

Name _____

Exam # 3
Physics 248
April 25, 2007

Problems will be graded on reasoning and intermediate steps as well as on the final answer. Be sure to include units and direction of vectors when needed.

Each problem is worth 25 points

Constants:

$$c \approx 3 \times 10^8 \text{ m/s}, k \approx 9 \times 10^9 \text{ Nm}^2/\text{C}^2, m_e = 9.1 \times 10^{-31} \text{ kg} = 0.51 \text{ MeV}/c^2,$$
$$m_{\text{proton}} = 1.67 \times 10^{-27} \text{ kg},$$
$$h = 6.62 \times 10^{-34} \text{ m}^2 \text{ kg/s}, \hbar c = 197.3 \text{ eV} \cdot \text{nm}, e = 1.6 \times 10^{-19} \text{ C}$$

Problem	Score
1	
2	
3	
4	
Total	

1. Multiple choice questions and short problems. Explain your reasoning that leads to the final answer.

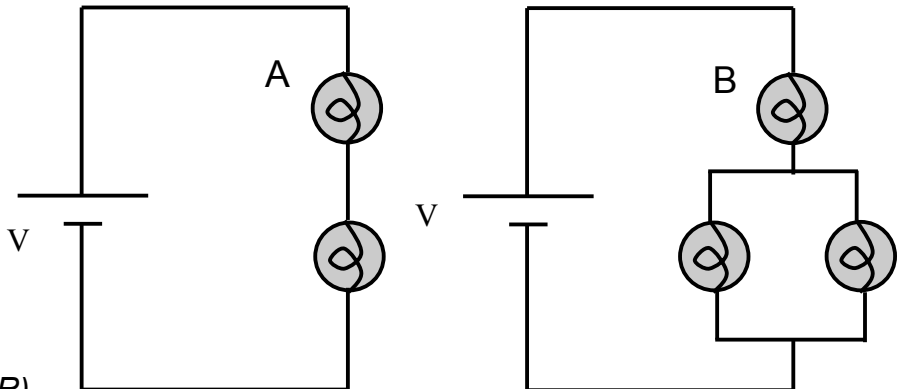
A) Circle the correct answer below

How does the brightness of the labeled bulbs compare in these two circuits? All bulbs are identical. The batteries are ideal and identical.

A brighter than B

A dimmer than B

A & B same brightness



2nd: the current in A is $I = V/(2R)$

And in B it is $I = 2/3 * (V/R)$ so it is larger and A is dimmer than B

B) How does the electric field of a charged conducting spherical shell of inner radius a and outer radius b depend on the distance from its center r ? Q is the charge of the shell.

Using Gauss' law:

$$r < a \quad E = 0$$

$$\text{in the shell } a < r < b \quad E = 0$$

$$r > b \quad E = kQ/r^2$$

C) A parallel plate capacitor of area A and distance between the plates d is charged with charge Q and insulated. If a dielectric of dielectric constant $\kappa=4$ is inserted between the plates so that it fills completely the space between the plates, which is the change in the capacitor potential energy respect to the case in which it is empty? Does the potential energy increase or decrease?

$$U_{\text{initial}} = Q^2/(2C_0) \text{ with } C_0 = \epsilon_0 A/d$$

$$U_{\text{final}} = Q^2/(2C) \text{ with } C = \kappa \epsilon_0 A/d. \text{ Hence } U_{\text{final}} = 1/4 U_{\text{initial}}$$

And the variation of the potential energy is

$$U_{\text{final}} - U_{\text{initial}} = 1/2 Q^2 d / (\epsilon_0 A) (1/\kappa - 1)$$

So the potential energy decreases.

D) Answer True or False for the following statements and explain why.

- The potential difference between the surfaces of a conducting charged shell is zero.

True because the electric field inside the conductor is zero.

- The potential of the inner surface is zero.

False because the potential of the inner surface is equal to the one of the outer surface so it must be not null.

2. Assume a nuclear charge of Ze with $Z = 4$ and a single electron orbiting. Answer to these short questions about the Bohr's model:

a. Find the radius of the electron in a circular orbit around the nucleus as a function of the velocity considering the interaction between the nucleus and the electron.

$$\text{From } F = kZe^2/r^2 = mv^2/r$$
$$r = kZe^2/(mv^2)$$

b. Apply the Bohr quantization condition on the angular momentum to find the velocity of the electron in the n state.

$$\text{From } L = mvr = n\hbar$$
$$v_n = kZe^2/(n\hbar)$$

c. To find out how relativistic is the electron motion in the orbit, calculate the numerical ratio of v/c for the ground state $n=1$ where c is the velocity of light (see front page for its value).

$$v/c = kZe^2/(c\hbar) = 2.92\%$$

3. In the circuit in the figure, $\varepsilon = 1.2 \text{ kV}$, $C = 6.5 \mu\text{F}$ e $R_1 = R_2 = R_3 = R = 1.0 \text{ M}\Omega$. C is completely discharged at $t = 0$ when the switch S is closed.

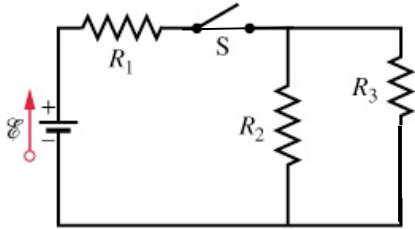
A) Draw the equivalent circuit and calculate the current through R_3 at $t = 0$;

B) Draw the equivalent circuit and calculate the current in R_1 and in R_3 after an infinite time when the capacitor can be considered fully charged.

Let's suppose that the capacitor is now fully charged. The switch is open and the capacitor begins to discharge.

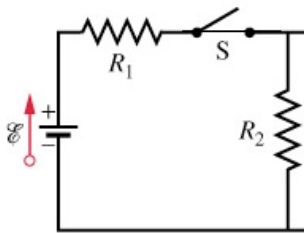
C) Calculate the value of the time constant of the circuit for the discharge of the capacitor (switch open)

A) The equivalent circuit is

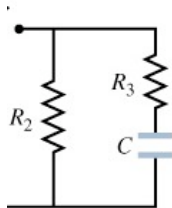


$$i_3 = \frac{\varepsilon}{3R} = 1.2/3 \text{ mA} = 0.4 \text{ mA}$$

B) $i_1 = \frac{\varepsilon}{2R} = 0.6 \text{ mA}$ $i_3 = 0$



C) $\tau = 2RC = 13 \text{ s}$



4. Calculate the cyclotron frequency of a proton moving in a plane perpendicular to a uniform magnetic field of 1.0 T. Does it depend on the velocity of the proton?

From $qvB = \frac{mv^2}{r}$ and $\omega = \frac{v}{r} \Rightarrow f = \frac{\omega}{2\pi} = \frac{qB}{2\pi m} = 1.5 \times 10^7 \text{ s}^{-1}$
 independent on the velocity