

2003-2004 Physics Olympiad Preparation Program

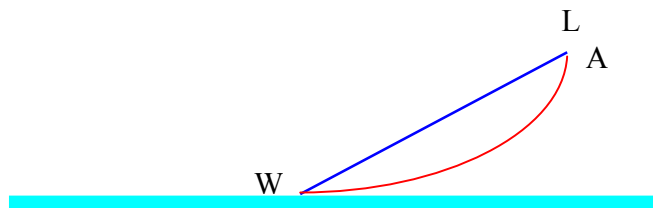
– University of Toronto –

Problem Set 1: General

Due November 3, 2003

1. **Lily and Ann in Wonderland.**

Two girl friends spent almost all their summer vacation in the Water Park. Lily liked to slip down the plane slide LW with small angle of inclination, while Ann liked the arc slide AW. Their start points L and A were at the same height. Both slides were cut at the water level, where arc had its tangent line coincided with the horizontal direction. The girls always started down simultaneously. Try to calculate who first achieved the water in the pool. You may neglect friction.



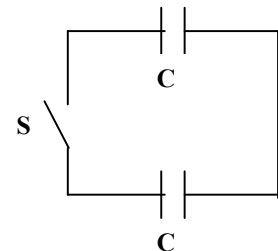
2. **Let us disprove the Law of Conservation of Energy!**

Two identical capacitors with capacitance C are connected with each other and with switch S as shown. One of the capacitors initially had charge Q . Another one was uncharged. What was the electric field energy initially?

After switch S is closed and system comes to equilibrium, calculate the total energy of the electric field of the system.

Where does the energy “disappear”?

Examine two cases: a) significant and b) negligible resistance of the wires in the circuit.



3. **Why not to use heat when it is hot?**

Heat engine is a device that takes in heat from a high-temperature source or heat reservoir, converts part of this heat into work, and releases the remaining heat to the environment at a lower temperature or to the low temperature reservoir. The gasoline engine in a car is also a heat engine. The productiveness of any heat engine can be defined by calculating its efficiency. For this problem you need to find as much

information as you can about the specific heat engine that was designed by Carnot and its efficiency.

Now suppose that you wish to increase the efficiency of a Carnot engine as much as possible. You can do this by increasing T_H (temperature of the high-temperature reservoir) a certain amount while keeping T_L (temperature of the low-temperature reservoir) constant. Or by decreasing T_L the same amount while keeping T_H constant. Which would you do? Prove your choice quantitatively.

Under what conditions would a Carnot engine be 100% efficient?

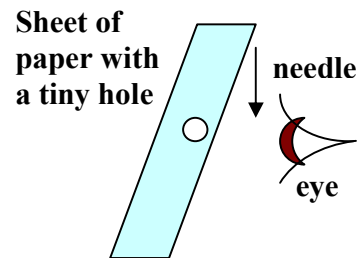
Imagine you have all facilities and funds to realize any scientific idea. What object should you choose as the best low-temperature reservoir for your heat engine? Of course, you are very smart and thrifty.

4. Inverted image without lens and mirror.

Take a standard sheet of paper and pierce it with a sharp needle.

a) Try to look through this tiny hole and start your observation keeping the sheet at the approximate distance of 20 cm. Then little by little advance the hole in the direction of one of your eyes until the paper touches your eyelashes. Describe what you see looking at and through this hole during this approaching and explain the result.

b) Keeping the sheet at the approximate distance of 1" from your eye and a needle vertically above the hole and at the middle distance between your eye and the sheet, slowly lower the needlepoint attentively looking at the hole behind it. To protect your eye put on any glasses. It may be either transparent sunglasses or glasses with lenses. Lenses do not play any role in this experiment except eye protection.



Describe the results of observation of the needlepoint motion against the background of the hole and explain them.

5. She is so young and pretty!

To solve this problem you should remember the general decay law from your high school Mathematics. The radioactive decay of nuclei is usually described quantitatively with the parameter T . Let us define the half-life, T , as the time in which $1/2$ of the particles decay.

The natural uranium ore now consists of $\eta_1 = 99.28\%$ ^{238}U and $\eta_2 = 0.72\%$ ^{235}U . Half-life periods of ^{238}U and ^{235}U nuclei are correspondingly equal to $T_1 = 4.47 \times 10^9$ years and $T_2 = 0.70 \times 10^9$ years. Estimate the Earth's age assuming the amounts of two isotopes were equal at the moment of birth of our planet. Find in any handbook on Physics the corresponding data, and calculate the percentage difference between the tabled data and your result.