Workshop Tutorials for Introductory Physics
TI4: **First Law of Thermodynamics**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
into, sun, thermal, internal, physics, friction, isolated, $\Delta U = W$, $\Delta U = Q$, small, work, Rebecca, positive

Conservation of Energy and the First Law of Thermodynamics

Conservation of Energy is one of the most useful and widely used concepts in _____. You may have seen the concept of conservation of energy in the study of motion (mechanics), but often with a qualifying statement - providing the effects of _____ can be ignored. The first law of thermodynamics is a statement of conservation of energy that includes any flow of _____ energy in or out of a system. It establishes Conservation of Energy as a central principle in physics.

To discuss the flow of energy in or out of a system we first have to define the system we are talking about. A system may or may not be an isolated system. An _____ system is one where no energy flows in or out of the system. Consider the situation where Brent and _____ are sitting on the beach with the cool box of drinks. The cool box is not an isolated system as thermal energy flows in. Consider the system of the earth plus cool box. Since energy flows to the earth from the _____ this system is not isolated either. One of the essential skills of a physicist is to be able to judge which features of a situation are essential to solving a problem and which features are not really significant. It may be that a system can be treated as an isolated system when the flow of energy is very _____.

The First Law of Thermodynamics states that any change in _____ energy, ΔU, of a system is equal to the sum of the work done on the system and the heat flow into the system. Mathematically it can be written $\Delta U = Q + W$, where the work, W, is _____ when work is done on the system and the heat, Q, is positive when heat flows _____ the system.

In the example of the cool box the increase in internal energy is due to the flow of thermal energy into the cool box. No _____ is being done on the cool box. So _____ . Pumping bicycle tyres is another example. Here we are compressing the gas as we pump and so work is being done on the gas. If we do it quickly the thermal energy has no time to flow out and the internal energy of the gas increases. This is an example of an adiabatic process, where _____.

B. Activity Questions:

1. Bicycle pump
Put your finger on the end of 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?
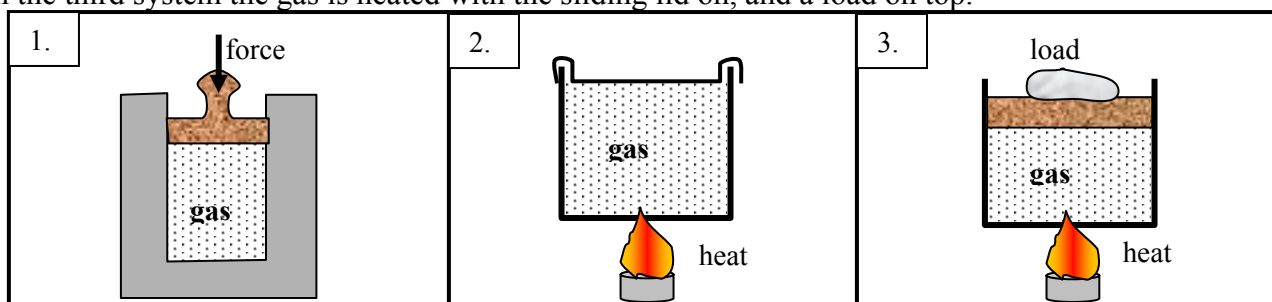Could you use this technique to reheat a cold cup of coffee?

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. Qualitative Questions.

1. Consider the human body as a system and apply the first law of thermodynamics to it. We know that over any given period of sufficient length (say one day), there will be a net heat flow from the body (i.e. Q is negative) and the body will do some external work on its surroundings (i.e. W is positive). The first law then tells us that ΔU is negative. So, each day there would be a decrease in internal energy.

a. Does the internal energy of the human body decrease as described above?

b. Explain how (and in what form) internal energy is added to the body to balance the continual decrease due to heat flow from the body and work being done by the body.

c. In the context of the human body, explain the following statement, "the first law of thermodynamics is a restatement of the law of conservation of energy".

2. 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?

D. Quantitative questions.

A series of thermodynamic processes is shown in the pV-diagram below. In process ab, 150 J of heat are added to the system, and in process bd, 600 J of heat are added. Find:

a. the internal energy change in process ab;
b. the internal energy change in process abd;
c. the total heat added in process acd.