Last Name: Bruin

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MIDTERM #2
Physics 1BH
Prof. David Saltzberg
February 11, 2016

Time: 50 minutes. Closed Notes. Closed Book. Allowed the standard "cheat sheet". Calculators are allowed. Show your work.

If a problem is confusing or ambiguous, notify the professor. Clarifications will be written on the blackboard. Check the board.

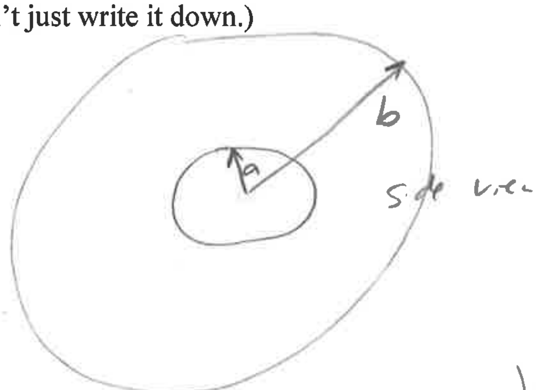
There are 5 pages including this cover sheet. Make sure you have them all. Extra workspace is given and extra paper is at the front of the room.

Problem	Points
1	25 /25
2	25 /25
3	25 /25
4	26 /25
TOTAL	101 /100

Good job

1) A coaxial cable has a solid inner copper conductor of radius a=0.5 mm and thin, hollow outer copper conductor of radius b=1.0 cm.

Calculate the capacitance per meter of the cable using the definition of capacitance. (Show your work. If you happen to remember a particular formula for this geometry, don't just write it down.)



put on charge Q & −Q

$\lambda = Q/l$ l = length

$$E = \frac{\lambda}{2\pi\epsilon_0 r}$$

$$V = -\int_a^b \vec{E}\cdot d\vec{r} = \frac{\lambda}{2\pi\epsilon_0}\ln(b/a)$$

$$V = \frac{(Q/l)\ln(b/a)}{2\pi\epsilon_0}$$

I am not worrying about overall minus sign since I know C is positive

$$C = \frac{Q}{V} = \frac{2\pi\epsilon_0 l}{\ln(b/a)}$$

$$\frac{C}{l} = \frac{\text{capacitance}}{\text{meter}} = \frac{2\pi\epsilon_0}{\ln(b/a)}$$

$$= \frac{2\pi(8.85\times10^{-12})}{\ln(0.01/0.0005)}$$

$$= 1.9\times10^{-11}\ \text{F/m}$$

$$= 19\ \text{picofarads/m}$$

~~2~~ 36000 Ω-m

2) The region between two thin concentric spherical shells of a conductor is filled with material with resistivity ρ=~~2.0~~ Ω–m. The inner conductor has a radius a =2.0 m and the outer conductor radius b=4.0 m. What is the resistance between the inner and outer conductor?

$R = \frac{\rho l}{A}$ for each shell of area $4\pi r^2$ and thickness dr

$$R = \int_a^b (\rho) \frac{dr}{4\pi r^2}$$

$$= \frac{\rho}{4\pi}\left[-\frac{1}{r}\right]_a^b$$

$$R = \frac{\rho}{4\pi}\left[\frac{1}{a} - \frac{1}{b}\right]$$

$$R = \frac{\rho}{(4\pi)}\left[\frac{1}{2} - \frac{1}{4}\right]$$

$$= \frac{36000}{4\pi}\left[\frac{1}{4}\right]$$

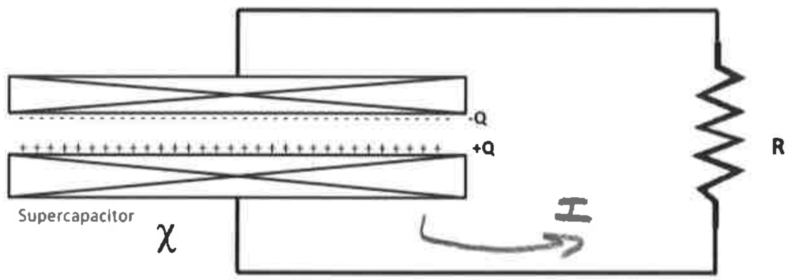
$$= \frac{2250}{\pi}$$

$$R \simeq 700\ \Omega$$

$= 717\ \Omega$ with calculator

3) Recently, physicists at a top-secret government laboratory invented a super-capacitor. The relationship that determines potential φ between parallel plates and the magnitude of charge Q on each plate of this device is given by $Q=\chi\varphi^{1/3}$ where χ is a constant with the appropriate SI units called super-farads. Suppose a super-capacitor is charged with initial potential of 8.0 V between each plate and that χ is 2.0 super-farads. If it is disconnected from the battery and then connected to a resistor with resistance R=10 Ω how long does it take to discharge by 50%?

$Q_0 = \chi V_0^{1/3}$



$I = -\frac{dQ}{dt}$

(I discharges capacitor)

Loop rule

$\Delta\varphi_{cap} - IR = 0$

$\left(\frac{Q}{\chi}\right)^3 + \frac{dQ}{dt}R = 0$

$\frac{Q^3}{\chi^3} = -\frac{dQ}{dt}R$

$\int_0^t \frac{dt'}{\chi^3} = \left(-\int_{Q_0}^{Q_0/2} \frac{dQ}{Q^3}\right)R$

$\frac{t}{\chi^3} = \frac{R}{2}\left[\frac{1}{Q^2}\right]_{Q_0}^{Q_0/2}$

$\frac{t}{\chi^3} = \frac{R}{2}\left[\frac{4}{Q_0^2} - \frac{1}{Q_0^2}\right]$

$\frac{t}{\chi^3} = \frac{3R}{2Q_0^2}$

$t = \frac{3\chi^3 R}{2Q_0^2} = \frac{3\chi^3 R}{2\chi^2 V_0^{2/3}}$

$= \frac{\left(\frac{3}{2}\right)(2)(10)}{8^{3/2}} = $ 7.5 seconds

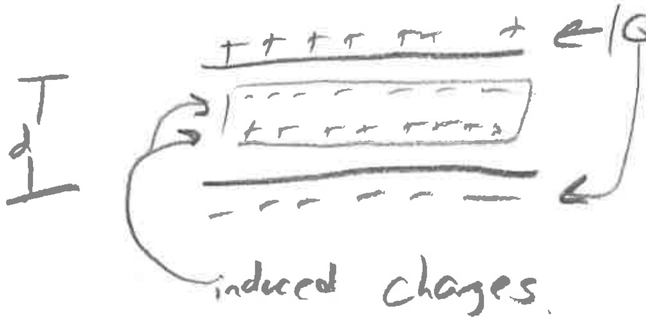
4) Multiple choice <u>with</u> explanation:

A parallel-plate capacitor is "charged" by a battery and disconnected. You slide a slab of dielectric material (for example, plastic) between the plates. What effect does adding the dielectric have on the potential difference between the plates?

A) The potential difference increases.
B) The potential difference decreases
C) The potential difference stays the same
D) There is not enough information to decide.

(B)

Explain (you probably need a drawing):



Q stays the same

E↓ d stays the same ⇒ $V\downarrow$

note $C = Q/V$ ⇒ capacitance goes up as expected