國立東華大學
Department of Physics
National Dong Hwa University, 1, Sec. 2,
Da Hsueh Rd., Shoufeng, Hualien, 974, Taiwan

General Physics II, Midterm 3
PHYS1000AA, AB, AC, Class year 111-2
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Solution

*Note: You can use pencil or any pen in answering the problems. Dictionary, calculators and mathematics tables **are not** allowed. Please hand in both solution and this problem sheet. **ABSOLUTELY NO CHEATING!***

Problems (5 Problems, total 110%)
Note: in all problems, if a parameter is not given, you can assume it with the symbol you like.

1. **<u>Electric charge</u>:** (a) If we place a total charge **Q** (made up of small charges ***q***) on a solid conducting sphere. What will the charge distribution? In (a), if we have total charge ***Q*** place on a sphere of radius ***R***. What will be the charge density? (20%)

ANS: (a) The charge will be evenly distributed on the surface of the sphere, since the sphere is a solid conductor, charges will repel one another. As a result, the charges will spread evenly on the surface. (b) Follow (a) the charges will be on the surface, and we will have a surface charge density of $\frac{Q}{4\pi R^2}$

2. **<u>Electric Power</u>:** In a circuit powered by a battery with a potential difference ***ΔV***, the total loading of the circuit can be represented by a resistor loading of ***R***. What is the power consumption of the resistor?

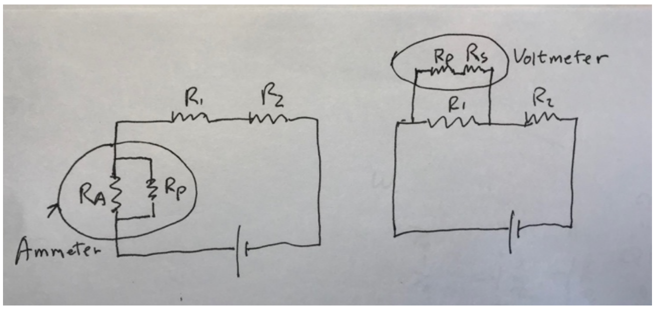
ANS: When the circuit is connected (ON), the battery provides the energy by pushing charge Q through the circuit passing the resistor. Let ***U*** be the electrical potential energy, the energy consumption rate is

$$\frac{dU}{dt} = \frac{d}{dt}(Q\Delta V) = \Delta V\left(\frac{dQ}{dt}\right) = I\Delta V$$

Power is the energy consumption rate, and $\Delta V = IR$; or $\frac{\Delta V}{R} = I$. Therefore,

$$P \equiv \frac{dU}{dt} = I\Delta V = I\,IR = I^2R = \frac{(\Delta V)^2}{R}.$$

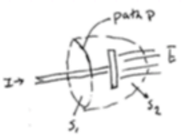
3. **<u>Measurements</u>:** (20%) (a) As shown in the figure, an Ammeter is usually used to measure the current in the circuit and connected in series with the circuit. The ammeter itself usually possess some internal resistance represented by the resistor R_A, typically 60 Ω. In addition, inside, the ammeter usually parallelly connect a small resistor of R_p with its resistor much less than R_p; (b) however to measure the voltage, the voltmeter should be connected in parallel with the measured component. Inside the voltage, there is usually a large resistor connected to internal resistor in series. In both cases, explain why?



ANS: (a) The connection of a smaller resistor inside the ammeter is to ensure most of the measured current will go through the smaller resistor (less power dissipation), so the measurement does not affect the total current in the circuit. (b) The connection of a larger resistor inside the ammeter is to ensure most of the measured current will NOT go through the larger resistor (less power dissipation), so the measurement does not affect the total current in the circuit. In both cases, the effects were tried NOT to affect the circuit due to measurement.

4. **Curernt in the capacitor:** (30%). The following figure schematically represents the current in a circuit involving capacitor. Between the two plates that are charged, there is no real current go through it; this make the discontinuation of the current. This problem is solved by Maxwell by inserting a term in the equation of Ampere's law. (a) What is Ampere's law for magnetism? (b) to make the current continuous, not discontinued, what is Maxwell's postulation? (c) Prove this team is indeed equivalent to the current ***I***.

ANS:



1) Path P as boundary of S_1
Real current passes it

2) Path P as boundary of S_2.
No conduction current passes

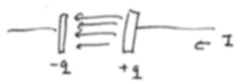
→ Contradictory situation due to the discontinuity current.

Maxwell postulated an additional term in the Ampere's law called displacement current

$I_d \equiv$ displacement current $\equiv \epsilon_0 \frac{d\Phi_E}{dt}$. $\Phi_E = \int E \cdot dA$

$\therefore \oint \vec{B} \cdot d\vec{s} = \mu_0 (I + I_d) = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$

in Fig. 30.26



$\Phi_E = EA = \frac{q}{\epsilon_0}$

$I_d = \epsilon_0 \frac{d\Phi_E}{dt} = \frac{dq}{dt} = I$ Same as the conduction current I.