

## 8.02x Electricity and Magnetism

### Problem Set 5

~~Issued: Fri, Mar 4~~

~~Due: Fri, Mar 11, 4PM < note Date + Time!~~

~~Note that the EF write-up from both lab partners is also due on 3/11 4PM!~~

~~Reading suggestions (from Young & Freedman)~~

~~Mon: Electric Current, Resistivity, Circuits, chapters 25.1 to 25.5~~

~~Wed: DC Circuits, Kirchoffs Rules, chapters 26.1 to 26.3~~

~~Fri: Quiz 2 review~~

### Homework Problems (30 points total)

**Problem 1 (10 points)** Consider a simple parallel plate capacitor of Area  $A$  for each plate and separation  $d$  between the plates. The plates are given equal and opposite charges  $Q$  and the capacitor is isolated from the rest of the world

- (a) What is the potential difference between the plates in terms of the given variables?
- (b) What is the stored energy in the capacitor?
- (c) Assume the plates are moved from a separation  $d$  to  $2*d$ . How much does the stored energy in the capacitor change?
- (d) Show that the change in potential energy in question (c) is identical to the work done on the plates when moving them from  $d$  to  $2*d$ .
- (e) Assume a dielectric with dielectric constant  $k=10$  is inserted such that it fills the gap of the capacitor. How much does the stored energy change? How is energy conservation satisfied?

~~**Problem 2 (5 points)** For the HVPS experiment, you found that the voltage across the output capacitor was lowest when the load had the lowest resistance. Explain this observation.~~

~~**Problem 4 (5 points)** Young & Freedman, page 972, Question Q25.11~~

~~**Problem 5 (5 points)** Young & Freedman, page 975, 25.34~~

~~**Problem 6 (5 points)** Young & Freedman, page 975, 25.38~~

~~Note that check-off and experiment write-up for experiment 'Electrostatic Force (EF)' are due on Fri, 3/11. EF questions were provided in a separate document. There will be 2 bonus points for EF check-off on 3/7 and 1 bonus point on 3/8.~~

## MIT Department of Physics

Physics 8.02X

Spring 2005

## Solution to Problem Set #5

**Problem 1 (10 points)** Consider a simple parallel plate capacitor of Area  $A$  for each plate and separation  $d$  between the plates. The plates are given equal and opposite charges  $Q$  and the capacitor is isolated from the rest of the world

(a) What is the potential difference between the plates in terms of the given variables?

$$\Delta V = \frac{Qd}{\epsilon_0 A}$$

(b) What is the stored energy in the capacitor?

$$U = \frac{Q^2}{2C} = \frac{Q^2}{2(\epsilon_0 A/d)} = \frac{Q^2 d}{2\epsilon_0 A}$$

(c) Assume the plates are moved from a separation  $d$  to  $2*d$ . How much does the stored energy in the capacitor change?

From the result of (b) we know that the new energy must be twice the old one, thus the energy change should be  $\Delta U = 2U - U = U$ .

(d) Show that the change in potential energy in question (c) is identical to the work done on the plates when moving them from  $d$  to  $2*d$ .

Work done on the plate = -Work done by electric field = Work done against the field

created by  $-Q$ :  $\left( E_- = -\frac{Q}{2A\epsilon_0} \right)$  for moving the plate with charge  $+Q$ :

$$\Delta U = -QE_-d = \frac{Q^2 d}{2A\epsilon_0} = U$$

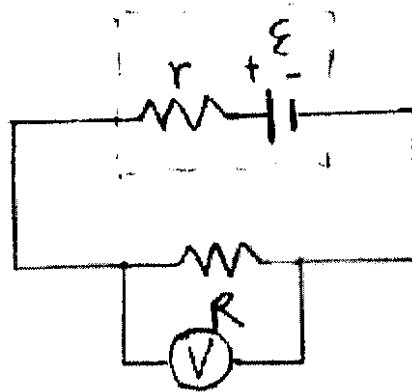
(e) Assume a dielectric with dielectric constant  $k=10$  is inserted such that it fills the gap of the capacitor. How much does the stored energy change? How is energy conservation satisfied?

$$\text{The old energy: } U = \frac{Q^2}{2C} = \frac{Q^2}{2(\epsilon_0 A/d)} = \frac{Q^2 d}{2\epsilon_0 A}$$

$$\text{The new energy: } U' = \frac{Q^2}{2KC} = \frac{Q^2}{2(K\epsilon_0 A/d)} = \frac{Q^2 d}{2K\epsilon_0 A}$$

The energy conservation is still satisfied by noticing that the electric field did work on the dielectric:  $W = U - U'$ , which causes the reduce of stored energy in the capacitor.

**Problem 2 (5 points)** For the HVPS experiment, you found that the voltage across the output capacitor was lowest when the load had the lowest resistance. Explain this observation.



HVPS has an internal resistance  $r$ . Denote the resistance of the load by  $R$ :

$$V = IR = \frac{\varepsilon R}{R + r} = \frac{\varepsilon}{1 + (r/R)} \Rightarrow \text{the lower the resistance } R, \text{ the lower the voltage across } R.$$

**Problem 4 (5 points)** Young & Freedman, page 972, Question Q25.11

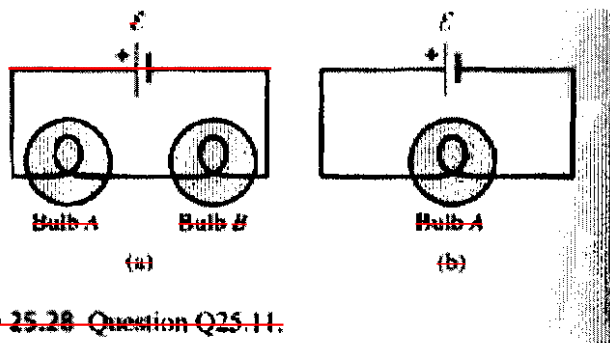


Figure 25.28 Question Q25.11.

Denote the resistance of the battery as  $r$ , and the resistance of Bulb A as  $R_A$ , the resistance of the battery as  $R_B$ . Since Bulb A and Bulb B are identical, we have  $R_A = R_B = R$ .

a) The current in the circuit is  $I_a = \frac{\varepsilon}{r + 2R}$ , and the power dissipated in the Bulb A and Bulb B are the same  $I_a^2 R$ . Thus Bulb B should be as bright as Bulb A.