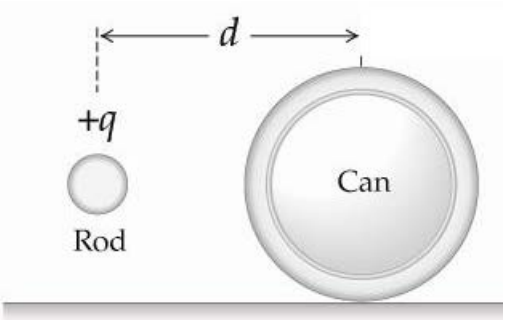
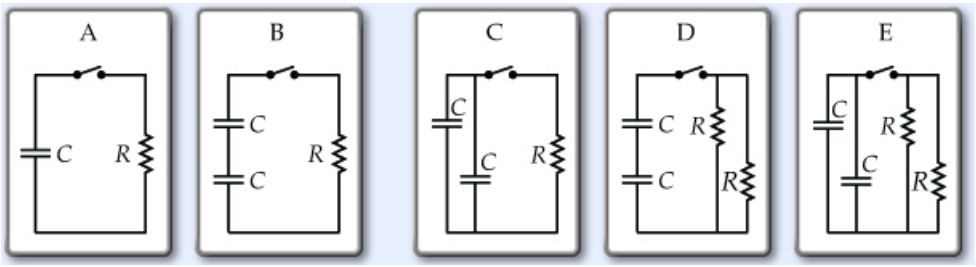
Answer all exercises 1-6

1. Phenomena:

   (a) What happens when an insulating rod, charged to $+q$, is brought to the vicinity of an aluminum can placed on an insulating table? Explain thoroughly by using text and figures. (4p)

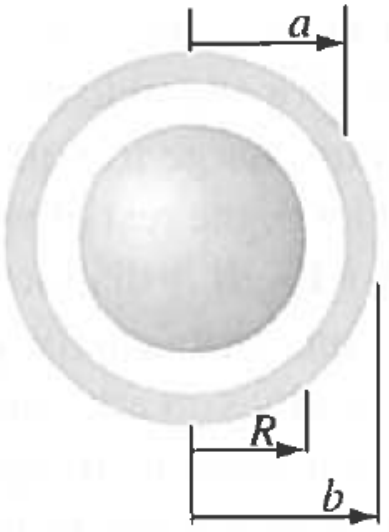


   (b) In the figures below all resistors R are identical (incandescent) light bulbs. Identical capacitors C are fully charged before closing the switch. Arrange the circuits A-E based on the time the bulbs stay lit (from shortest the longest). The bulb is lit if the current through it exceeds a threshold value I_0. For each circuit A-E $I > I_0$ at the moment when the switch is closed. (4p)
   Pure guessing → maximum 2 points.



2. Coulomb's force and electric field:
   (a) The length of a massless, insulating and unstressed spring is 4 cm. When the spring is hung vertically and a mass of 1 g is attached to its lower end, the length of the spring is measured to be 5 cm. When the spring is set horizontally on top of a frictionless insulating plate and charges $+4Q$ and $+Q$ are attached to its ends, the length of the spring is 4.5 cm. Calculate the charge Q. (4p)
   (b) Let's hang the spring vertically from the insulating roof and charge the 1 gram mass with $+Q$. What is the surface charge density of the sealing required to force the spring to its original length of 4 cm? Ignore possible oscillations. (4p)

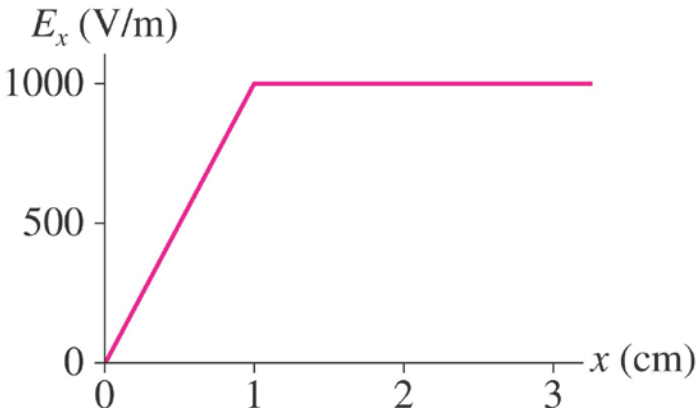
3. Consider a solid metal ball (radius R). Let's charge the ball to $+Q$ and position it concentrically inside a conducting spherical shell (inner radius a, outer radius b). The net charge of the conducting shell is zero.
   (a) What is the charge density on surfaces R, a and b? Explain your answer thoroughly! (4p)
   (b) What is the electrical potential at the center of the ball? The potential is zero infinitely far from the system. (4p)



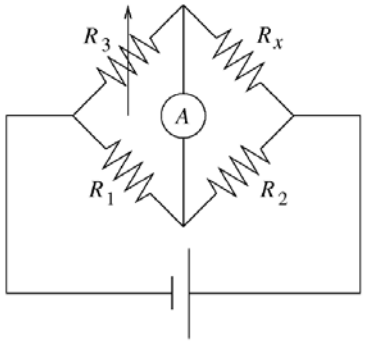
4. The figure below shows the electric field component E_x as a function of distance x on x-axis.

   (a) Calculate the work done when a proton is moved along the x-axis from x = 3 cm to x = 0 cm? (5p)

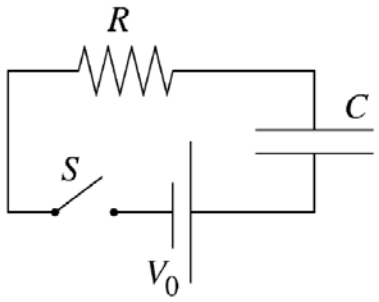
   (b) Let's shoot the proton from x > 3 cm towards x = 0. What is the minimum velocity of the proton at x = 3 cm, when it barely makes its way to x = 1 before turning? (3p)



5. The circuit shown below is so-called Wheatstone bridge which can be used for determining an unknown resistance R_x. The emf of the battery is 10 V, R_1 = 100 Ω and R_2 = 200 Ω. The variable resistor R_3 is adjusted to 150 Ω, corresponding to zero current through the ammeter. What is the resistance R_x? (8p)



6. A resistor R, uncharged capacitor C, switch S and battery (emf = V_0) are connected as shown below. The switch is closed at $t = 0$ (time).



(a) Using Kirchhoff's rule write the differential equation describing the charge $Q(t)$ on the lower plate of the capacitor (1p)

(b) Which conservation law of physics did you apply when using Kirchhoff's rule? (1p)

(c) Show that $Q(t) = CV_0(1-e^{-t/RC})$ is a solution of the differential equation. (1p)

(d) What is the current flowing in the circuit at t_1 ($t_1 > 0$)? (1p)

(e) How much energy is stored in the capacitor at t_1? (2p)

(f) How much energy has been converted to heat in the resistor within the time interval $0 < t < t_1$? (2p)