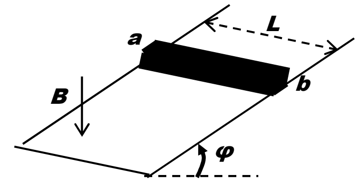
In each problem express your answer in terms of known variables listed for that problem.
In addition to the known variables, all mathematical and physical constants are also known (***R***, ***π***, ***g***, ε_o , ***G***, μ_o ***...)***
Not all variables need to be used in your answers. Show your work, box your answers, check units.

Problem 1(total: 20 points)

The known variables are ***L R m φ***

A metal bar of length ***L***, resistance ***R*** and weight ***m*** is placed on a frictionless rail inclined at angle ***φ*** as shown. The rails have negligible electric resistance. A uniform magnetic field of magnitude ***B*** is directed downward as shown. The bar is released from rest and slides down the rail

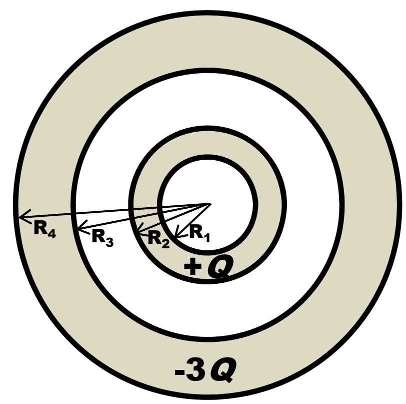


1) In which direction is the current flowing in the bar (from ***a*** to ***b*** or from ***b*** to ***a***)? The answer involves the right hand rule; draw a three-vector schematic to justify your answer.
2) What is the terminal speed ***v*** of the bar?
3) Conceptual question: power is dissipated in the resistor, by conservation of energy where is this power coming from?

Problem 2 (total: 20 points)

The known variables are: R_1 R_2 R_3 R_4 ***Q r***

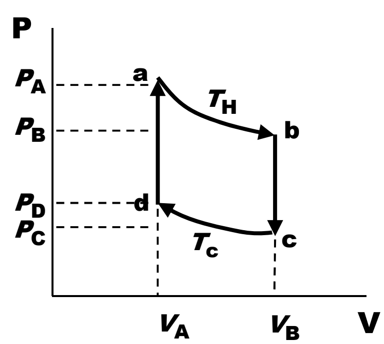
Three thick concentric and conducting shells have radii and charges as shown. Six regions of space can be identified:
$0 \rightarrow R_1$ $R_1 \rightarrow R_2$ $R_2 \rightarrow R_3$, $R_3 \rightarrow R_4$ $R_4 \rightarrow$ oo



1) Find the electric fields as a function of ***r*** for each region of space [use the following convention: the field is positive when radially pointing outward and negative when pointing inward].
2) Find the electric potential as a function of ***r*** for each region of space (state what is your choice for reference point).
3) Plot the electric field as a function of ***r*** clearly indicating 0 R_1 R_2 R_3 and R_4 on the horizontal ***r***-axis and the corresponding values for the electric fields on the vertical axis..
4) Separately plot the electric potentials clearly indicating 0 R_1 R_2 R_3 and R_4 on the horizontal ***r***-axis and the corresponding values for the electric potentials on the vertical axis.
Note*: Plots with unphysical curves will receive NO credit*.

Problem 3 (total: 20 points)

The given variables are T_H T_C V_A V_B
(Note → P_A P_B P_C P_D are NOT given variables)
A Sterling Heat Engine cycle has two isovolumetric processes (d→a and b→c) and two isothermal processes (a→b and c→d), as shown. Assume that the working substance is one mole of a monoatomic gas.

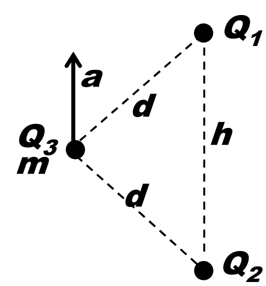


1) Find the efficiency of the Sterling heat engine
2) Compare the efficiency of the Sterling engine to that of the Carnot engine. Justify your answer.

Problem 4 (total: 20 points)

The known variables are Q ***h d m a***

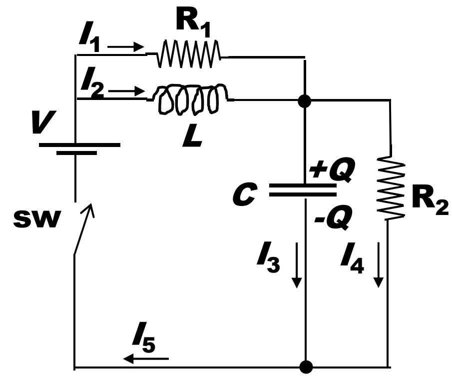
Two point charges Q_1 and Q_2 are held in place a distance ***h*** apart. Another charge $Q_3 = -|Q|$ of mass m is initially located a distance $d < h$ from each of the other two charges, as shown, and is released from rest. You observe that the initial acceleration ***a*** of Q_3 is upward and parallel to the line connecting the two point charges Q_1 and Q_2.



Ignoring the effect of gravity, find the signs and magnitudes of Q_1 and of Q_2.

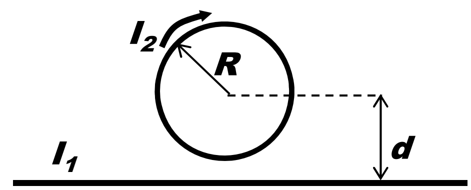
Problem 5 (total: 20 points) – *no figure is provided for that problem.*
The known variables are ***Q R L***
Consider a uniformly charged thin cylinder of total charge Q radius R and length L (like the cardboard tube in a roll of paper towels). Take the origin to be on axis and at the center of the tube (mid-length) and take the potential to be zero at infinity.

Calculate the electric potential at all points along the axis of the tube, within the tube.



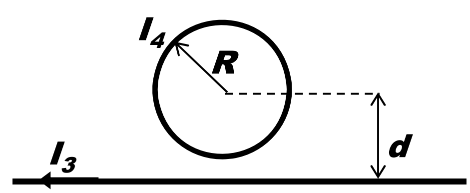
Problem 6 (total: 20 points): The known variables are: L C R_1 R_2 V
Consider the circuit as shown. At time $t < 0$ there is no current in the inductor and no charge in the capacitor. At time $t = 0$, the switch is closed.
1) At time $t = 0$ find the currents I_1 I_2 I_3 I_4 I_5 the charge Q and the rate of change for I_2 , d/dt(I_2)
2) At time t = oo find I_1 I_2 I_3 I_4 I_5 the charge Q and the rate of change for I_2 , d/dt(I_2)

Problem 7 (total: 20 points – parts 2,3,4 are conceptual questions)
The known variables are R d I_2
A circular loop of radius R and carries a steady current I_2 in a clockwise direction as shown on the top figure. The center of the loop is a distance $d > R$ above a long straight wire carrying current I_1



1) What is the direction and magnitude of the steady current I_1 in the wire if the magnetic field at the center of the loop is zero?
2) Is the force between the ring and the wire zero, repulsive or attractive?

Now consider the lower figure. Suppose that for $t < 0$ the current in the ring and in the wire are zero. At time $t = 0$ a current I_3 in the wire is made to flow in the direction right to left and is made to increase at a steady rate.



3) What is the direction of the current I_4 in the loop (clockwise or anticlockwise)?
4) Is the force between the ring and the wire zero, repulsive or attractive?