Physics 2102

Exam 2: Review Session
CH 25–28

Some links on exam stress:
http://appl003.lsu.edu/slas/cas.nsf/$Content/Stress+Management+Tip+1
http://wso.williams.edu/orgs/peerh/stress/exams.html
http://www.thecalmzone.net/Home/ExamStress.php
http://www.staithes.demon.co.uk/exams.html
Exam 2

- (Ch 26) **Capacitors**: capacitance and capacitors; caps in parallel and in series, dielectrics; energy, field and potential in capacitors.

- (Ch 27) **Current and Resistance**: current, current density and drift velocity; resistance and resistivity; Ohm’s law.

- (Ch 28) **Circuits**: emf devices, loop and junction rules; resistances in series and parallel; DC single and multiloop circuits, power; RC circuits.
Capacitors

\[ E = \frac{\sigma}{\varepsilon_0} = \frac{q}{A\varepsilon_0} \]
\[ E = V \frac{d}{d} \]
\[ q = C \cdot V \]
\[ C = \varepsilon_0 \frac{A}{d} \]
\[ C = \kappa \varepsilon_0 \frac{A}{d} \]
\[ C = \varepsilon_0 \frac{ab}{(b-a)} \]
Current and resistance

\[ i = \frac{dq}{dt} \]

Junction rule

\[ V = iR \]

\[ E = J\rho \]

\[ R = \frac{\rho L}{A} \]

\[ \rho = \rho_0(1 + \alpha(T - T_0)) \]
DC Circuits

Single loop

Multiloop

Loop rule

\[ V = iR \]
\[ P = iV \]
## Resistors and Capacitors

### Key formula: \( V = iR \)

**Resistors**

- **In series:** same current
  - \( R_{eq} = \sum R_j \)

**Capacitors**

- **In parallel:** same voltage
  - \( C_{eq} = \sum C_j \)

**In series:**
- same charge
  - \( \frac{1}{C_{eq}} = \sum \frac{1}{C_j} \)

**In parallel:**
- same voltage
  - \( \frac{1}{R_{eq}} = \sum \frac{1}{R_j} \)
Capacitors and Resistors in Series and in Parallel

- What’s the equivalent resistance (capacitance)?
- What’s the current (charge) in each resistor (capacitor)?
- What’s the potential across each resistor (capacitor)?
- What’s the current (charge) delivered by the battery?
**RC Circuits**

Time constant: $RC$

**Charging:** $q(t) = CE \left(1 - e^{-t/RC} \right)$

**Discharging:** $q(t) = q_0 e^{-t/RC}$

$i(t) = dq/dt$
Capacitors: Checkpoints, Questions

(a)  

(b)  

(c)  

(1)  

(2)  

(3)  

(a)  

(b)  

(c)  

(d)
Problem 25-21

When switch S is thrown to the left, the plates of capacitor 1 acquire a potential \( V_0 \). Capacitors 2 and 3 are initially uncharged. The switch is now thrown to the right. What are the final charges \( q_1 \), \( q_2 \), and \( q_3 \) on the capacitors?
21. The charges on capacitors 2 and 3 are the same, so these capacitors may be replaced by an equivalent capacitance determined from
\[
\frac{1}{C_{eq}} = \frac{1}{C_2} + \frac{1}{C_3} = \frac{C_2 + C_3}{C_2 C_3}.
\]

Thus, \(C_{eq} = \frac{C_2 C_3}{C_2 + C_3}\). The charge on the equivalent capacitor is the same as the charge on either of the two capacitors in the combination and the potential difference across the equivalent capacitor is given by \(q_2/C_{eq}\). The potential difference across capacitor 1 is \(q_1/C_1\), where \(q_1\) is the charge on this capacitor. The potential difference across the combination of capacitors 2 and 3 must be the same as the potential difference across capacitor 1, so \(q_1/C_1 = q_2/C_{eq}\). Now some of the charge originally on capacitor 1 flows to the combination of 2 and 3. If \(q_0\) is the original charge, conservation of charge yields \(q_1 + q_2 = q_0 = C_1 V_0\), where \(V_0\) is the original potential difference across capacitor 1.
(a) Solving the two equations

\[
\frac{q_1}{C_1} = \frac{q_2}{C_{eq}} \quad \text{and} \quad q_1 + q_2 = C_1 V_0
\]

for \( q_1 \) and \( q_2 \), we obtain

\[
q_1 = \frac{C_1^2 V_0}{C_{eq} + C_1} = \frac{C_1^2 V_0}{\frac{C_2 C_3}{C_2 + C_3} + C_1} = \frac{C_1^2 (C_2 + C_3) V_0}{C_1 C_2 + C_1 C_3 + C_2 C_3}.
\]

With \( V_0 = 12.0 \) V, \( C_1 = 4.00 \ \mu\text{F} \), \( C_2 = 6.00 \ \mu\text{F} \) and \( C_3 = 3.00 \ \mu\text{F} \), we find \( C_{eq} = 2.00 \ \mu\text{F} \) and \( q_1 = 32.0 \ \mu\text{C} \).

(b) The charge on capacitors 2 is

\[
q_2 = C_1 V_0 - q_1 = (4.00 \mu\text{F})(12.0\text{V}) - 32.0 \mu\text{F} = 16.0 \mu\text{F}
\]

(c) The charge on capacitor 3 is the same as that on capacitor 2:

\[
q_3 = C_1 V_0 - q_1 = (4.00 \mu\text{F})(12.0\text{V}) - 32.0 \mu\text{F} = 16.0 \mu\text{F}
\]
Current and Resistance: Checkpoints, Questions
Problem 26-56

A cylindrical resistor of radius 5.0mm and length 2.0 cm is made of a material that has a resistivity of $3.5 \times 10^{-5}$ Ωm. What are the (a) current density and (b) the potential difference when the energy dissipation rate in the resistor is 1.0W?
56. (a) Since \( P = i^2 R = J^2 A^2 R \), the current density is

\[
J = \frac{1}{A} \sqrt{\frac{P}{R}} = \frac{1}{A} \sqrt{\frac{P}{\rho L / A}} = \sqrt{\frac{P}{\rho LA}}
\]

\[
= \frac{1.0 \text{ W}}{\sqrt{\pi (3.5 \times 10^{-5} \Omega \cdot \text{m}) (2.0 \times 10^{-2} \text{ m}) (5.0 \times 10^{-3} \text{ m})^2}} = 1.3 \times 10^5 \text{ A} / \text{m}^2.
\]

(b) From \( P = iV = JAV \) we get

\[
V = \frac{P}{AJ} = \frac{P}{\pi r^2 J} = \frac{1.0 \text{ W}}{\pi (5.0 \times 10^{-3} \text{ m})^2 (1.3 \times 10^5 \text{ A} / \text{m}^2)} = 9.4 \times 10^{-2} \text{ V}.
\]
Circuits: Checkpoints, Questions
1. HRW7 27.P.018. [406649]
Figure 27-33 shows five 5.00 resistors.
(Hint: For each pair of points, imagine that a battery is connected across the pair.)

Fig. 27-33
(a) Find the equivalent resistance between points F and H.

(b) Find the equivalent resistance between points F and G.
18. (a) \( R_{\text{eq}} (FH) = \frac{(10.0 \, \Omega)(10.0 \, \Omega)(5.00 \, \Omega)}{[(10.0 \, \Omega)(10.0 \, \Omega) + 2(10.0 \, \Omega)(5.00 \, \Omega)]} = 2.50 \, \Omega. \)

(b) \( R_{\text{eq}} (FG) = \frac{(5.00 \, \Omega) \, R}{(R + 5.00 \, \Omega)}, \) where

\[
R = 5.00 \, \Omega + \frac{(5.00 \, \Omega)(10.0 \, \Omega)}{(5.00 \, \Omega + 10.0 \, \Omega)} = 8.33 \, \Omega.
\]

So \( R_{\text{eq}} (FG) = \frac{(5.00 \, \Omega)(8.33 \, \Omega)}{(5.00 \, \Omega + 8.33 \, \Omega)} = 3.13 \, \Omega. \)
In an RC series circuit, $\mathcal{E} = 17.0 \text{ V}$, $R = 1.50 \text{ M}\Omega$, and $C = 1.80 \mu\text{F}$.

(a) Calculate the time constant.

(b) Find the maximum charge that will appear on the capacitor during charging.

(c) How long does it take for the charge to build up to 10.0 $\mu\text{C}$?
46. (a) \( \tau = RC = (1.40 \times 10^6 \, \Omega)(1.80 \times 10^{-6} \, \text{F}) = 2.52 \, \text{s} \).

(b) \( q_o = \varepsilon C = (12.0 \, \text{V})(1.80 \, \mu \text{F}) = 21.6 \, \mu \text{C} \).

(c) The time \( t \) satisfies \( q = q_0(1 - e^{-t/RC}) \), or

\[
t = RC \ln \left( \frac{q_0}{q_0 - q} \right) = (2.52 \, \text{s}) \ln \left( \frac{21.6 \, \mu \text{C}}{21.6 \, \mu \text{C} - 16.0 \, \mu \text{C}} \right) = 3.40 \, \text{s}.
\]
Magnetic Forces and Torques

\[ \vec{F} = q \vec{v} \times \vec{B} + q \vec{E} \]

\[ d\vec{F} = i d\vec{L} \times \vec{B} \]

\[ \vec{\tau} = \vec{\mu} \times \vec{B} \]
5. HRW7 28.P.024. [566302]
In the figure below, a charged particle moves into a region of uniform magnetic field, goes through half a circle, and then exits that region. The particle is either a proton or an electron (you must decide which). It spends 160 ns in the region.

(a) What is the magnitude of B?

(b) If the particle is sent back through the magnetic field (along the same initial path) but with 3.00 times its previous kinetic energy, how much time does it spend in the field during this trip?
24. We consider the point at which it enters the field-filled region, velocity vector pointing downward. The field points out of the page so that \( \vec{v} \times \vec{B} \) points leftward, which indeed seems to be the direction it is “pushed”; therefore, \( q > 0 \) (it is a proton).

(a) Eq. 28-17 becomes \( T = \frac{2\pi m_p}{e|\vec{B}|} \), or

\[
2\left(130 \times 10^{-9}\right) = \frac{2\pi \left(1.67 \times 10^{-27}\right)}{\left(1.60 \times 10^{-19}\right)|\vec{B}|}
\]

which yields \( |\vec{B}| = 0.252 \text{ T} \).

(b) Doubling the kinetic energy implies multiplying the speed by \( \sqrt{2} \). Since the period \( T \) does not depend on speed, then it remains the same (even though the radius increases by a factor of \( \sqrt{2} \)). Thus, \( t = T/2 = 130 \text{ ns} \), again.