PHY 202 Homework 6

Due Friday, March 5 at SE 316 at 4:30 PM.

There will be a physics tea at 3510 5th Ave. on Thursday, March 4, 7:30–9:30 pm. The second test will be held on Friday, March 12.

1. Verify that the product RC has units of seconds.

2. In class, we derived an expression for the velocity of a slowly moving boat—with its motor off—subject to frictional forces:

$$v(t) = v_0 \, \mathrm{e}^{-\beta t/m}$$

   The "viscous" frictional force is $F = -\beta v$. Integrate this equation to find the displacement of the boat as a function of time.

3. A boat on the Ohio river shuts off its engines and coasts along until it stops due to a viscous force $-\beta v$. The initial velocity of the boat is 1 m/s, and the boat comes to a halt after moving a total distance of 200 m.

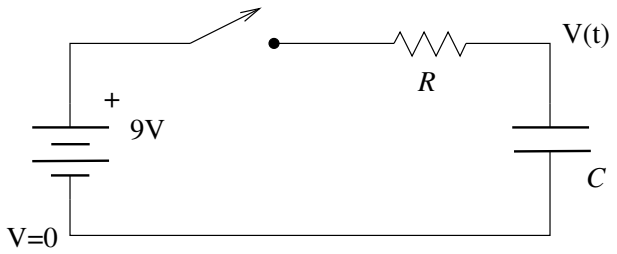
   (a) If the mass of the boat is 5×10^5 kg, what is the coefficient of viscosity β?

   (b) Graph distance as a function of time.

   (c) How much time does is take the boat to travel 50 m, 100 m, and 150 m?

   (d) What is the velocity at each of these distances?

4. At time $t = 0$, I close the switch on the following circuit:



   (a) Find an equation that governs the behavior of the circuit. Point out where you used: Kirchoff's laws, Ohm's law, and charge conservation.

   (b) Find an expression[1] for $V(t)$ as a function of time.

   (c) What is the asymptotic value of the voltage $V(\infty)$?

   (d) Find the time t such that the voltage is 75% its final value.

[1] That is, verify the ansatz given in lecture.

5. Suppose we charge a capacitor (capacitance $C = 50\,\mu\text{F}$), by connecting it in series with a resistor (resistance $R = 500\,\Omega$), and a 10 V power supply (constant voltage).

   (a) Draw the circuit.

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

   (c) Find the behavior of this circuit as a function of time.

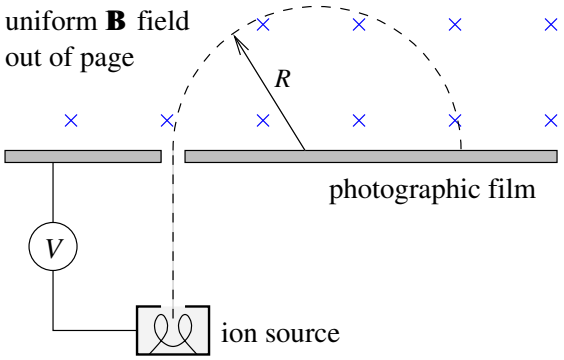
   (d) By integrating the power dissipated by the resistor $\int \text{power}\, dt$, show that the total energy dissipated by the resistor is equal to the final energy stored in the capacitor.

6. A particle with charge q has a velocity $\mathbf{v} = v_x\hat{x} + v_y\hat{y}$. I apply a magnetic field $\mathbf{B} = B_x\hat{x}$. Find the force (vector) acting on the particle due to the magnetic field.

7. An electron with speed $v = 3 \times 10^6\,\text{m/s}$. is moving along the x-axis in the positive x-direction. Find the force acting on the electron if I apply a uniform magnetic field $\mathbf{B} = (0.4\hat{x} + 0.3\hat{y} + 0.1\hat{z})\,\text{T}$.

8. A 4.2 MeV alpha particle[2] emitted during the radioactive decay of a ^{238}U nucleus enters an area with a uniform magnetic field of 0.04 T with its velocity perpendicular to the field. Find the radius of curvature of the particle's path.

9. A mass spectrometer consists of an ion source, usually a wire filament. As the filament is heated, ions "boil off" the filament and are accelerated as they move through an electric potential V. They enter a region containing a uniform magnetic field $\mathbf{B}$ and the ions travel in a circular arc.



   (The little ×'s represent the magnetic field coming out of the page.) The whole device is enclosed in a vacuum system.

[2]The 4.2 MeV is the kinetic energy. An "alpha particle" is produced by the decay of certain radioactive nuclei. It is actually a helium nucleus, consisting of two protons and two neutrons.

(a) Find an expression for the radius R of the arc as a function of $||\mathbf{B}||$, V, ion charge q, and mass m.

(b) Lithium has two isotopes of 6 u and 7 u (one "unified mass unit" u $= 1.66 \times 10^{-27}$ kg). If singly charged Lithium ions are put though this spectrometer, the two isotopes are separated and two distinct dots on the photographic film are produced. Find the distance x between these two dots for the case $||\mathbf{B}|| = 0.050$ T, and $V = 1000$ V.

Resist the temptation to put in numbers before the last step.

An honest answer is like a kiss on the lips.
Prov. 24:26