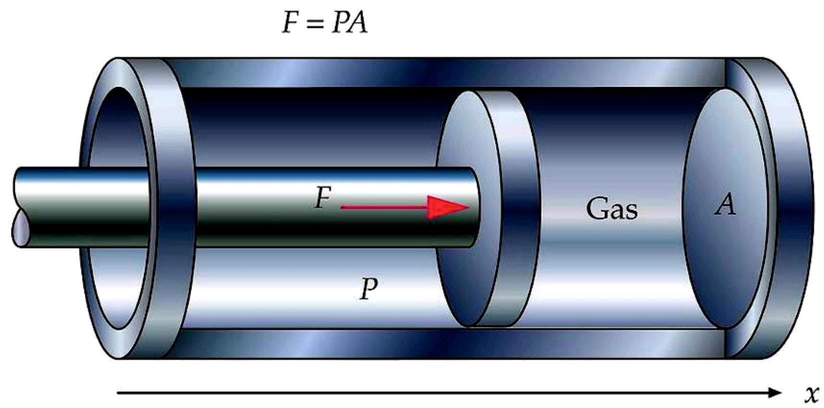
Physics 115

General Physics II



Session 11

Exam review: sample questions Thermodynamic processes

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- Home page: http://courses.washington.edu/phy115a/

Lecture Schedule (up to exam 1)

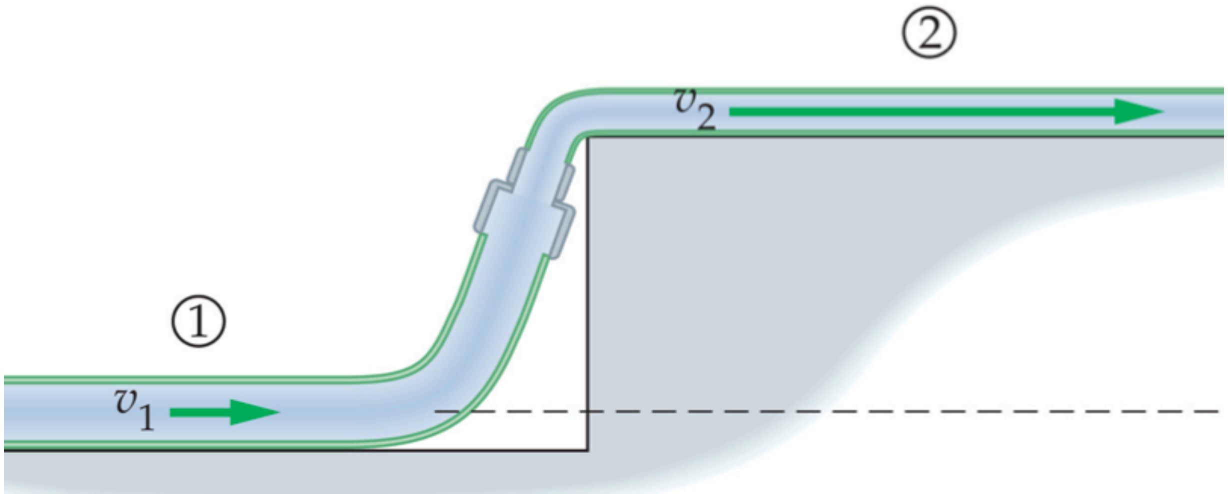
Date	Day	Lect.	Topic	readings in Walker
31-Mar	Mon	1	Introduction, Preview	
1-Apr	Tues	2	Density & Pressure	15.1-15.3
3-Apr	Thurs	3	Static Fluids, Buoyancy	15.4-15.5
4-Apr	Fri	4	Fluid Flow, Bernoulli	15.6-15.8
7-Apr	Mon	5	Viscosity, Flow, Capillaries	15.9
8-Apr	Tues	6	Temperature, expansion	16.1-16.3
10-Apr	Thurs	7	Heat, Conduction	16.4-16.6
11-Apr	Fri	8	Ideal gas	17.1-17.2
14-Apr	Mon	9	Heat, Evaporation	17.4-17.5
15-Apr	Tues	10	Phase change	17.6
17-Apr	Thurs	11	First Law Thermodynamics	18.1-18.3
18-Apr	**Fri**		**EXAM 1 Ch 15,16,17**	

Today

See course home page
courses.washington.edu/phy115a/
for course info, and slides from previous sessions

Announcements

- Exam 1 **tomorrow Friday 4/18**, in class, posted formula sheet provided
  - YOU bring a bubble sheet , pencil, calculator (NO laptops or smartphones; **NO personal notes allowed**.)
    - If you forget, buy one in hBar cafe in C wing, or fellow student
  - We'll go over solutions to posted sample questions today
  - No special seat assignments – also, **every seat will be needed**
  - Pick up exam paper at front of room when you arrive, do NOT begin until 1:30 bell – no extra copies! Take only 1
  - 50 minutes allowed, last call at 2:20 – you must leave then, next class has exam also!
  - Turn in the bubble sheet AND the exam paper
    - If you want to keep your paper, write your name on it and put it in the "keep" bin
    - If not, put it in the "Recycle" bin
    - DO NOT LEAVE THE ROOM without turning in exam paper!



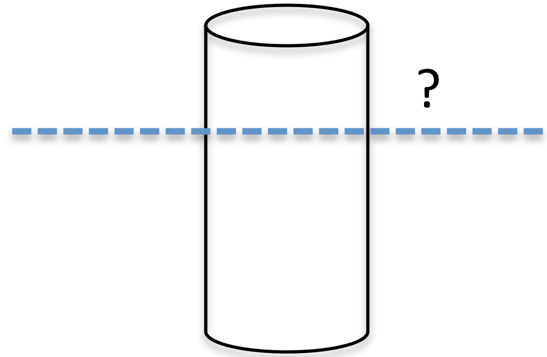
1. Water (assume it is incompressible and non-viscous) flows in a pipe as shown above. The pipe is horizontal at point 1, then rises in elevation while decreasing in diameter and is again horizontal at point 2. Which of the following statements is correct?

A $P_1 > P_2$
B $P_1 < P_2$
C $P_1 = P_2$
D The answer depends on the direction of the flow.
E The answer depends on the speed of the flow.
Answer: A

$$(h_1 - h_2) < 0; \quad A_1 v_1 = A_2 v_2 \rightarrow v_2 = \frac{A_1}{A_2} v_1 > v_1 \rightarrow (v_1^2 - v_2^2) < 0$$

$$P_2 = P_1 + \rho g (h_1 - h_2) + \tfrac{1}{2}\rho (v_1^2 - v_2^2) < P_1$$

Ref: Sec. 15-7



2. A spar buoy consists of a circular cylinder, which floats with its axis oriented vertically. It has a radius of 1.00 m, a height of 2.00 m and weighs 40.0 kN. What portion of it is submerged when it is floating in fresh water?

A 1.35 m
B 1.30 m
C 1.25 m
D 1.20 m
E 1.50 m

Answer: B

$$B = \rho_{WATER} g V_{SUBMERGED} = (1000kg/m3)(9.8m/s2)(\pi r^2 h)$$

$$F_g = B \rightarrow 40kN = h(9800kg/m2/s2)(3.14m^2) = (30.772\,h)kN/m$$

$$h = 40kN/30.772(kN/m) = 1.299m$$

Ref: Sec. 15-4

3. A glass tea kettle containing 500 g of water is on top of the stove. The portion of the tea kettle that is in contact with the heating element has an area of 0.090 m2 and is 1.5 mm thick. At a certain moment, the temperature of the water is 75°C, and it is rising at the rate of 3 C° per minute. What is the temperature of the outside surface of the bottom of the tea kettle? The thermal conductivity of glass is 0.840 W/(m·K). Neglect the heat capacity of the kettle.

A 39°C
B 92°C
C 120°C
D 86°C
E 77°C

Answer: E

Heat transferred in 1 minute = heat to raise T of water 3 K

$$Q = m_W c_W (\Delta T) = (0.5kg)(4186J/kg/K)(3K) = 6279J$$

$$Q = kA\frac{(T_1 - T_2)}{L}(60s) \rightarrow (T_1 - T_2) = \frac{QL}{kA(60s)} = \frac{(6279J)(0.0015m)}{(0.84J/s/m/K)(0.090m2)(60s)} = 2.07K$$

$$T = 75 + 2 = 77$$

Ref: Sec. 16-6

4. Two identical objects are placed in a room with a temperature of 20°C. Object A has a temperature of 50°C, while object B has a temperature of 90°C. What is the ratio of the net power emitted by object B to that emitted by object A?

A 1.7

B 2.8

C 81

D 17

E 21

Answer: B

$$P_A = P_{rad} - P_{absorbed} = \varepsilon A \sigma \left(T^4 - T_0^4\right) = (const)\left(\left[323K\right]^4 - \left[293K\right]^4\right)$$

$$P_B = (const)\left(\left[363K\right]^4 - \left[293K\right]^4\right) \rightarrow \frac{P_B}{P_A} = \frac{9.993\times10^9}{3.51\times10^9} = 2.8$$

Ref: Sec. 16-6

5. Two containers of equal volume each hold samples of the same ideal gas. Container A has twice as many molecules as container B. If the gas pressure is the same in the two containers, the correct statement regarding the absolute temperatures and in containers A and B, respectively, is

A $T_A = T_B$.

B $T_A = 2T_B$.

C $T_A = \frac{1}{2} T_B$.

D $T_A = \frac{1}{\sqrt{2}} T_B$.

E $T_A = \frac{1}{4} T_B$.

Answer: C

$$PV = NkT \rightarrow \frac{T_A}{T_B} = \frac{PV/N_{(A)}k}{PV/N_{(B)}k} = \frac{N_{(B)}}{N_{(A)}} = \frac{1}{2}$$

Ref: Sec. 17-2

6. A 35-g block of ice at -14°C is dropped into a calorimeter (of negligible heat capacity) containing 400 g of water at 0°C. When the system reaches equilibrium, how much ice is left in the calorimeter? The specific heat of ice is 2090 J/(kg K) and the latent heat of fusion of water is 33.5 × 104 J/kg.

A 32 g
B 33 g
C 35 g
D 38 g
E 41 g
Answer: D

$$\text{"ice is left..."} \rightarrow T_{\text{f}} = 0°\text{C}$$

$$Q_{\text{out of liquid}} + Q_{\text{into ice}} = 0 \rightarrow -Q_{\text{out of liquid}} = Q_{\text{into ice}} = m_{ice}c_{ice}\left(T_{\text{f}} - T_i\right) = \left(0.035kg\right)\left(2090J/kg/K\right)\left(+14K\right) = 1024J$$

Liquid is already at 0°C, so heat lost by liquid $\rightarrow$ make more ice

$$Q_{\text{out of liquid}} = m_{new\ ice}L_{ice} \rightarrow m_{new\ ice} = Q_{\text{out of liquid}} / L_{ice} = 1024J / 33.5 \text{ x } 10^4 \text{ J/kg=0.003kg} \rightarrow m_{ice,final} = 38g$$

Ref: Sec. 17-6

Standard strategy: finish easy problems (low points) first, then tackle hard ones

Next topic: Laws of Thermodynamics

(Each of these 4 "laws" has many alternative statements)

We'll see what all these words mean later...

- 0th Law: if objects are in thermal equilibrium, they have the same T, and no heat flows between them
  - Already discussed
- 1st Law: Conservation of energy, including heat:

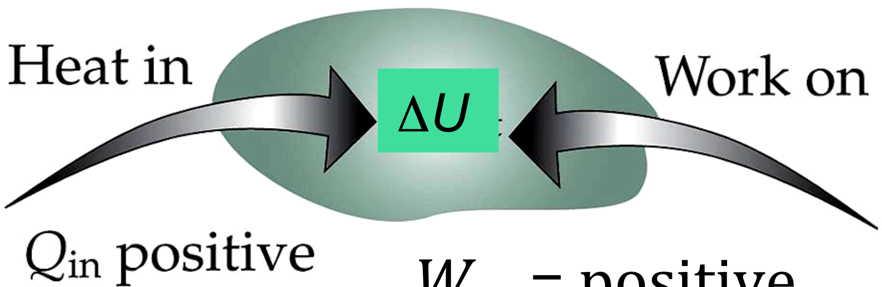
  Change in internal energy of system = Heat added – Work done
- 2nd Law: when objects of different T are in contact, *spontaneous* heat flow is from higher T to lower T
- 3rd Law: It is impossible to bring an object to T=0K in any finite sequence of processes

Internal energy and 1st Law

- **1st Law of Thermodynamics:**
  The change in internal energy of a system equals the heat transfer into the system plus the work done by the system.

$$\Delta U = Q_{in} - W$$

(Essentially: conservation of energy).



W_{by} = positive
W_{on} = negative

Work done by the system
Example: expanding gas pushes a piston

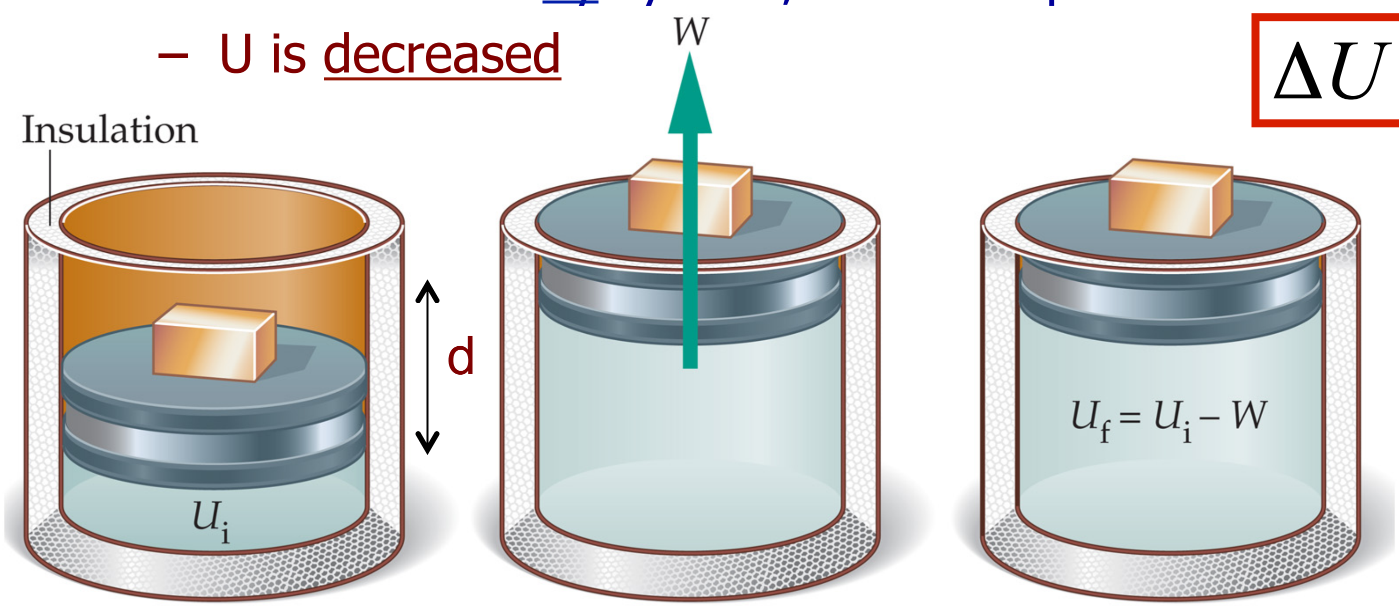
Work done on the system
Example: piston pushed by external force compresses gas

Minus sign in equation means:
W increases U if work is on system
W decreases U if work is by system

Example of sign convention

- Ideal gas in insulated container: no Q in or out
- Gas expands, pushing piston up (F=mg, so W=mgd)
  - Work is done by system, so W is a positive number
  - U is decreased

$$\Delta U = -W$$



- If instead: we add weights to compress gas
  - Work done on gas, W is a negative number
  - U is increased

$$\Delta U = -(-W) = +W$$

System state, and state variables

- U is another quantity, like P, V, and T, used to describe the **state of the system**
  - They are connected by equations describing system behavior: for ideal gas, PV=NkT, and U=(3/2)NkT

    "equation of state"
- Q and W are not state variables: they describe changes to the state of the system
  - Adding or subtracting Q or W moves the system from one state to another: points in a {P,V,T} coordinate system
  - The system can be moved from one point to another via different sequences of intermediate states

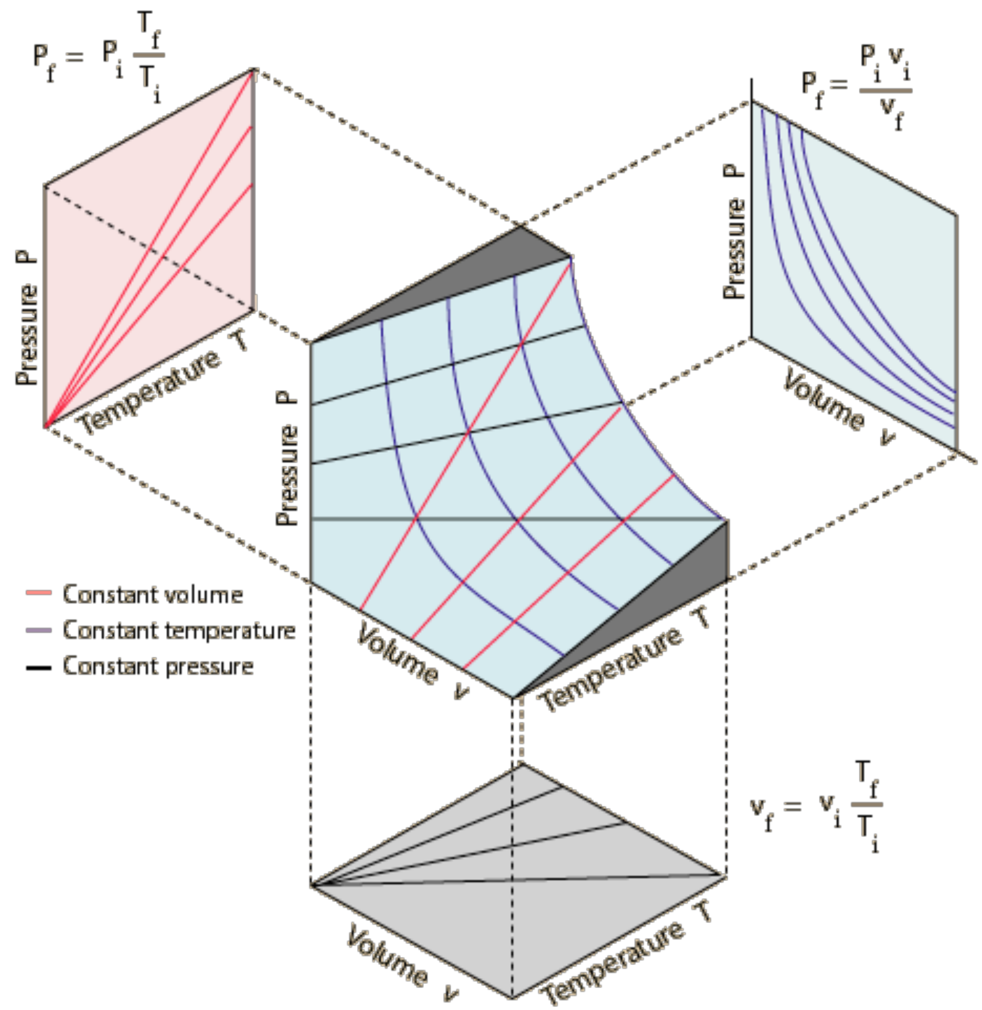
    = different paths in PVT space

    = different sequences of adding/subtracting W and Q

    = different thermodynamic processes

Recall that 3D model of PVT surface

- Ideal gas law PV=NkT constrains state variables P,V,T to lie on the curved surface shown here
- Every point on the surface is a possible state of the system
- Points off the surface cannot be valid combinations of P,V,T, for an ideal gas



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Thermodynamic processes

- For ideal gas, we can describe processes that are
  - Isothermal (T=const)
  - Constant P
  - Constant V
  - Adiabatic (Q=0)
- Quasi-static processes : require very slow changes
  - System is ~ in equilibrium throughout

  Example: push a piston in very small steps

  At each step, let system regain equilibrium