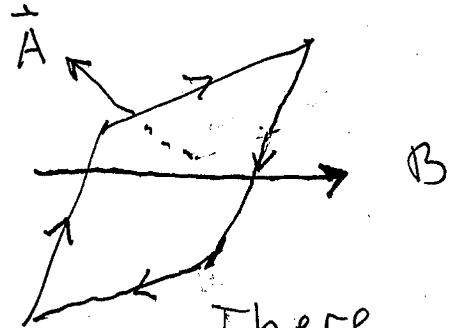
Lecture # 15

Magnetism &
Review

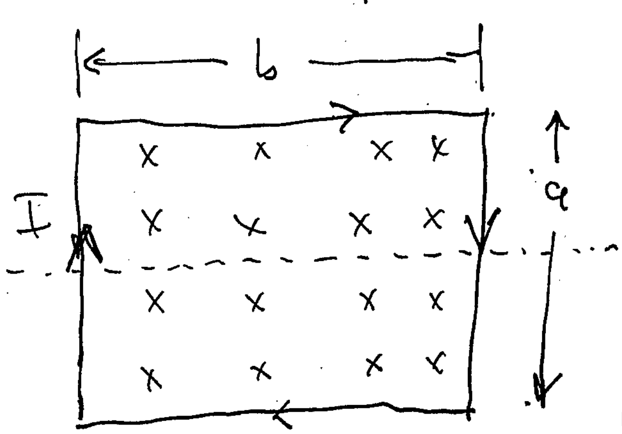
Force on a loop



There is a total force of a loop in a uniform magnetic force.

(a) true (b) false

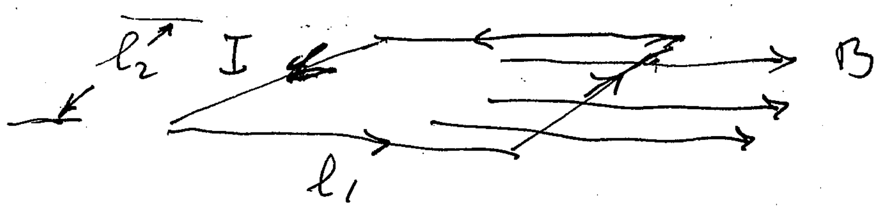
Torque on a loop



There is a torque on this loop

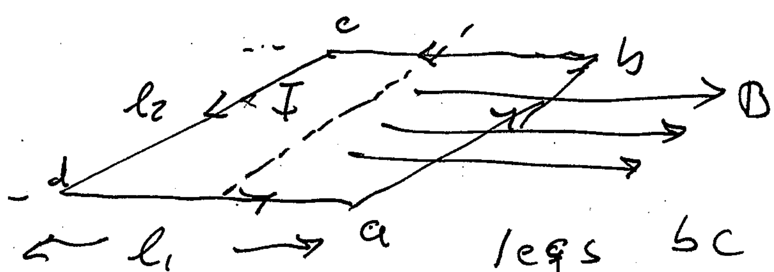
(a) true (b) false

There is a torque on this loop



(a) True (b) False

What is torque



legs bc & da no torque

leg ab has downward force IBl_2

force moment about midline clockwise $F\frac{l_1}{2} = IB\frac{l_2 l_1}{2}$

leg cd has upward force IBl_2

force moment about midline

$F\frac{l_1}{2} = IB\frac{l_2 l_1}{2}$, clockwise

Total torque is sum of two torques

$\tau = IBl_2l_1 = IAB = mB \quad (m = IA)$

m is magnetic moment

Generalization of a torque and magnetic moment

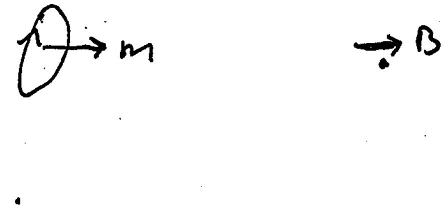
$\tau = \vec{m} \times \vec{B}$

$\vec{m} = I\vec{A}$ for a single current loop.

$\vec{m} = NI\vec{A}$ for a current loop with N turns

on axis magnetic field from a magnetic dipole (at distances large compared to dipole dimensions)

$$\vec{B} = \frac{\mu_0 \vec{m}}{2\pi |\vec{r}|^3}$$



magnetic field in meridian plane of dipole

$$\vec{B} = -\frac{\mu_0 \vec{m}}{4\pi |\vec{r}|^3}$$

Dipole can be made by current loops, or from internal currents of atoms and spin of electron:

Permanent magnets are dipoles even in absence of external magnetic field

Many materials form induced dipoles in presence of magnetic field

$$\frac{\text{magnetic moment}}{\text{volume}} = \chi \vec{B} \quad \begin{pmatrix} \chi > 0 \text{ paramagnetic} \\ \chi < 0 \text{ diamagnetic} \end{pmatrix}$$

↑ magnetic susceptibility

In such medium, induced magnetic moments change $\vec{B}$ field from imposed currents

$$d\vec{B} = \frac{\mu}{4\pi} I \frac{d\vec{s} \times \vec{r}}{|\vec{r}|^3} \quad [\mu = \mu_0(1+\chi)]$$

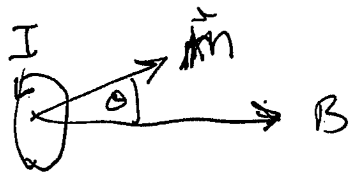
What is magnetic field in a solenoid filled with a material with a susceptibility χ?

Alignment Energy:

Lowes energy is when $\vec{m} \parallel \vec{B}$

$$U = -\vec{m} \cdot \vec{B}$$

$$= -|\vec{m}||\vec{B}| \cos\theta$$



Note: magnetic moment likes to align itself so that its fields are parallel to external field

Checkup 26.1

A parallel-plate capacitor has plates measuring 10 cm × 10 cm and a plate separation of 2.0 mm. If we want to construct a parallel-plate capacitor of the same capacitance but with plates measuring 5.0 cm × 5.0 cm, what plate separation do we need?

a. 8.0 mm

b. 4.0 mm

c. 2.0 mm

d. 1.0 mm

e. 0.5 mm

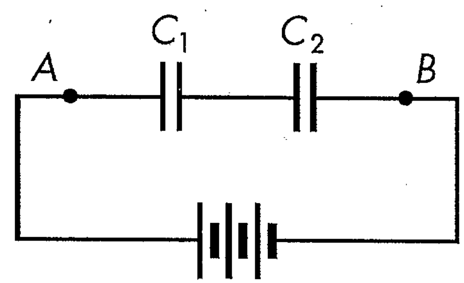
Checkup 26.2

If you connect 10 capacitors of 1.0 μF each in parallel, what is the net capacitance? What if you connect them in series?

a. 10 μF, 10 μF
b. 0.10 μF, 10 μF
c. 10 μF, 0.10 μF
d. 0.10 μF, 0.10 μF

PhysiQuiz 26-3

Capacitors 1 and 2 are connected to a battery as shown.
$C_1 = 1\ \mu f$, $C_2 = 2\ \mu f$, and $V_{AB} = 3$ V.



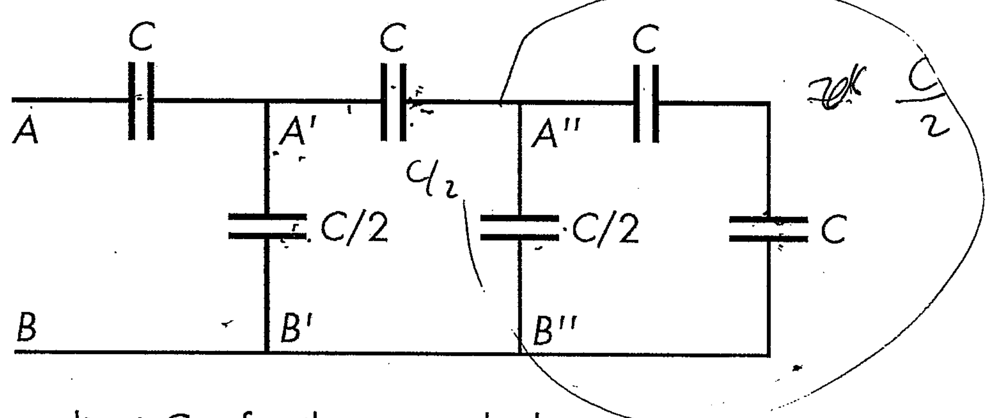
Find the ratio Q_1/Q_2, where Q_1 and Q_2 are the charges on the respective capacitors:

	A	B	C	D
Q_1/Q_2	2	1	1/2	1/3

Hint: Use the relationship $Q = VC$ and the idea that in series $V = V_1 + V_2$.

Extra: Show that the ratio $V_1/V_2 = 2$.

PhysiQuiz 26-4



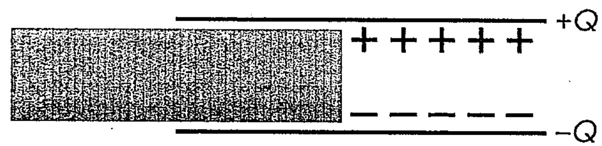
Determine the resultant C_{AB} for the network shown:

	A	B	C
C_{AB}	C	$C/2$	$2C$

Hint: For a parallel connection between C_1 and C_2, the resultant capacitance is: $C = C_1 + C_2$.

For a series connection: $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$, $C = \frac{C_1 C_2}{C_1 + C_2}$.

PhysiQuiz 26-10



If a dielectric slab is inserted halfway into a charged capacitor, find the direction of the force on the slab:

	A	B	C
Direction of force	To left	0	To right

Hint: The natural tendency for the slab is to move from high potential to low potential.

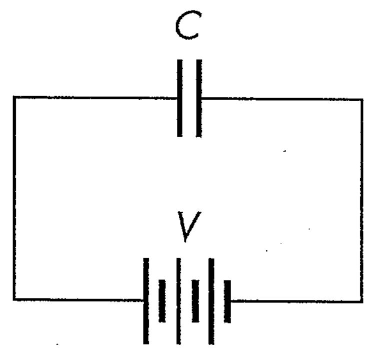
Find the capacitance C' at this point The dielectric constant is κ ?

(a) κC (b) $(1 + \kappa)C/2$ (c) $2\,C/(1+ \kappa)$

Extra: Show that the magnitude of the work in inserting the slab into the system is given by $\left(1 - \frac{1}{\kappa}\right)\frac{Q^2}{2C}$.

Why is this?

PhysiQuiz 26-8



A capacitor with a capacitance C is connected to a battery with a voltage V. The capacitor has a plate charge Q and a total energy U. Now fill the capacitor's gap with a material that has a dielectric constant κ. The corresponding new quantities are Q' and U'.

Determine the ratio of charges Q'/Q:

	A	B	C
Q'/Q	κ	1	$1/\kappa$

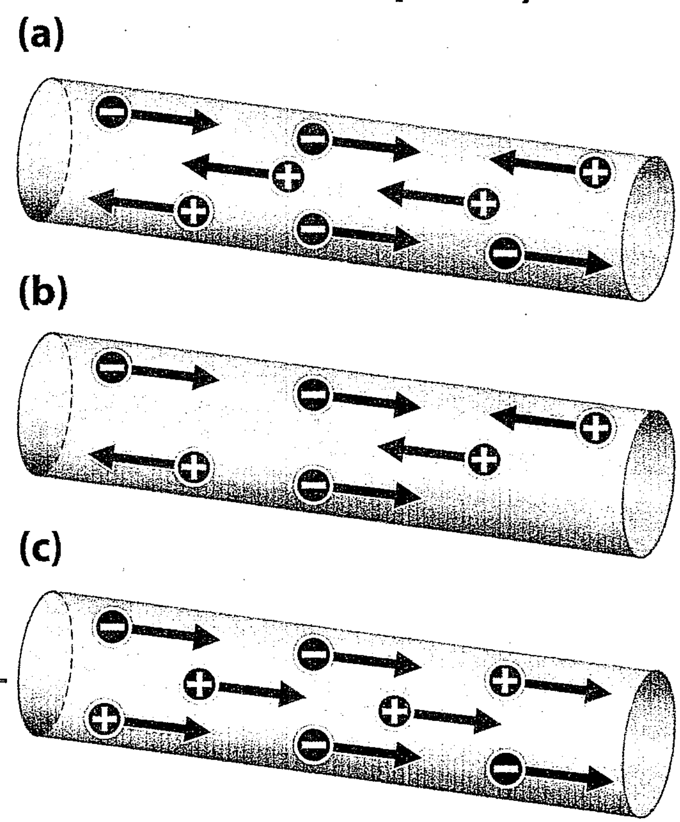
Hint: $V' = V$, $Q = VC$, and $U = \frac{Q^2}{2C} = \frac{1}{2}CV^2$.

Extra: Show that the ratio of total energies is $U'/U = \kappa$.

Checkup 27.1

Suppose some currents consist of both positive and negative moving elementary charges, as shown in the figure below. Which of the currents has the largest magnitude? The smallest magnitude? (Assume all speeds are equal.)

a. (a), (b)
b. (a), (c)
c. (b), (c)
d. (c), (a)
e. (c), (b)



Take the number of arrows to be proportional to the current density of a given carrier

✓ Checkup 27.2

If the average collision time gets longer, what happens to the resistivity? What happens to the resistivity when the density of electrons increases?

a. Increases, increases
b. Increases, decreases
c. Decreases, increases
d. Decreases, decreases

✓ Checkup 27.4

If you connect 10 resistors of 1 Ω in series, what is the net resistance? What if you connect them in parallel?

a. 10 Ω, 10 Ω

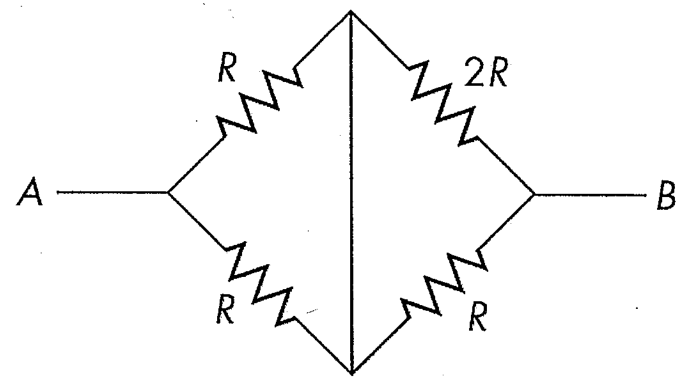
b. 0.1 Ω, 10 Ω

c. 10 Ω, 0.1 Ω

d. 0.1 Ω, 0.1 Ω

PhysiQuiz 27-4

Consider this resistor network:



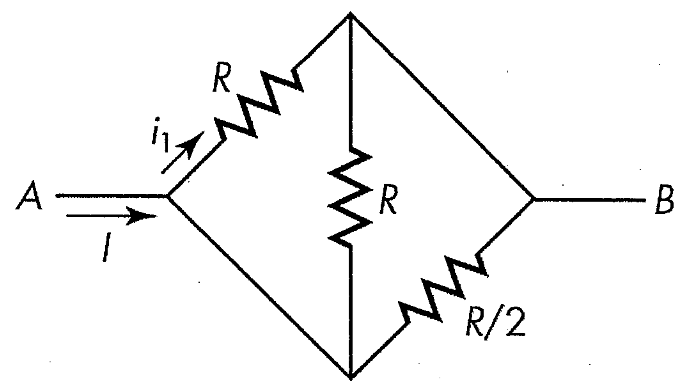
Determine R_{AB}:

	A	B	C
R_{AB}	$7R/6$	$6R/5$	$5R$

Hint: Analogous to the capacitor network case, we may use the same deformation rule. In other words, a segment of wire in a circuit may be contracted to a point. A point may be stretched out to a segment.

Tricky Problem

PhysiQuiz 27-5



A current I enters the resistor network shown. Find the current i_1:

	A	B	C
i_1	$I/2$	$I/3$	$I/4$

Checkup 28.1

Suppose that we change the current through a conventional battery. As it runs down completely, the battery will then deliver:

a. The same energy
b. Less energy
c. More energy

Checkup 28.2

Two identical single-cell batteries are stacked in series; another two are connected in parallel. The two arrangements have a different:

a. Amount of stored energy
b. Electromotive force
c. Form of stored energy

Checkup 28.3

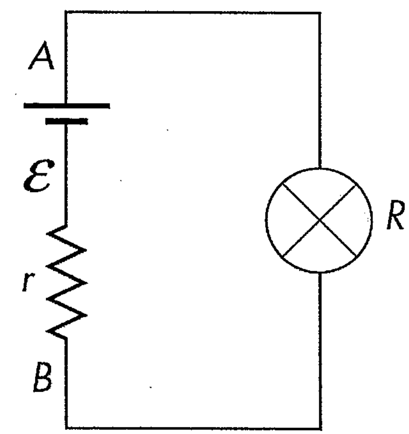
Suppose that a battery with emf E has a somewhat large internal resistance, $R_i \approx 2\Omega$. If we connect a thick piece of wire with a resistance $R \approx 0.1\Omega$ between the terminals of the battery, the voltage at the terminals of the battery is:

a. Exactly equal to E

b. Slightly less than E

c. Much less than E

PhysiQuiz 28-1



In the circuit shown, the battery has an emf $\mathcal{E} = 10$ V with an internal resistance $r = 1\ \Omega$. Consider two cases: Case I: $R = 0.01\ \Omega$.

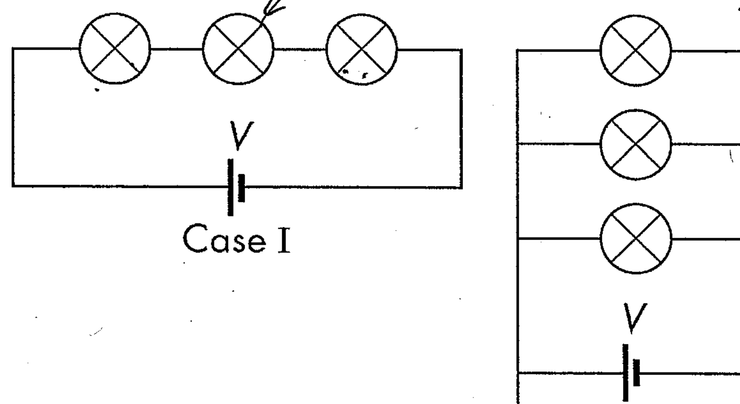
Case II: $R = 100\ \Omega$.

Compare V_{AB} with $\mathcal{E}$ for case I. Choose one:

	A	B
Case I	$V_{AB} << \mathcal{E}$	$V_{AB} \sim \mathcal{E}$

	A	B
Case II	$V_{AB} << \mathcal{E}$	$V_{AB} \sim \mathcal{E}$

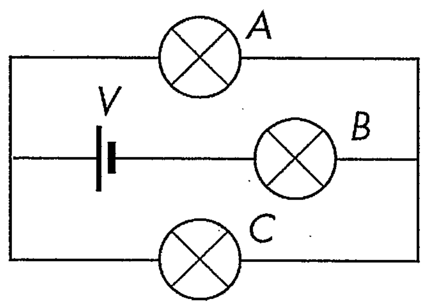
PhysiQuiz 28-4



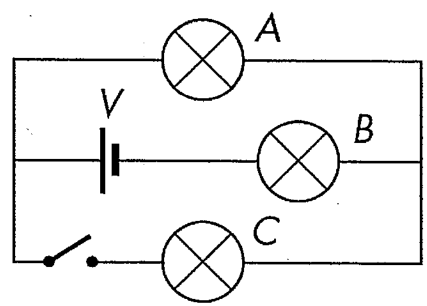
Three identical lightbulbs, each with a resistance R, are connected in two ways as shown. Determine P_{II}/P_{I}, where P_{I} is the power per bulb in case I, and P_{II} is the power per bulb in case II:

	A	B	C	D
P_{II}/P_{I}	9	3	1/3	1/9

PhysiQuiz 28-5



Case 1

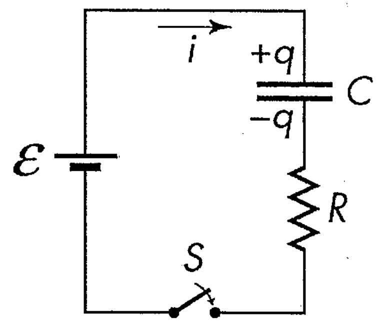


Case 2

Three identical lightbulbs are connected in two ways as shown. Denote I_B and P_B to be the current and power at bulb B in case 1 and I_B' and P_B' as the corresponding quantities in case 2. The ratio of currents through bulbs B is given by which of the following?

	A	B	C	D
I'_B/I_B	4/3	1	3/4	2/3

PhysiQuiz 28-6

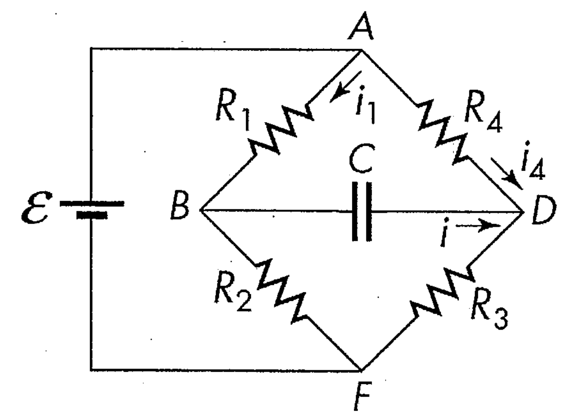


Consider the RC circuit shown. The capacitor is initially uncharged. The loop equation is given by $\mathcal{E} - \frac{q}{C} - iR = 0$. Determine q and i immediately after closing S at $t = 0$:

	q_0	i_0
A	0	$\frac{\mathcal{E}}{R}$
B	0	$\mathcal{E}R$
C	$\mathcal{E}C$	$\frac{\mathcal{E}}{R}$
D	$\mathcal{E}C$	$\mathcal{E}R$

Extra: After a long time (in other words, at $t = \infty$) there is no more current. Show that $q_\infty = \mathcal{E}C$.

PhysiQuiz 28-7



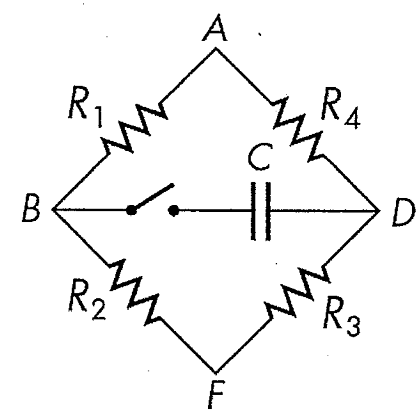
Consider the circuit shown. The currents are all flowing at a constant rate; in other words, the system is in a steady state. Given $R_1 = R_3 = R_4 = R$ and $R_2 = 2R$, determine $V_B - V_A$.

	A	B	C	D
$V_B - V_A$	$\mathcal{E}/3$	$2\mathcal{E}/3$	$-\mathcal{E}/3$	$-2\mathcal{E}/3$

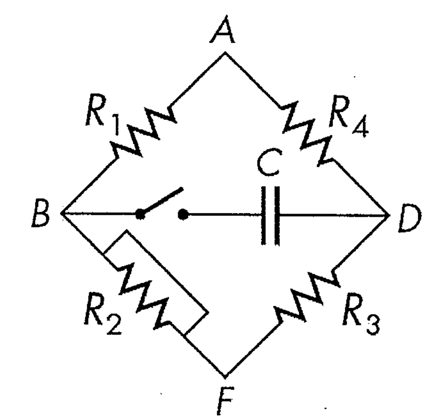
Hint: In a steady state, by definition the charge on the capacitor has a constant value. This implies that the current from B to D vanishes; in other words, $i = 0$.

Extra: Show that the potential difference $V_B - V_D = \mathcal{E}/6$.

PhysiQuiz 28-8



Case 1



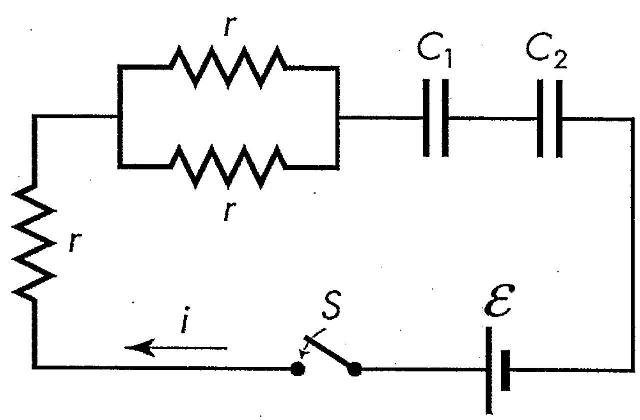
Case 2

Consider the RC circuit in Case 1, in which $R_1 = R_2 = R_3 = R_4 = r$. The capacitor is charged initially to Q_0. Close the switch at $t = 0$. At any t later, the charge Q on the capacitor may be written in the form $Q = Q_0 e^{-\frac{t}{\tau}}$. Determine an algebraic expression for the characteristic time of the circuit τ:

	A	B	C	D
τ	$rC/2$	rC	$2rC$	$4rC$

Extra: Show that if we "short" R_2 by connecting a wire across R_2 (see Case 2), then the new characteristic time is given by $\tau = (2/3)rC$.

PhysiQuiz 28-9



In the circuit diagram here, $C_1 = C_2 = C$. If S is closed at $t = 0$, find i at $t = 0$:

	A	B	C
i at $t = 0$	$\mathcal{E}/r$	$2\mathcal{E}/(3r)$	$\mathcal{E}/(3r)$

Extra: Show that the plate charge on C_1 at $t = \infty$ is $\mathcal{E}C/2$.