

2002-2003 Physics Olympiad Preparation Program
- University of Toronto -
Problem Set 6: Circuits and Modern Physics
Due: 7 April 2003

1. A circuit consists of a battery of voltage V , resistor of resistance R , and a capacitor of capacitance C in series.
 - (a) What is the voltage across the capacitor as a function of time when the circuit is complete? A detailed mathematical solution is not required.
 - (b) If the capacitor is not ideal, then a spark can be produced when the voltage between the plates reaches V' . Assume that after the spike, the capacitor does not break and begins recharging. Draw a graph of the voltage across the capacitor as a function of time for $V' < V$. Show that it would result in a sawtooth voltage waveform.
 - (c) How can the peak voltage or the period of this sawtooth voltage waveform be changed?

2. An electromagnetic wave in a vacuum has an electric field $\mathbf{E} = E_0 \cos(\omega t - kz)\hat{x} + E_0 \sin(\omega t - kz)\hat{y}$. What is direction of propagation and the momentum of the wave?

3. A light pulse travels with speed c along \hat{z} between two parallel mirrors that are separated by a distance L . See Figure 1. How long does it take for the pulse to make a round trip according to an observer who is (a) at rest with respect to the mirrors and (b) travelling along \hat{y} with a speed V relative to the mirrors? Is there a situation in which the pulse is seen to never return to its starting point?

4. The energy needed to break a system into its components is called its binding energy E_b . Calculate E_b for a hydrogen atom by (a) assuming that the electron is a classical particle orbiting a proton at a radius $r_0 = 5.29 \times 10^{-11}$ m and (b) using the data $m_e = 5.48579903 \times 10^{-4}$ u, $m_p = 1.007276470$ u, and $m_H = 1.007825035$ u (u=931.49432 MeV= $1.66053873 \times 10^{-27}$ kg). Are your computations in agreement?

5. Make a circuit consisting of a battery (V), some conducting wire and material, and a small light bulb (B). See Figure 2. Alter the resistance R of the circuit by introducing different lengths of conducting material between the points X and Y. How does R vary with the length of the path between X and Y? Determine the resistance according to the brightness of the bulb.

