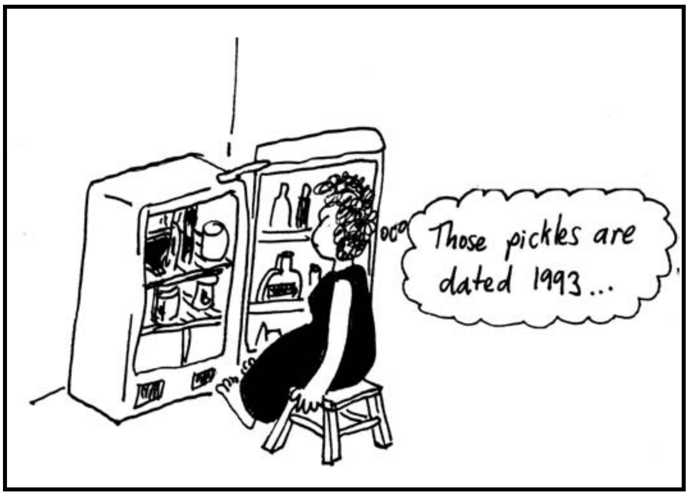
Workshop Tutorials for Technological and Applied Physics

TR4T: **First Law of Thermodynamics**

A. Qualitative Questions:

1. On a very hot day Brent comes home and finds Rebecca sitting in front of the fridge with the door open. She explains that the air conditioner stopped working, so she's using the fridge to cool the room instead.

a. Will this cool the kitchen? What will happen to the temperature of the kitchen?
b. What would happen if Rebecca tried to cool the kitchen with an ice box full of ice instead?
c. How does an air conditioner keep a room cool without violating the first law of thermodynamics?



2. A certain quantity of an ideal gas is compressed to half its initial volume. The process may be adiabatic, isothermal or isobaric (constant pressure).

a. Graph each of these processes on a P-V diagram.
b. For which process is the greatest amount of mechanical work required? Explain your answer.

B. Activity Questions:

1. Bicycle pump

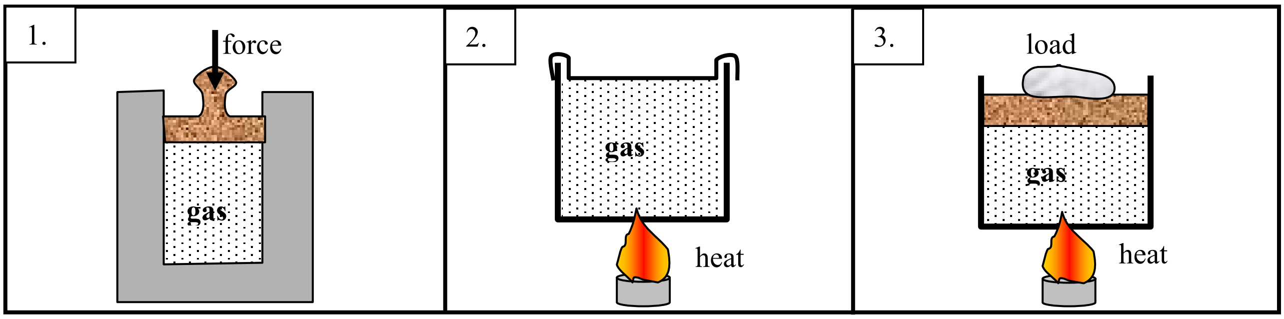
Put your finger at the end the nozzle so that the air in the pump is trapped.
Pump the bicycle pump and feel what happens to the cylinder.
Explain your observations using the first law of thermodynamics.

2. Ball bearings in a tube

Check the temperature of the ball bearings inside of the tube.
Now shake the tube vigorously for a minute or more.
What is the temperature of the ball bearings now?
Why has it changed?
Could you use this technique to reheat a cold cup of coffee?

3. Heat and Work

There are three processes to perform.
In the first system, the piston is pushed down into the insulated cylinder.
In the second system, the gas inside the tin is heated with the lid on.
In the third system the gas is heated with the sliding lid on, and a load on top.



Which, if any, of these processes is adiabatic?
Are any of them isochoric? What about isobaric?
Draw a table showing the heat, work and change in internal energy for each process.

C. Quantitative Questions:

1. A bullet (made of lead) is fired into a heavy target. The bullet is at 30°C just before impact, and melts upon striking the target. Assume 60% of the bullet's kinetic energy has gone into internal energy of the bullet, and the other 40% has gone into making a hole in the target and heating the target. If the bullet melts on impact, as they sometimes do, what minimum speed was the bullet doing prior to impact?

2. The compression ratio of an engine is the ratio of the volume of compressed gas in the cylinder to the volume of uncompressed – the difference in volume between the piston being at the top of the cylinder and at the bottom. For a particular diesel engine the compression ratio is 1:15. It draws in air at atmospheric pressure and temperature, about 1.0×10^5 Pa and 300 K.
a. Find the temperature and pressure of the air after the adiabatic compression, taking air to be a mixture of oxygen and nitrogen with $\gamma = 1.4$ with $C_v = 20.8$ J.mol^{-1}.K^{-1}.
The high temperature at the end of compression causes the fuel to ignite when it is injected into the cylinder at the end of compression. This happens spontaneously. In a normal petrol engine a spark plug is used to ignite the fuel mix because such high temperatures are not obtained. A four cylinder diesel engine has a listed engine capacity of 2.2 l.
b. How much work does the gas do during the compression in one cylinder?

Data:
Melting point of lead = 600 K,
Latent heat of fusion of lead = 24.7 kJ.kg^{-1},
Heat capacity of lead = 0.13 kJ.kg^{-1}.K^{-1}.
R = 8.31 J.mol^{-1}.K^{-1}.