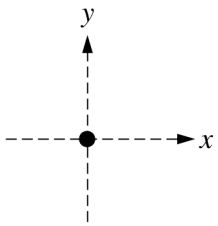
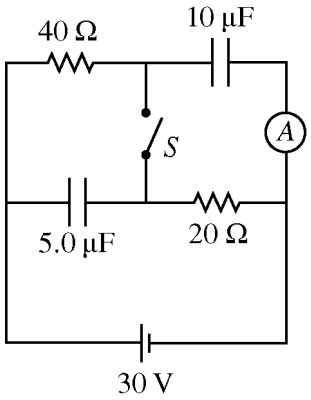
(b) Determine an expression for the electric potential at point P due to the charge Q.

(c) A positive point charge q with mass m is placed at point P and released from rest. Derive an expression for the speed of the point charge when it is very far from the origin.

(d) On the dot representing point P below, indicate the direction of the electric field at point P due to the charge Q.



(e) Derive an expression for the magnitude of the electric field at point P.



E&M. 2.

In the circuit illustrated above, switch S is initially open and the battery has been connected for a long time.

(a) What is the steady-state current through the ammeter?

(b) Calculate the charge on the $10\ \mu F$ capacitor.

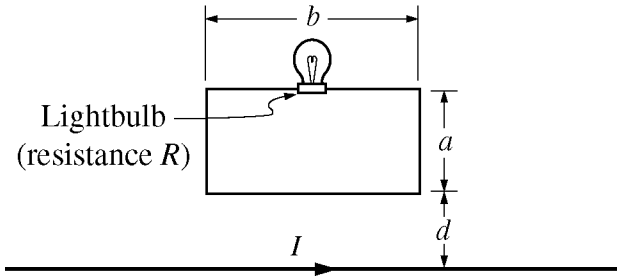
(c) Calculate the energy stored in the $5.0\ \mu F$ capacitor.

The switch is now closed, and the circuit comes to a new steady state.

(d) Calculate the steady-state current through the battery.

(e) Calculate the final charge on the $5.0\ \mu F$ capacitor.

(f) Calculate the energy dissipated as heat in the $40\ \Omega$ resistor in one minute once the circuit has reached steady state.



E&M. 3.

The long straight wire illustrated above carries a current I to the right. The current varies with time t according to the equation $I = I_0 - Kt$, where I_0 and K are positive constants and I remains positive throughout the time period of interest. The bottom of a rectangular loop of wire of width b and height a is located a distance d above the long wire, with the long wire in the plane of the loop as shown. A lightbulb with resistance R is connected in the loop. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) Indicate the direction of the current in the loop.

____Clockwise ____Counterclockwise

Justify your answer.

(b) Indicate whether the lightbulb gets brighter, gets dimmer, or stays the same brightness over the time period of interest.

____Gets brighter ____Gets dimmer ____Remains the same

Justify your answer.

(c) Determine the magnetic field at $t = 0$ due to the current in the long wire at distance r from the long wire.

(d) Derive an expression for the magnetic flux through the loop as a function of time.

(e) Derive an expression for the power dissipated by the lightbulb.

END OF EXAM

AP® PHYSICS C: ELECTRICITY AND MAGNETISM
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Question 2

15 points total | **Distribution of points**

(a) 2 points

For correctly stating that there is no current in the steady state — 2 points
$I = 0$ A

(b) 2 points

$Q = CV$
For correct substitution of capacitance into the equation above — 1 point
$Q = (10\ \mu\text{F})(30\ \text{V})$
For a correct numerical answer with units — 1 point
$Q = 300\ \mu\text{C}$

(c) 3 points

$U = \frac{1}{2}CV^2$
For substitution of the correct capacitance (in units of μF or F) into the correct expression for energy — 1 point
For substitution of the battery voltage into the correct expression for energy — 1 point
$U = \frac{1}{2}(5\ \mu\text{F})(30\ \text{V})^2$
For correct units on a numerical answer — 1 point
$U = 2250\ \mu\text{J}$

(d) 2 points

For recognizing the two resistors are now in series and correctly calculating the equivalent resistance — 1 point
$R_T = 20\ \Omega + 40\ \Omega = 60\ \Omega$
$V = IR$
$I = V/R$
For substitution of the correct voltage and the calculated equivalent resistance into Ohm's law — 1 point
$I = 30\ \text{V}/60\ \Omega$
$I = 0.5$ A

Question 2 (continued)

Distribution of points

(e) 3 points

For recognizing that the voltage across the $5.0\ \mu\text{F}$ capacitor is the same as that for the $40\ \Omega$ resistor and calculating that voltage — 1 point

$V_{40\ \Omega} = (0.5\ \text{A})(40\ \Omega) = 20\ \text{V}$

$Q = CV$

For correctly substituting the value of the capacitance into the above equation — 1 point

$Q = (5.0\ \mu\text{F})(20\ \text{V})$

For the correct answer — 1 point

$Q = 100\ \mu\text{C}$

Alternate solution — *Alternate points*

For correctly applying the loop equation to the loop that includes the $5.0\ \mu\text{F}$ capacitor, the $20\ \Omega$ resistor and the $30\ \text{V}$ battery — *1 point*

$V - IR - \frac{Q}{C} = 0$

$Q = (C)(V - IR)$

For correctly substituting the current and the resistances — *1 point*

$Q = (5.0\ \mu\text{F})[(30\ \text{V}) - (0.5\ \text{A})(20\ \Omega)]$

For the correct answer — *1 point*

$Q = 100\ \mu\text{C}$

(f) 3 points

$P = I^2R$

For correct substitution of the total current from part (d) and the resistance into the above equation for power (or substituting correct values into $P = V^2/R$ or $P = IV$) — 1 point

$P = (0.5\ \text{A})^2(40\ \Omega) = 10\ \text{W}$

For correctly substituting the power into an equation for energy — 1 point

For correctly substituting the time in seconds into an equation for energy — 1 point

$E = Pt$

$E = (10\ \text{W})(60\ \text{s})$

$E = 600\ \text{J}$

Note: If time is not substituted using seconds, the units on the final answer must be consistent with the substitution.