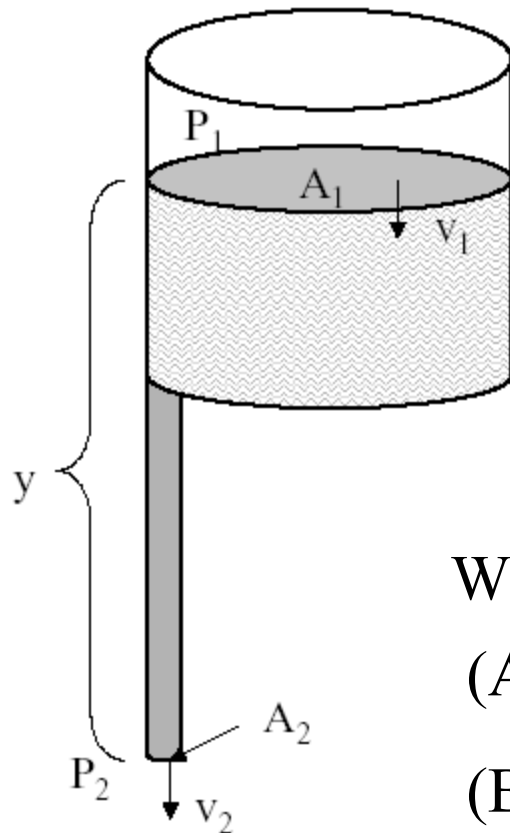


Announcements

1. 3rd hour exam – will be returned at end of class; up to 10 extra credit points for reworking the exam
2. Problem solving advice
3. Today's topic -- heat

Problem solving advice:

4.



The figure on the left shows an enclosed water storage tank having a cross sectional area $A_1 = 13 \text{ m}^2$, attached to a pipe of cross sectional area $A_2 = 0.02 \text{ m}^2$. The density of water is $\rho = 1000 \text{ kg/m}^3$ and the water level above the height of the pipe outlet is $y = 10 \text{ m}$. The water begins to flow out of the bottom of the pipe with a velocity of $v_2 = 3 \text{ m/s}$. Note that $P_2 = P_0 = 1 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$.

(a) What is the velocity v_1 ?

(b) What is the pressure P_1 ?

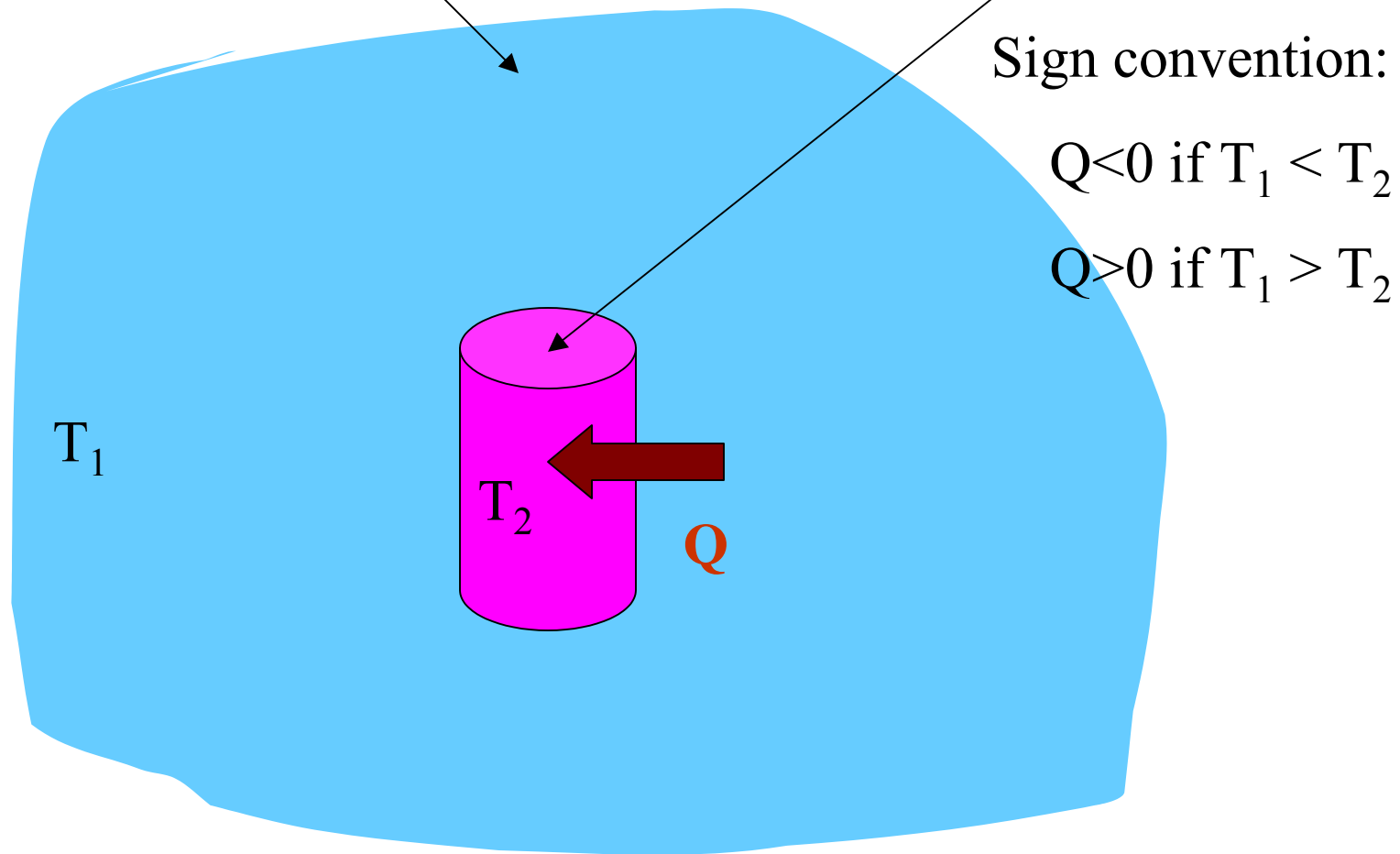
What equations should you write down first?

(A) $v_1 A_1 = v_2 A_2$

(B) $P_2 + \frac{1}{2} \rho v_2^2 + \rho g h_2 = P_1 + \frac{1}{2} \rho v_1^2 + \rho g h_1$

(C)
$$v_1 = \sqrt{\frac{2((P_2 - P_1)/\rho - gy)}{1 - (A_1/A_2)^2}}$$

Heat – Q -- the energy that is transferred between a “system” and its “environment” because of a temperature difference that exists between them.



Units of heat: Joule

Other units: calorie = 4.186 J

Kilocalorie = 4186 J = Calorie

Heat capacity: C = amount of heat which must be added to the “system” to raise its temperature by 1K (or 1° C).

More generally:

$$Q = C \Delta T$$

$$Q_{i \rightarrow f} = \int_{T_i}^{T_f} C(T) dT$$

Heat capacity per mass: $C = mc$

Heat capacity per mole (for ideal gas): $C = nC_v$

$$C = nC_p$$

Some typical specific heats

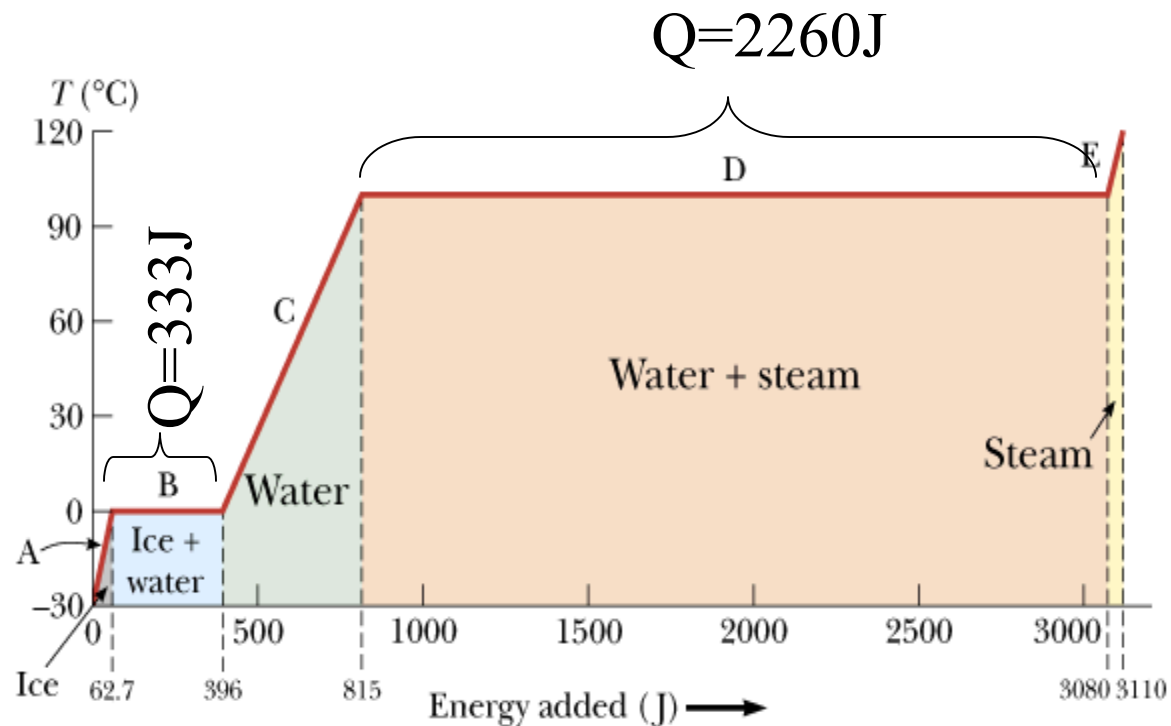
Material	J/(kg·°C)	cal/(g·°C)
Water (15°C)	4186	1.00
Ice (-5°C)	2096	0.50
Steam (100°C)	2010	0.48
Wood	1700	0.41
Aluminum	900	0.22
Iron	448	0.11
Gold	129	0.03

Heat and changes in phase of materials

Example: A plot of temperature versus Q added to

1g = 0.001 kg of ice (initially at $T = -30^\circ\text{C}$)

Serway, Physics for Scientists and Engineers, 5/e
Figure 20.2



Some typical latent heats

Material	J/kg
Ice \Rightarrow Water (0°C)	333000
Water \Rightarrow Steam (100°C)	2260000
Solid N \Rightarrow Liquid N (63 K)	25500
Liquid N \Rightarrow Gaseous N ₂ (77 K)	201000
Solid Al \Rightarrow Liquid Al (660°C)	397000
Liquid Al \Rightarrow Gaseous Al (2450°C)	11400000

Peer instruction question

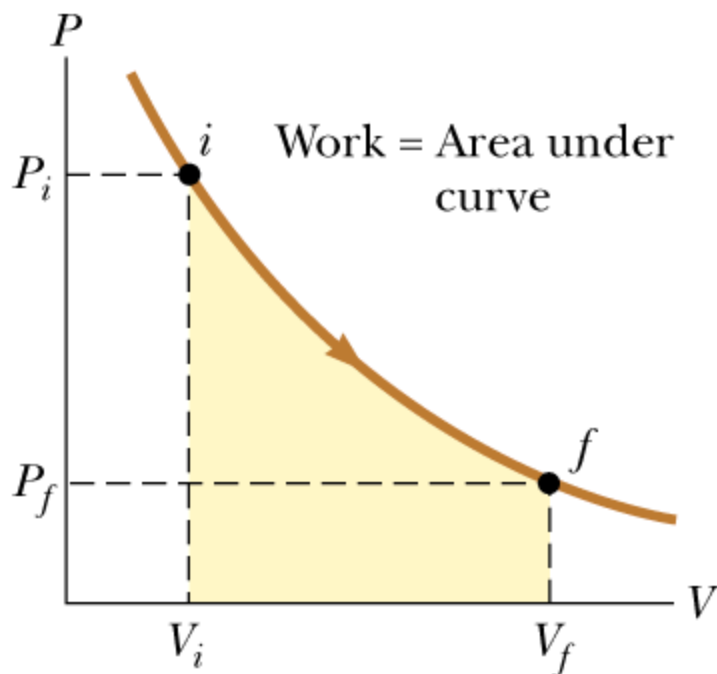
Suppose you have a well-insulated cup of hot coffee ($m=0.25\text{kg}$, $T=100^\circ\text{C}$). In order to get to class on time you add 0.25 kg of ice (at 0°C). When your cup comes to equilibrium, what will be the temperature of the coffee.

- (A) 0°C (B) 20°C (C) 50°C (D) 100°C

Energy effects on an ideal gas

Work done *by the “system”* due to volume change

$$W = \int_{x_i}^{x_f} F dx = \int_{x_i}^{x_f} \frac{F}{A} A dx = \int_{V_i}^{V_f} P dV$$



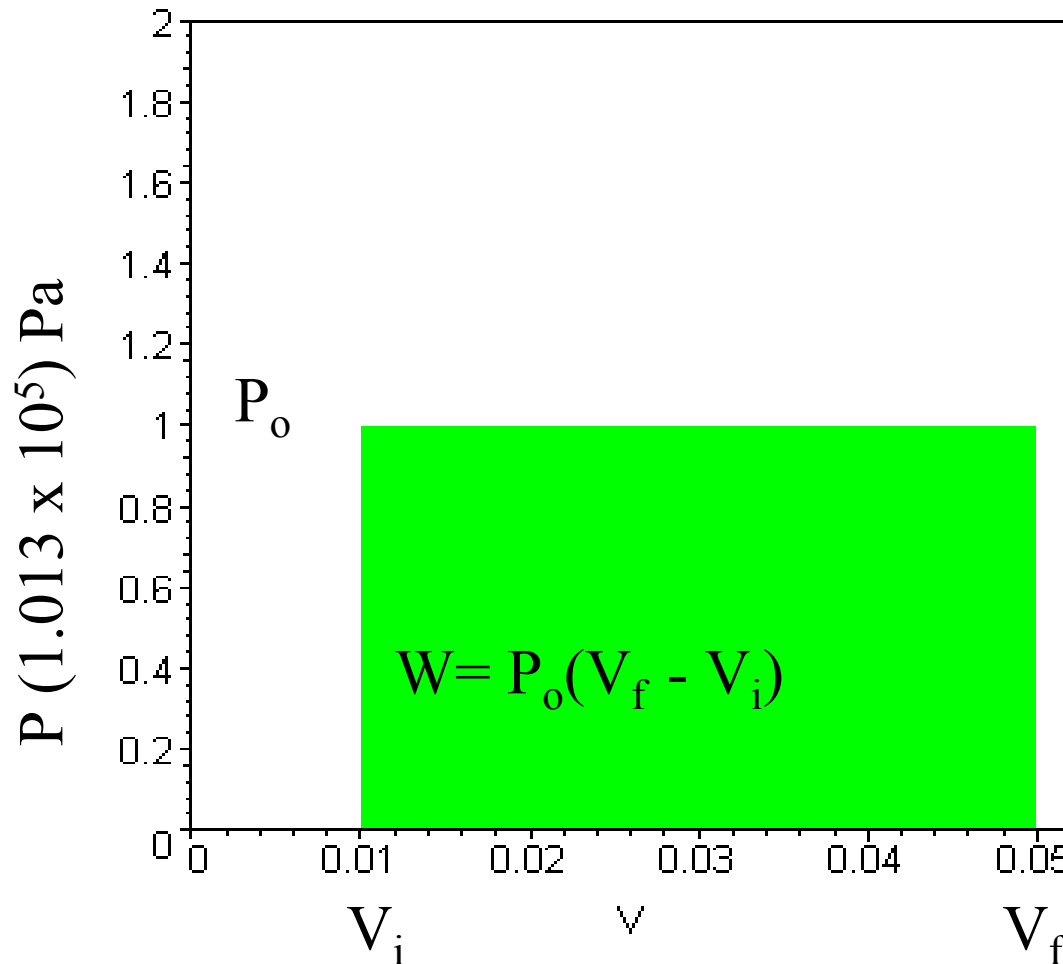
Sign convention:

$W > 0$ if $V_f > V_i$ (expansion)

$W < 0$ if $V_f < V_i$ (contraction)

Work done by a gas:

“Isobaric” (constant pressure process)



**Peer instruction
question**

What happens to the temperature of the gas during the isobaric expansion $V_i \Rightarrow V_f$.

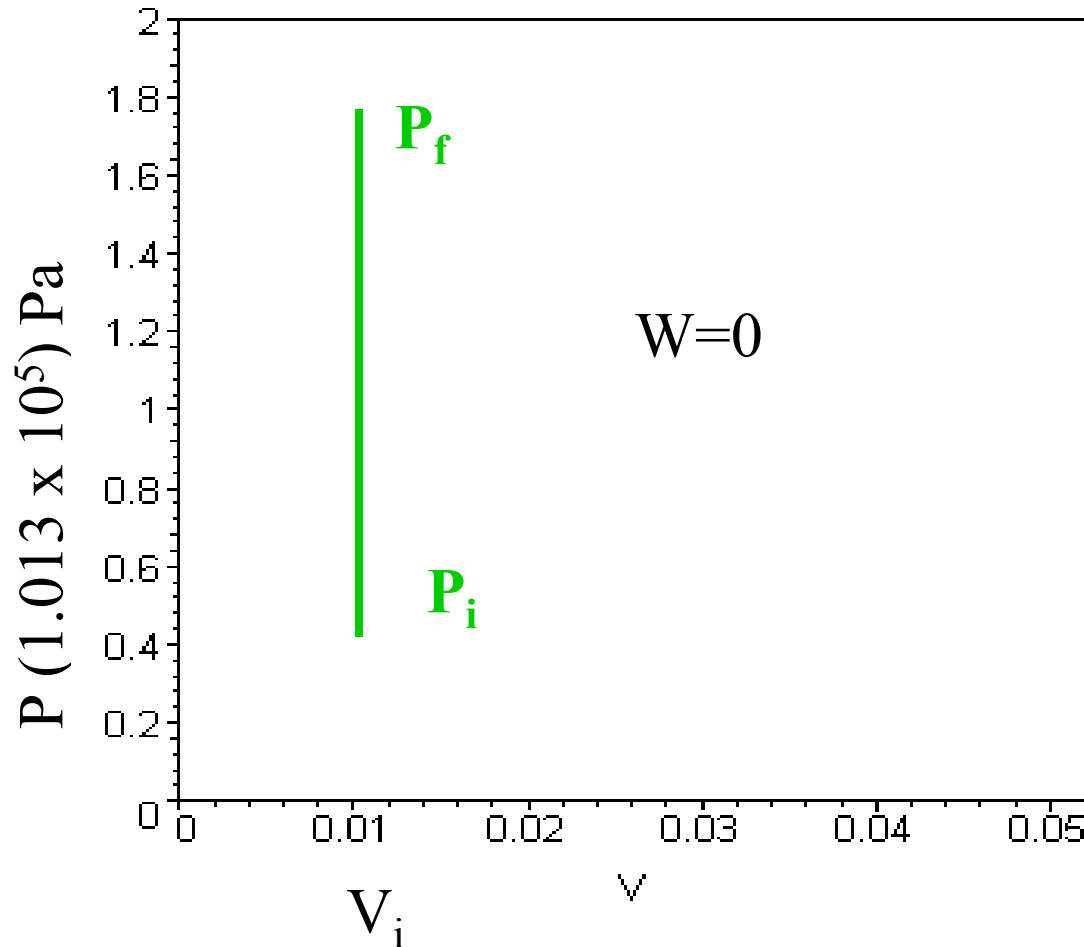
(A) $T_i < T_f$

(B) (B) $T_i > T_f$

(C) $T_i = T_f$

Work done by ideal gas:

“Isovolumetric” (constant volume process)



**Peer instruction
question**

What happens to the temperature of the gas during the isovolumetric expansion

$P_i \Rightarrow P_f$.

(A) $T_i < T_f$

(B) (B) $T_i > T_f$

(C) $T_i = T_f$

Thermodynamic statement of conservation of energy –

First Law of Thermodynamics

$$E_{\text{int}} = Q - W$$

Work done by system

Heat added to system

“Internal” energy of system