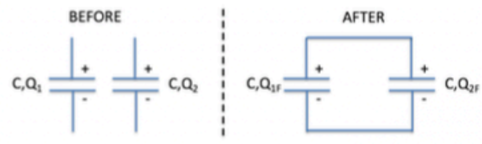
1)

[8 pts.] Two separate capacitors of the same capacitance C are initially charged to Q_1= 2 μC and Q_2=8 μC. Then their positive plates are connected to each other and their negative plates are connected to each other. The final charges Q_{1F} and Q_{2F} become :



4 μC and 6 μC

5 μC and 5 μC

4 μC and 4 μC

3 μC and 7 μC

2 μC and 4 μC

3 μC and 3 μC

- total charge $= Q_1 + Q_2 = 8 + 2\,\mu C = 10\,\mu C$
- Since ΔV equal & C equal, final charges also equal, $Q_1 = Q_2 = 5\,\mu C$

2)

[8 pts.] A parallel-plate capacitor is held at a fixed voltage. If the separation of its plates is doubled, the electric energy stored in the capacitor is :

1/4 of the original

1/2 of the original

unchanged

doubled

quadrupled

$U = \frac{1}{2} C (\Delta V)^2, \quad C = \frac{\epsilon_0 A}{d}$

$C \to \frac{1}{2}$ original with ΔV constant.

3)

[8 pts.] A charged air-filled capacitor is disconnected from the battery. A sheet of dielectric with κ=3 is inserted completely filling the volume between its plates. As a result, the electric energy stored in the capacitor is :

Q constant

1/9 of the original

1/3 of the original

unchanged

tripled

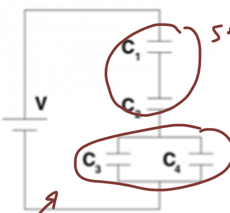
here Q = const, so use $U = \frac{1}{2}\frac{Q^2}{C}$

$C = \frac{\epsilon_0 A}{d} \Rightarrow \frac{K \epsilon_0 A}{d}$ (3x larger)

so U is 3x smaller

4)

[*10 pts.*] Consider the circuit shown with voltage V and 4 capacitors with equal capacitance C. Calculate the total capacitance and the final charge on capacitor 2.



series $\hookrightarrow C/2$

parallel $2C$

$\frac{C}{2}$ & $2C$ in series,

$$C_{eff} = \frac{(2C)(C/2)}{2.5C}$$

$$\boxed{C_{eff} = \frac{2}{5}C}$$

$C_{tot} = 0.25\ C$, $Q_2 = 0.5\ CV$

$C_{tot} = 0.4\ C$, $Q_2 = 0.8\ CV$

$C_{tot} = 1\ C$, $Q_2 = 2\ CV$

$C_{tot} = 0.25\ C$, $Q_2 = 0.25\ CV$

$C_{tot} = 0.4\ C$, $Q_2 = 0.4\ CV$

$C_{tot} = 1\ C$, $Q_2 = 1\ CV$

C_2 in series → same Q as on entire network,

$$Q = C_{eff}\,\Delta V = \boxed{\frac{2}{5}CV}$$

5)

5) [*6 pts.*] A current flows in an aluminum wire with a drift speed of the conduction electrons of 0.002 m/s. The conduction electron density in aluminum is $6.0\times10^{28}/\ m^3$. What is the current density in the wire?

$J = n e v_d$, $v_d = 0.002\ m/s$

$e = 1.6\times10^{-19}\ C$

$3.3\ 10^{24}\ A/m^2$

$3.0\ 10^{31}\ A/m^2$

$4.3\ 10^{20}\ A/m^2$

$1.2\ 10^{26}\ A/m^2$

✓ $1.92\ 10^{6}\ A/m^2$

$1.92\ 10^{9}\ A/m^2$

6)

) *[8 pts.]* Calculate the power used by a circuit that has a resistance of 150 Ω and draws a current of 0.4 A.

0.0026 W

0.16 W

$P = I^2 R = (0.4A)^2(150\Omega) = 24W$

24 W

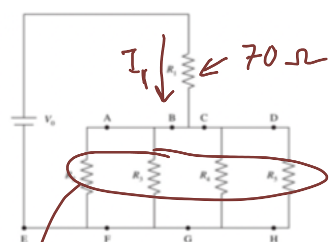
60 W

150 W

375 W

7)

[10 pts.] A voltage of V_0 = 24 V is supplied to the resistor configuration shown, with R_1 = 70 Ω and R_2=R_3=R_4=R_5= 200 Ω. Calculate the current through point A (i.e., through R_2) and through point B.



I_1 ↓ ← 70 Ω

I_A = 0.15 A, I_B = 0.15 A

$R_{eff} = \frac{200\Omega}{4} = 50\Omega$

I_A = 0.15 A, I_B = 0.3 A

so $I_1 = \frac{24V}{(70+50\Omega)} = 0.2A$, thru R_1

I_A = 0.05 A, I_B = 0.05 A

- at center junction, junction rule & symmetry ⇒ $I_B = I_C = I_1/2$ so $I_B = 0.1$ A

I_A = 0.05 A, I_B = 0.1 A

- junction at left similarly divides I_B further in half.

I_A = 0.02 A, I_B = 0.04 A

I_A = 0.01 A, I_B = 0.02 A

8)

[8 pts.] Order the circuits shown below according to their power output, from highest to lowest. All batteries have the same voltage, and all light bulbs have the same resistance.

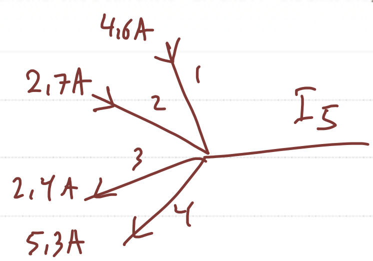
parallel R/3   series 3R   parallel R/2   series 2R

- 1234
- 1342
- 2314
- 2413
- 3412
- 3124
- 4123
- 4213

$$P = \frac{V^2}{R} \rightarrow \text{largest } R = \text{smallest } P$$

9)

[8 pts.] Five wires meet at a junction. In two of the wires, a current of I1 =4.6 A and I2 = 2.7 A enters the junction, and in another two a current I3 = 2.4 and I4 = 5.3 exits the junction. Determine the current in wire 5.



- 0.2 A into the junction
- 0.2 A out of the junction
- 0.4 A into the junction
- 0.4 A out of the junction
- 0.6 A into the junction
- 0.6 A out of the junction

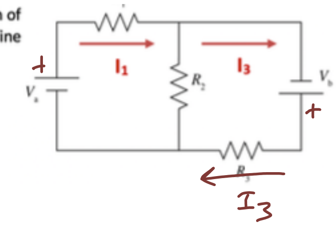
$\sum I = 0$ (junction rule)

sum of $I_1 - I_4 = 0.4$ A <u>out</u>

$\rightarrow I_5$ 0.4 <u>in</u>

10)

10) [*8 pts.*] In the circuit shown V_a = 20 V and V_b = 5 V. Which of the following relations is correct (the arrows below define the direction of current flow for I_1 and I_3).



$20\,V - R_1 I_1 - 5\,V + R_3 I_3 = 0$

$20\,V + R_1 I_1 - 5\,V - R_3 I_3 = 0$

$20\,V - R_1 I_1 + 5\,V + R_3 I_3 = 0$

$20\,V + R_1 I_1 + 5\,V - R_3 I_3 = 0$

$20\,V - R_1 I_1 + 5\,V - R_3 I_3 = 0$

this is loop rule for loop around perimeter

11)

1) [8 pts.] You charge an initially uncharged 68 mF capacitor through a 32 Ω resistor by means of a battery. After what time has the charge on the capacitor reached 90% of its maximum?

$I = I_{max}\underbrace{\left(1 - e^{-t/RC}\right)}_{=0.90}$

0.23 seconds

5 seconds

so $e^{-t/RC} = 0.10$ with $RC = 2.18\,s$

15 seconds

$t = RC \ln 10 = 5.0\,s$

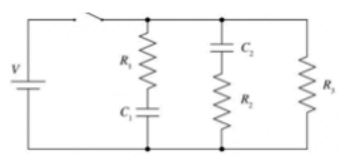
25 seconds

50 seconds

12)

[*5 pts.*] Consider the RC circuit shown in the diagram, with a battery voltage V. Before the switch is closed, both capacitors are uncharged. All the resistances are the same and equal to R, and the capacitances are C_2=2C_1.

What is the amount of current supplied by the battery immediately after the switch is closed ?



$3\frac{V}{R}$

at time=0, capacitors have no ΔV ("like wires")

$\frac{V}{R}$

so effectively the 3 resistors act as a parallel combination

$\frac{2}{3}\frac{V}{R}$

$\hookrightarrow R_{eff} \Rightarrow R/3$

$\frac{1}{2}\frac{V}{R}$

so $I = \frac{\Delta V}{R_{eff}} = \frac{V}{R/3}$

$\frac{1}{3}\frac{V}{R}$

13)

) [5pts] Same circuit as problem 12. What is the amount of current supplied by the battery a long time after the switch is closed ?

$3 \frac{V}{R}$

$\frac{V}{R}$

$\frac{2}{3} \frac{V}{R}$

$\frac{1}{2} \frac{V}{R}$

$\frac{1}{3} \frac{V}{R}$

0

for $t \to \infty$ capacitors don't admit any current

Battery must supply current to far-right resistor only,

$R_{eff} = R$.