$\left(30\%\right)$ (1) Consider the circuit shown in the following figure. The switch S is closed at $t = 0$, calculate the charge $q(t)$ on C as a function of time for $t \geq 0$. Assume that C is uncharged initially.
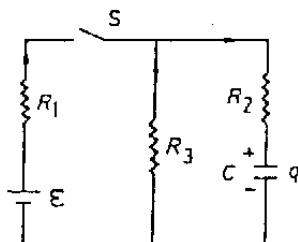
$\left(40\%\right)$ (2) Consider a coaxial cable made of a central cylindrical wire of radius a surrounded by by a coaxial conducting thin sheath of radius b as shown in the figure.

[a] Suppose there is a vacuum between the central wire and the sheath. The central wire and the sheath is kept at a constant potential difference V. Find the charge per unit length, λ, on the central wire. Hence find the capacitance per unit length of such an infinitely long coaxial cable.

[b] A hollow cylindrical plug with inner and outer radii a and b respectively, which is made of a material with dielectric constant κ, is used to change the capacitance of the coaxial cable. Such a plug is inserted between the central wire and the sheath to a depth x from the end of the cable. Suppose the charge per unit length on the central wire of the cable is λ before the plug is inserted and is kept constant during the insertion of the plug. Find the change in potential energy per unit length when the dielectric plug is inserted to a depth of x. Hence find the force (and its direction) exerted on the plug as it moves into the cable.

Solid wire

sheath
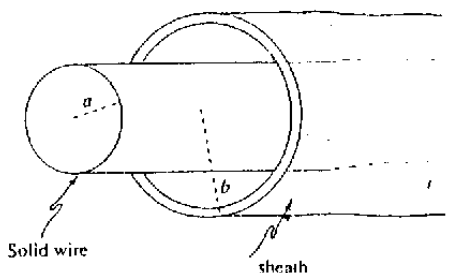
$\left(30\%\right)$ (3) Two infinite parallel wire separated by a distance d carry time dependent currents $I(t)$ in opposite directions. The rate of change of the currents is dI/dt. A $d \times d$ square wire loop lies on the same plane of the wires is placed a distance d from one of the wires as shown in the figure.

[a] Find the magnetic fluxes crossing the square loop due to wire 1 and wire 2.

[b] Hence find the induced emf in the square loop.

[c] If $dI/dt > 0$, find the direction of the induced current in the loop and explain your answer.