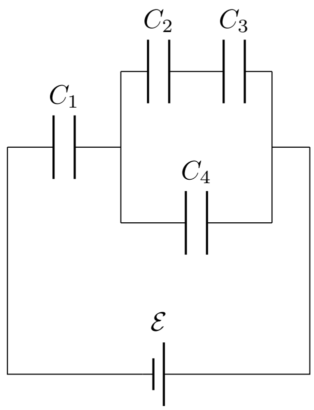
Make sure to fill out the grading sheet completely including your name, exam flavor and UIN. You are allowed to write and work on this exam copy, but your answers must be bubbled in on the grading sheet to receive credit. Your bubbled responses are the only responses that will be considered for the grade.

Physics 207 Exam 2 – Flavor 1

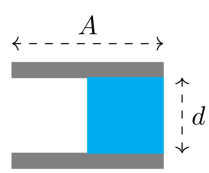
Problem 1 (8 points) In the diagram below, find the amount of charge stored on C_2 assuming each capacitor is identical and has capacitance C.

(a) $\frac{1}{5}C\mathcal{E}$
(b) $\frac{2}{5}C\mathcal{E}$
(c) $\frac{3}{5}C\mathcal{E}$
(d) $\frac{4}{5}C\mathcal{E}$
(e) $\frac{1}{3}C\mathcal{E}$
(f) $\frac{2}{3}C\mathcal{E}$



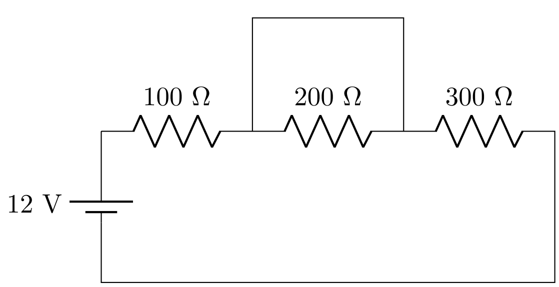
Problem 2 (6 points) A parallel plate capacitor is initially filled with air. A dielectric with constant κ is then inserted which fills half the volume as shown below. What happens to the capacitance of the capacitor?

(a) The capacitance is increased by a factor greater than κ.
(b) The capacitance is increased by a factor exactly κ.
(c) The capacitance is increased by a factor between κ and 1.
(d) The capacitance stays the same.
(e) The capacitance is decreased by a factor between κ and 1.
(f) The capacitance is decreased by a factor exactly κ.
(g) The capacitance is decreased by a factor greater than κ.

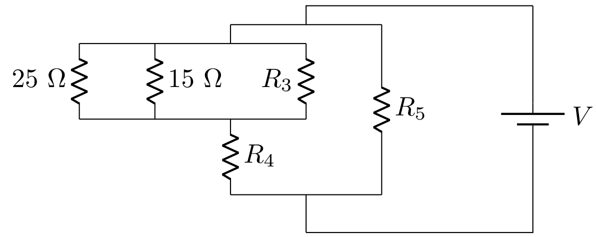


Problem 3 (6 points) The circuit below contains three resistors that were initially in series but a stray wire made contact and "shorted" the 200 Ω resistor. What is the potential difference across that 200 Ω resistor?

(a) 0 V
(b) 3 V
(c) 4 V
(d) 6 V
(e) 8 V
(f) 9 V
(g) 12 V



Problem 4 (6 points) In the circuit below, you know that the current through the battery is 350 mA and the current through R_4 is 275 mA. You also know the current through the 25 Ω resistor is 60 mA.
What is I_5, the current through R_5, and I_{15}, the current through the 15 Ω resistor?
(a) $I_5 = 625$ mA and $I_{15} = 215$ mA
(b) $I_5 = 625$ mA and $I_{15} = 75$ mA
(c) $I_5 = 35$ mA and $I_{15} = 215$ mA
(d) $I_5 = 35$ mA and $I_{15} = 75$ mA
(e) $I_5 = 275$ mA and $I_{15} = 100$ mA
(f) $I_5 = 275$ mA and $I_{15} = 36$ mA
(g) $I_5 = 75$ mA and $I_{15} = 100$ mA
(h) $I_5 = 75$ mA and $I_{15} = 36$ mA

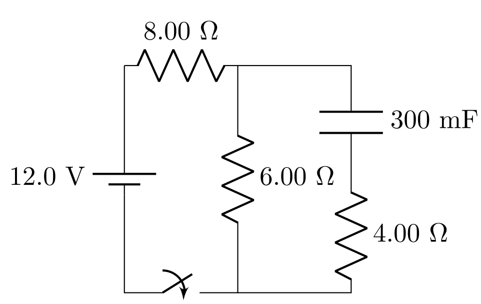


Problem 5 (8 points) When an *RC*-circuit charges, it takes 3.00 seconds to reach 25.0% of the maximum charge stored on the capacitor. When it discharges, how much time does it take to reach 25.0% of its initial charge (the charge at the time it starts to discharge)?

(a) 0.0692 s
(b) 0.111 s
(c) 0.333 s
(d) 0.622 s
(e) 1.00 s
(f) 3.00 s
(g) 9.00 s
(h) 14.5 s

Problem 6 (6 points) In the circuit below, what is the current through 6.00 Ω resistor (I_6) and the current through the 4.00 Ω resistor (I_4) after the switch has been closed for a long time?

(a) $I_6 = 0$ A and $I_4 = 0$ A
(b) $I_6 = 2.00$ A and $I_4 = 0$ A
(c) $I_6 = 2.00$ A and $I_4 = 3.00$ A
(d) $I_6 = 0.429$ A and $I_4 = 0.429$ A
(e) $I_6 = 0.462$ A and $I_4 = 0.692$ A
(f) $I_6 = 0.857$ A and $I_4 = 0$ A
(g) $I_6 = 0.857$ A and $I_4 = 0.857$ A

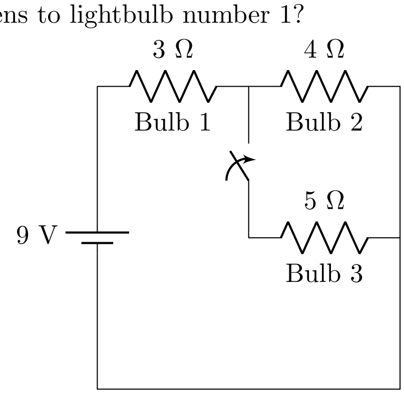


Problem 7 (5 points) A capacitor of capacitance C is connected to a battery of voltage V. The capacitor is fully charged, and then disconnected from the battery. A dielectric of constant κ is inserted into the capacitor. This new configuration is then shorted across a resistor R. What is the maximum current supplied by the discharging capacitor?

(a) $\frac{V}{R}$
(b) $\frac{V}{RC}$
(c) $\frac{\kappa V}{R}$
(d) $\frac{\kappa V}{RC}$
(e) $\frac{\kappa VC}{R}$
(f) $\frac{V}{\kappa R}$
(g) $\frac{V}{\kappa RC}$
(h) $\frac{VC}{\kappa R}$

Problem 8 (5 points) A 9 V battery is connected to three lightbulbs (represented as resistors) as shown in the figure below. When the switch is closed, what happens to lightbulb number 1?

(a) Bulb 1 gets brighter
(b) Bulb 1 gets dimmer
(c) Bulb 1 stays the same
(d) It is impossible to tell

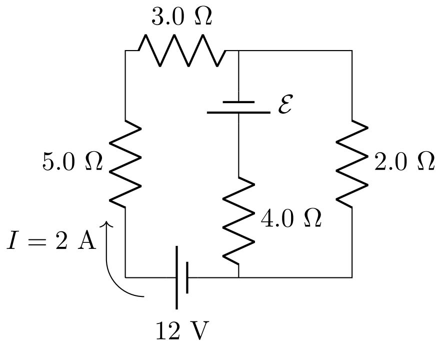


Problem 9 (8 points) Using the previous figure, when the switch is closed, what is the power dissipated in the 3 Ω resistor?

(a) 2.93 W
(b) 3.67 W
(c) 8.91 W
(d) 15.5 W
(e) 36.0 W
(f) 48.0 W

Problem 10 (8 points) In the figure below, what is the unknown battery voltage, $\mathcal{E}$?

(a) 10 V
(b) 12 V
(c) 15 V
(d) 16 V
(e) 18 V
(f) 20 V
(g) 24 V
(h) 25 V



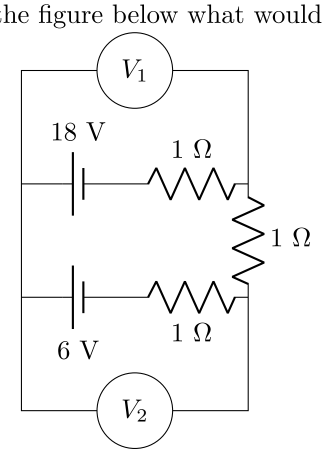
Problem 11 (6 points) A resistor exists from position $x = 0$ to $x = \ell$. It has a square cross-section with side length s and a resistivity as a function of position given by the formula below. What is the resistance of this device?

$$\rho(x) = \rho_0 e^{-x/\ell}$$

(a) $\frac{\rho_0}{s^2}\left(1 - \frac{1}{e}\right)$
(b) $\frac{\rho_0}{s^2}\left(\frac{1}{e} - 1\right)$
(c) $\frac{\rho_0}{s^2}\frac{1}{e}$
(d) $\frac{\rho_0}{s^2}$
(e) $\frac{\rho_0 \ell}{s^2}\left(1 - \frac{1}{e}\right)$
(f) $\frac{\rho_0 \ell}{s^2}\left(\frac{1}{e} - 1\right)$
(g) $\frac{\rho_0 \ell}{s^2}\frac{1}{e}$
(h) $\frac{\rho_0 \ell}{s^2}$

Problem 12 (6 points) In the figure below what would be the readings of the ideal voltmeters?

(a) $V_1 = 22$ V and $V_2 = 2$ V
(b) $V_1 = 22$ V and $V_2 = 10$ V
(c) $V_1 = 20$ V and $V_2 = 2$ V
(d) $V_1 = 20$ V and $V_2 = 10$ V
(e) $V_1 = 20$ V and $V_2 = 16$ V
(f) $V_1 = 14$ V and $V_2 = 2$ V
(g) $V_1 = 14$ V and $V_2 = 10$ V
(h) $V_1 = 14$ V and $V_2 = 16$ V



Problem 13 (5 points) In a circuit, a fuse is used to make sure that the total current in the circuit does not exceed 2.5 A. The emf in the circuit is 120 V. What is the maximum number of 120 W light bulbs that can be connected *in parallel* so that the fuse does not break?

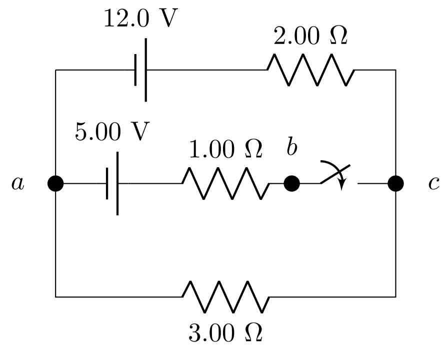
(a) None, the fuse will not support a single bulb
(b) One bulb
(c) Two bulbs
(d) Three bulbs
(e) Four bulbs

Problem 14 (5 points) When a parallel plate capacitor stays connected to a battery, the distance between the plates is reduced by a factor of 2. What happens to the charge stored on the capacitor and the energy stored in the capacitor?

(a) Charge increases by a factor of 2, Energy increases by a factor of 2
(b) Charge increases by a factor of 2, Energy increases by a factor of 4
(c) Charge increases by a factor of 2, Energy decreases by a factor of 2
(d) Charge increases by a factor of 2, Energy decreases by a factor of 4
(e) Charge decreases by a factor of 2, Energy increases by a factor of 2
(f) Charge decreases by a factor of 2, Energy increases by a factor of 4
(g) Charge decreases by a factor of 2, Energy decreases by a factor of 2
(h) Charge decreases by a factor of 2, Energy decreases by a factor of 4

Problem 15 (8 points) In the circuit below, what is the magnitude of the potential difference between point b and c when the switch is open?

(a) 2.20 V
(b) 4.80 V
(c) 7.20 V
(d) 9.00 V
(e) 11.8 V
(f) 12.2 V
(g) 14.2 V
(h) 17.0 V



Problem 16 (4 points) In the previous problem we assumed the 5 V battery was ideal. What if that battery and only that battery instead had an internal resistance of 0.5 Ω. What would happen to your answer in the previous problem for the potential difference between b and c?

(a) The potential difference would increase
(b) The potential difference would stay the same
(c) The potential difference would decrease
(d) There is not enough information to tell

Useful Constants:
Acceleration due to gravity: $g = 9.80$ m/s^2
Basic unit of charge: $e = 1.6 \times 10^{-19}$ C
Mass of electron: $m_e = 9.11 \times 10^{-31}$ kg
Mass of proton/neutron: $m_p = 1.67 \times 10^{-27}$ kg
Coulomb constant: $k = 8.99 \times 10^9$ Nm^2/C^2
Permittivity of free space: $\epsilon_0 = 1/(4\pi k) = 8.85 \times 10^{-12}$ C^2/Nm^2
Permeability of free space: $\mu_0 = 4\pi \times 10^{-7}$ Tm/A
Speed of light in a vacuum: $c = 3 \times 10^8$ m/s
Planck's Constant: $h = 6.626 \times 10^{-34}$ Js
eV to joule conversion: 1 eV = 1.6×10^{-19} J
kilowatt-hour to joule conversion: 1 kW·hr=3.6×10^6 J
Atomic Mass Unit: 1 u = 1.66054×10^{-27} kg = 931.5 MeV/c^2

Vector Concepts:
Unit Vector: $\hat{r} = \frac{\vec{r}}{r}$
Gradient: $\vec{\nabla} = \frac{\partial}{\partial x}\hat{x} + \frac{\partial}{\partial y}\hat{y} + \frac{\partial}{\partial z}\hat{z}$
Dot Product: $\vec{A} \cdot \vec{B} = |\vec{A}||\vec{B}|\cos\theta$
Dot Product: $\vec{A} \cdot \vec{B} = A_x B_x + A_y B_y + A_z B_z$
Cross Product:

$$|\vec{A} \times \vec{B}| = |\vec{A}||\vec{B}|\sin\theta$$
$$\vec{A} \times \vec{B} = (A_y B_z - A_z B_y)\hat{x} - (A_x B_z - A_z B_x)\hat{y} + (A_x B_y - A_y B_x)\hat{z}$$

Sample Indefinite Integrals:

$$\int \frac{dx}{\sqrt{x^2 \pm a^2}} = \ln(x + \sqrt{x^2 \pm a^2}) + c$$
$$\int \frac{xdx}{(x^2 + a^2)^{3/2}} = -\frac{1}{\sqrt{x^2 + a^2}} + c$$
$$\int \frac{dx}{(x^2 + a^2)^{3/2}} = \frac{x}{a^2\sqrt{x^2 + a^2}} + c$$
$$\int x^n dx = \frac{x^{n+1}}{n+1} + c (n \neq -1)$$
$$\int \frac{dx}{x} = \ln(x) + c$$
$$\int \frac{dx}{x^2 + a^2} = \frac{1}{a}\arctan\frac{x}{a} + c$$
$$\int \frac{dx}{\sqrt{a^2 - x^2}} = \arcsin\frac{x}{a} + c$$

SI Prefixes:
T=$\times 10^{12}$, G=$\times 10^9$, M=$\times 10^6$, k=$\times 10^3$
c=$\times 10^{-2}$, m=$\times 10^{-3}$
μ=$\times 10^{-6}$, n=$\times 10^{-9}$, p=$\times 10^{-12}$, f=$\times 10^{-15}$

Useful integral relationships:
Spherical: $\mathrm{d}V = 4\pi r^2 \mathrm{d}r$
Cylindrical (with constant r): $dV = \pi r^2 \mathrm{d}z$
Cylindrical (with constant z): $dV = z 2\pi r \mathrm{d}r$
Cylindrical (with constant r): $dA = 2\pi r \mathrm{d}z$
Cylindrical (with constant z): $dA = 2\pi r \mathrm{d}r$

Geometry:
Surface Area of a Sphere: $A = 4\pi r^2$
Volume of a Sphere: $V = \frac{4}{3}\pi r^3$
Area of curved region of a cylinder: $A = 2\pi r h$
Volume of a cylinder: $V = \pi r^2 h$

Physics 1 Concepts:
Work: $W = \int \vec{F} \cdot d\vec{\ell}$
Potential Energy of conservative force:
$W_{cons} = -\Delta U$
Kinetic Energy: $K = \frac{1}{2}mv^2$
Momentum: $\vec{p} = m\vec{v}$

Chapter 21:

Coulomb's Law [N]: $\vec{F} = \frac{kq_1q_2}{r^2}\hat{r}$

Force due to an electric field [N]: $\vec{F} = q\vec{E}$

E Field due to a pt. charge [N/C]: $\vec{E} = \frac{kq}{r^2}\hat{r}$

E Field due to a continuous charge dist. [N/C]:
$\vec{E} = \int \frac{kdq}{r^2}\hat{r}$

Electric dipole moment [Cm]: $\vec{p} = q\vec{d}$

Torque on an electric dipole [Nm]: $\vec{\tau} = \vec{p} \times \vec{E}$

Electric pot. energy stored in electric dipole [J]:
$U = -\vec{p} \cdot \vec{E}$

Chapter 22:

Electric Flux [Vm or Nm^2/C]: $\Phi_E = \int \vec{E} \cdot d\vec{A}$

Electric Flux when E and θ are const. on the surface: $\Phi_E = EA\cos\theta$

Gauss's Law (vacuum): $\Phi_E = \oint \vec{E} \cdot d\vec{A} = \frac{Q_{\text{encl}}}{\epsilon_0}$

Chapter 23: The below equations generally but not always assume that $V(\infty) = 0$ and/or $U(\infty) = 0$.

Elec. pot. energy between 2 pt charges [J]:
$U = \frac{kq_1q_2}{r}$

Elec. pot. difference btw. two locations [V or J/C]:
$\Delta V = \frac{\Delta U}{q}$ (or often) $V = \frac{U}{q}$

Electric potential due to a point charge [V]:
$V = \frac{kq}{r}$

Electric potential due to a charge dist. [V]:
$V = \int \frac{kdq}{r}$

Relating $\vec{E}$ and V: $\vec{E} = -\vec{\nabla}V$

$\Delta V = V_b - V_a = -\int_a^b \vec{E} \cdot d\vec{\ell}$

Chapter 24:

Capacitance [F]: $Q = CV$

Capacitance for Parallel Plates [F]: $C = \frac{\kappa\epsilon_0 A}{d}$

Energy stored in a capacitor [J]: $U = \frac{1}{2}CV^2$

E field energy density [J/m^3]: $u_E = \frac{1}{2}\kappa\epsilon_0 E^2$

Definition of Dielectric Constant: $C = \kappa C_0$

Eff. Cap. (series) [F]: $\frac{1}{C_{eff}} = \sum_i \frac{1}{C_i}$

Eff. Cap. (parallel) [F]: $C_{eff} = \sum_i C_i$

Chapters 25 and 26:

Electric Current [A]: $I = \frac{dq}{dt}$

I from current density [A]: $I = \int \vec{j} \cdot d\vec{A}$

j of uniform current [A/m^2]: $|\vec{j}| = \frac{I}{A}$

j for charges in motion [A/m^2]: $\vec{j} = nq\vec{v}_d$

Ohm's Law: $\vec{E} = \rho\vec{j}$

Ohm's Law: $\Delta V = IR$ (or often just) $V = IR$

Resistivity and conductivity: $\rho = \frac{1}{\sigma}$

Resistance of a wire [Ω]: $R = \frac{\rho\ell}{A}$

Resistance of an object [Ω]: $R = \int \frac{\rho(x)dx}{A(x)}$

Power in a circuit element [W]:
$P = I\Delta V$ (or often) $P = IV$

Eff. Res. (series) [Ω]: $R_{eff} = \sum_i R_i$

Eff. Res. (parallel) [Ω]: $\frac{1}{R_{eff}} = \sum_i \frac{1}{R_i}$

Time constant for an RC-circuit [s]: $\tau = RC$

Charge on a charging capacitor [C]:
$q(t) = q_{\max}(1 - e^{-t/\tau})$

Charge on a discharging capacitor [C]:
$q(t) = q_0 e^{-t/\tau}$

Current in an RC-circuit [A]: $I(t) = I_0 e^{-t/\tau}$