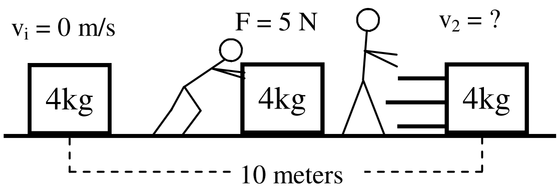
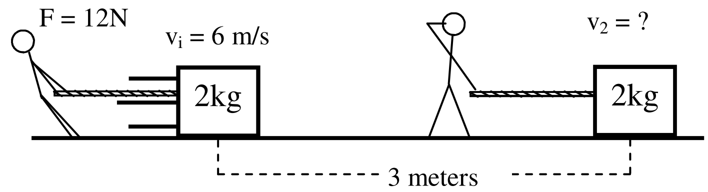
Due Fri., Feb 24

2012 Heat and Thermo 3



E_{before} =　　W =　　E_{after} =



E_{before} =　　W =　　E_{after} =

1. A. Is Slim Jim's force + or −?
   B. Is the distance the object moves + or −?
   C. * Is the work he is doing on the box + or −?
   D. * Calculate the work done on the box.

   E. * Calculate the final speed of the box.

2. A. Is Slim Jim's force + or −?
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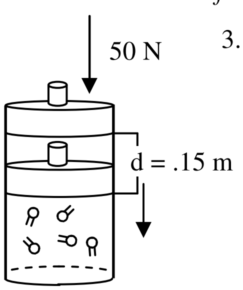
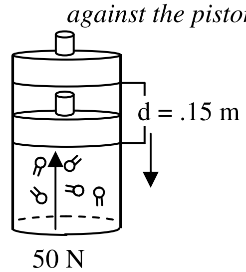
So, as we just saw, if the force and distance are in the same direction, the work done is + and vice versa. This is the same for the work done on or by a gas.



3. A force pushes down on a piston of a cylinder.
   A. Do the force and distance point in the same direction?
   B. * So, is the work done ON THE GAS (or on the system) + or −?
   C. Does the system's temperature increase or decrease?

But the gas molecules ALWAYS push UP against the piston.



4. Is the work done BY the gas + or −?

5. And negative work done by the gas causes the system's energy (and temperature) to:

The gas molecules always push up against the piston and the piston ALWAYS pushes down (a normal force) on the gas molecules. Need proof? The force of the piston must be down or the molecules would not bounce back from the piston when they hit.

6. +, −, or 0?
   A. _____* Work done by the gas if the gas is compressed.
   B. _____* Work done on the gas if the gas expands.
   C. _____* Work done on the gas if the gas is compressed.
   D. _____Work done by the gas if the volume of the gas increases.
   E. _____Work done by the gas if the volume doesn't change.

Work Done by a Gas

Work (*in J*) → $$W = P\Delta V$$ ← Change in Volume (*in* m^3)

Pressure (*in Pascals or* N/m^3) → P

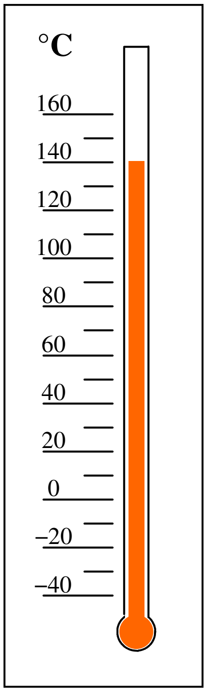
But we generally talk about the pressure and volume of a gas, instead of force and distance. I expect that you know how to find the volume of a cylinder: $\pi r^2 h$; *or a rectangular solid:* $l(w)h$.

Also, even though we know that the pressure of the gas does increase as the piston compresses, this is too hard to calculate, so we pretend that the pressure is constant (isobaric).

7. *A piston has a radius of 6 cm. It moves down 12 cm under a pressure of 3 atmospheres (3.03×10^5 Pa).
   A. Calculate the area of the circular piston.
   B. Calculate the change of volume of the piston.

   C. Calculate the work done by the gas.

8. The Celsius thermometer below is used to measure the temperature of 2 kg of water. We will assume that the water is at normal atmospheric pressure.



A. Label the boiling point and freezing point of water. Mark and label the freezing point of water.

A.

B. Label the phases of water on the thermometer.

B.

C. Label the Cp's for the different phases of water.

C. See "Heat" notes

D. Label the present reading as T_1.

D.

E. In what phase is water at this temperature?

E. Steam (over 100° C)

We want to lower the 2 kg of water to −10° C.

F. Mark the desired temperature as T_2.

F.

G. What is the lowest temperature water will stay steam?

G. 100°C

H. What will be the change of temperature during its gaseous phase (ΔT_{steam})?

H. Tf−Ti = (100−140) =−40°C

I. Calculate the heat change for the water to lower it to 100°C.

I. $Q = mc_{p\ steam}\Delta T$ = 2(2010)(−40) = −1.61E5 J

Now the 2 kg of water is at 100°C. At this point heat must be removed to UNvaporize it into liquid water. $Q = mL_{vaporization}$ *and* $L_{vapor\ for\ water} = \pm 2.26\times10^6$ *J/kg.*

J. How much heat must be removed to UNvaporize (condensate) the 2kg of water to liquid water?

J. 2(−2.26E6) = −4.52E6 J (− since condensating)

K. What will be the initial temperature of this water when it has turned to liquid?

K. 100°C

Now this liquid water needs to be cooled to −10° C.

L. But what is the lowest temperature for liquid water?

L. 0°C

M. What will be the change of temperature of this water during its liquid phase (ΔT_{liquid})?

M. Tf−Ti = 0−100 = −100°C

N. Calculate the heat added or removed from the liquid water to lower it to 0°C.

N. $Q = mc_{p\ liquid}\Delta T$ = 2(4186)(− 100) = − 8.37E5J

Of course, now you have to convert it to ice. The equation is $Q = mL_{fusion}$ *and* $L_{fusion\ for\ ice} = \pm 3.33\times10^5$ *J/kg. It is + when melting and −when freezing.*

O. Calculate the total heat added or removed to freeze the water at 0°C.

O. 2(-3.33E5) = −6.66E5 J (− since freezing)

P. Now how much heat is added or removed to lower the water from 0°C to −10°C?

P. $Q = mc_{p\ ice}\Delta T$ = 2(2090)(−10) = − 8.37E5J

Q. Now calculate the total heat added or removed to change 2 kg of ice from 140°C to −10°C

Q. $Q_{steam} + Q_{condensation} + Q_{liquid} + Q_{freeze} + Q_{ice}$ =
−1.61E5 J
− 4.52E6 J
− 8.37E5J
− 6.66E5 J
− 8.37E5J =
Q_{total} = −6.23E6 J

1C: + 1D: 50 J 1E: 5 m/s 2C: − 2E: 0 m/s 3B: +
4: − 5: increase 6A: − 6B: − 6C: + 7A: $A = \pi r^2 = 0.0113\ m^2$ (r = 0.06 m)
7B: $\Delta V = -1.36E{-3}\ m^3$ 7C: W = −411 J