirement.
   Any combination of resistors such that $R_f/R_1=18.46$
   (b) At what input voltage will the op-amp output voltage become saturated?
   $V_{in}=0.65V$

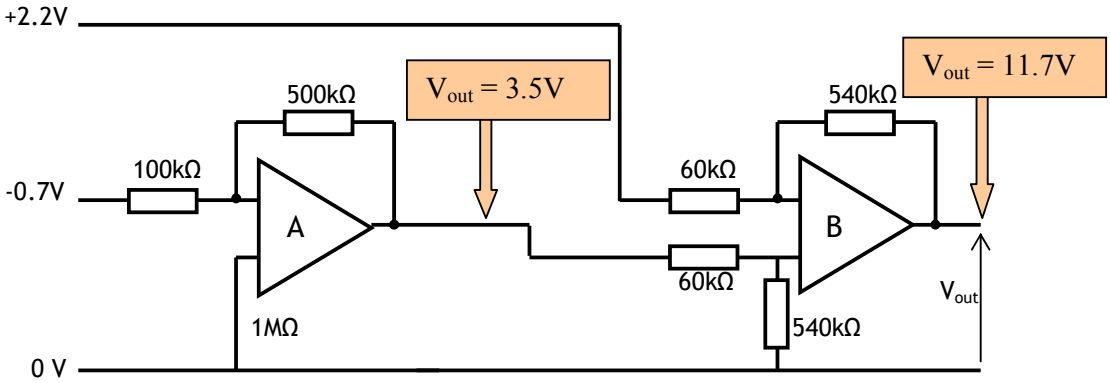
Tutorial 9
Differential Mode Op-Amps

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



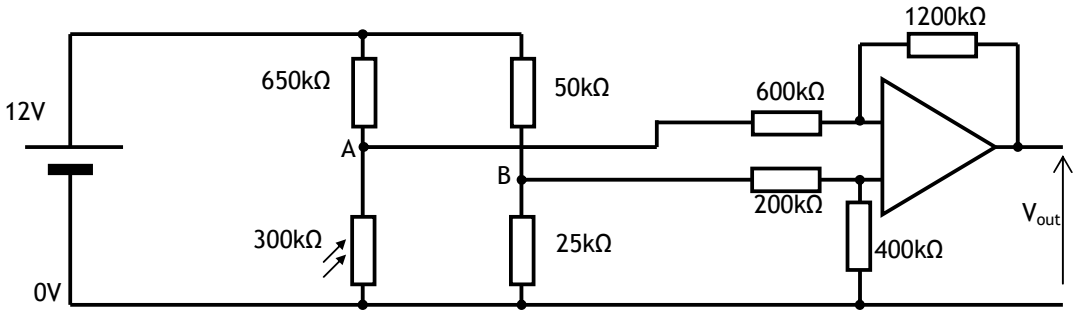
2. *An operational amplifier is set up in differential mode fitted with 500kΩ input resistors and 2MΩ feedback resistors in their normal positions. The non inverting input has a voltage of 0.4V applied to it. An unknown voltage is applied to the inverting input. The output voltage is measured to be 1.4V.*
   (a) Draw the circuit diagram for this op-amp including all the information given in the question.
   (b) Calculate the unknown voltage. V_1=+0.05V

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

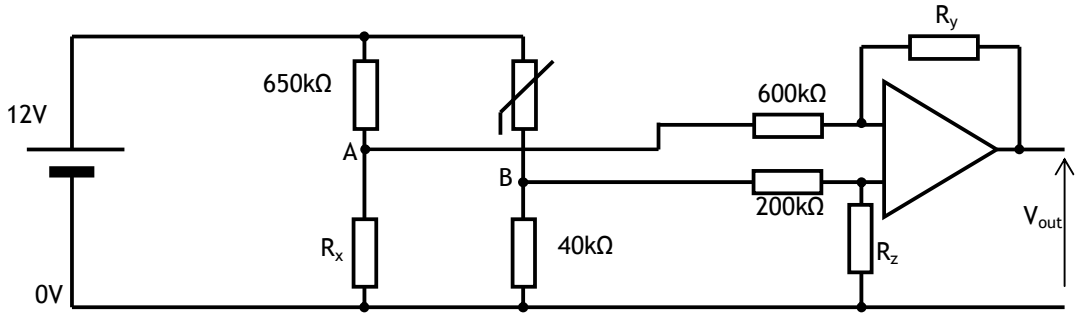


Tutorial 10
Op-Amp Control Circuits

1. *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 ±14 V. Under current conditions the LDR has a resistance of 300kΩ.*
   (a) State the mode in which the op-amp is operating Differential Mode
   (b) Calculate the potential at point A 3.79V
   (c) Calculate the potential at point B 4V
   (d) Calculate the potential difference between point A and point B 0.21V
   (c) Calculate the output voltage of the op-amp 0.42 V
   (d) If the light level changes such that the output voltage is zero, calculate the resistance of the LDR. If $v_{out}=0$, $V_A=V_B$, $R_{LDR}=325\Omega$

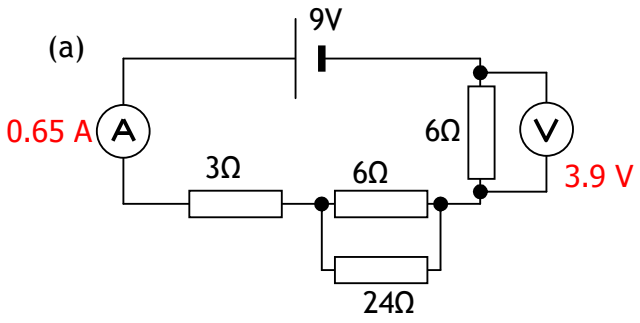


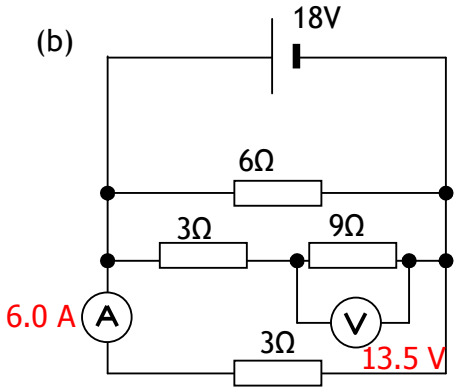
2. *The circuit below is to be used as a digital thermometer. As the resistance of the thermistor changes, the voltage output will also change and his reading can be converted to a temperature. In order to calibrate the system, you must choose appropriate values of resistor for R_x, R_y, and R_z.*
   You test the resistance of the thermistor at 0°C and 100°C and find the resistances to be 34kΩ and 30kΩ respectively.
   (a) $R_x=765\Omega$
   (b) $V_A=6.48V$ … $V_B=6.86V$ … $V_{AB}=0.37V$
   (c) $R_y=162M\Omega$ … $R_z=54M\Omega$



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:*
   (a) 0.78 A
   (b) 0.86 V
   (c) 0.67 W
   (d) 73 J
   (e) 0.63 W

3. *A 120μF capacitor is charged to 23V. It is then allowed to discharge through a 3kΩ resistor. Calculate:*
   (a) 0.032 J
   (b) 2.8 mC
   (c) 7.7mA

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.*