11.3 Temperature, Thermal Energy, and Heat

9. Rank in order, from highest to lowest, the temperatures $T_1 = 0$ K, $T_2 = 0°C$, and $T_3 = 0°F$.

$T_2 > T_3 > T_1$

0°C -17.8°C -273°C

10. "Room temperature" is often considered to be 68°F. What is room temperature in °C and in K?

20°C = 293 K

11. a. What is the average kinetic energy of atoms at absolute zero? 0 J

b. Can an atom have negative kinetic energy? No

c. Is it possible to have a temperature less than absolute zero? Explain. No, lowest translational kinetic energy

12. Do each of the following describe a property of a system, an interaction of a system with its environment, or both? Explain.

a. Temperature:

Property of a system: Average kinetic energy of all molecules.

b. Heat:

Property of a system: Total kinetic energy of all molecules.

c. Thermal energy:

Both: the internal energy (kinetic, rotational, + elastic bond) in a system that is changed by heat input.

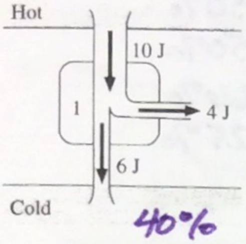
11.4 The First Law of Thermodynamics

13. For each of the following processes:
    a. Is the value of the work W, the heat Q, and the change of thermal energy ΔE_{th} positive (+), negative (−), or zero (0)?
    b. Does the temperature increase (+), decrease (−), or not change (0)?

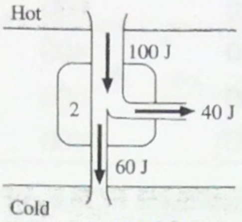
	W	Q	ΔE_{th}	ΔT
• You hit a nail with a hammer.	+ IN	+ OUT	+	+
• You hold a nail over a Bunsen burner.	0	+	+	+
• High-pressure steam spins a turbine.	− OUT	+	+	0
• Steam contacts a cold surface and condenses.	0	+	−	−
• A moving crate slides to a halt on a rough surface.	−	0	+	+

11.5 Heat Engines

14. Rank in order, from largest to smallest, the efficiencies e_1 to e_4 of these heat engines.



40%



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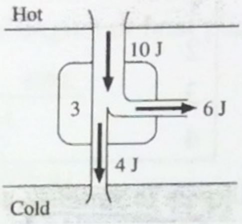
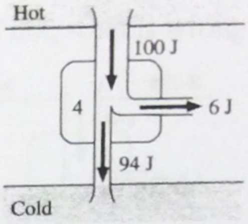


60%



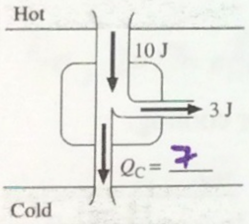
6%

Order: $e_3 > \boxed{e_1 = e_2} > e_4$

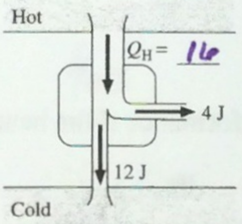
Explanation:

See % above

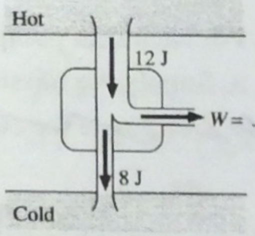
15. For each engine shown,
   a. Supply the missing value.
   b. Determine the efficiency.



e = 30%



e = 25 %



e = 33 %

16. ~~Efficiency is a dimensionless quantity, so why is it necessary to measure temperatures in Kelvin rather than °C or °F to determine efficiency when using the equation $e_{\text{max}} = 1 - \frac{T_C}{T_H}$?~~

17. Four heat engines with maximum efficiency (Carnot engines) operate with the hot and cold reservoir temperatures shown in the table.

Engine	T_C (K)	T_H (K)	
1	300	600	50%
2	200	400	50%
3	200	600	66%
4	300	400	25%

Rank in order, from largest to smallest, the efficiencies e_1 to e_4 of these engines.

Order: $e_3 > \boxed{e_1 = e_2} > e_4$

Explanation:

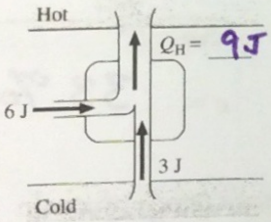
See % above

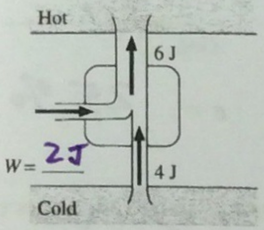
11.6 Heat Pumps, Refrigerators, and Air Conditioners

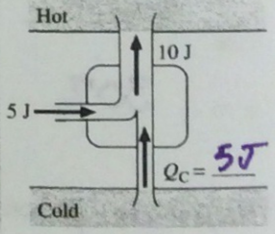
18. For each heat pump shown,

a. Supply the missing value.

~~b. Determine the coefficient of~~ performance if the heat pump is used for cooling.







~~COP =~~ ~~COP =~~ ~~COP =~~

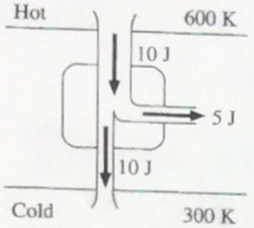
19. Does a refrigerator do work in order to cool the interior? Explain.

11.7 Entropy and the Second Law of Thermodynamics

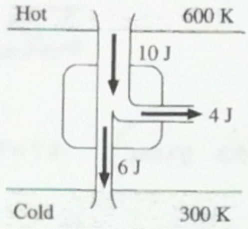
11.8 Systems, Energy, and Entropy

20. Do each of the following represent a possible heat engine or heat pump? If not, what is wrong?

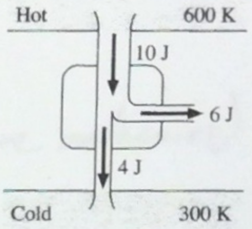
a.



b.



c.

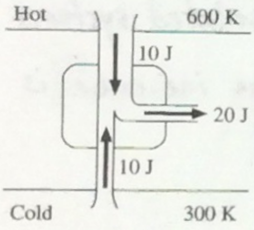


No, 15 J out 10 J in

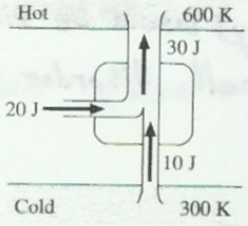
Yes

No, over carnot eff. of 50% (ε=60%)

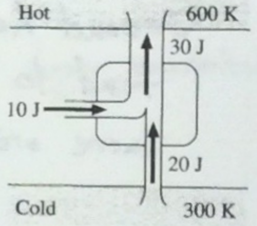
d.



e.



f.



No, 200% efficiency

Yes

No, over carnot eff. of 50% (ε=66%)

21. If you place a jar of perfume in the center of a room and remove the stopper, you will soon be able to smell the perfume throughout the room. If you wait long enough, will all the perfume molecules ever be back in the jar at the same time? Why or why not?

No, 2nd Law says entropy results in more randomness (disorder) as time goes on.

22. Suppose you place an ice cube in a cup of room-temperature water and then seal them in a well-insulated container. No energy can enter or leave the container.

   a. If you open the container an hour later, which do you expect to find: a cup of water, slightly cooler than room temperature, or a large ice cube and some 100°C steam?

   b. Finding a large ice cube and some 100°C steam would not violate the first law of thermodynamics. $W = 0$ J and $Q = 0$ J, because the container is sealed, and $\Delta E_{\text{th}} = 0$ J because the increase in thermal energy of the water molecules that have become steam is offset by the decrease in water molecules that have turned to ice. Energy is conserved, yet we never see a process like this. Why not?

   Second Law (Entropy) would be violated. Isolated systems tend to more overall disorder — a large ice cube is more ordered.

23. Are each of the following processes reversible or irreversible? Would the second law of thermodynamics be violated by any of the processes? Explain.

   a. A freshly baked pie cools on a window sill.

   Irreversible

   b. A neatly raked pile of leaves is scattered by the wind.

   Irreversible

   c. The wind gathers up the fallen leaves in a yard and leaves them in a neat pile.

   Reversible — violation of entropy

12.3 Ideal-Gas Processes

10. Consider an ideal gas contained in a confined volume. How would the pressure of the gas change if

a. the number of molecules of the gas were doubled, without changing the container or the temperature?

$$\underset{\boxed{\uparrow}}{P}\underset{\leftrightarrow}{V} = \underset{\uparrow}{n}\underset{\leftrightarrow}{R}\underset{\leftrightarrow}{T}$$

Pressure must increase (more collisions w/more molecules)
(2x)

b. the volume of the container were doubled, without changing the number of molecules or the temperature?

$$\underset{\boxed{\downarrow}}{P}\underset{\uparrow}{V} = \underset{\leftrightarrow}{n}\underset{\leftrightarrow}{R}\underset{\leftrightarrow}{T}$$

Pressure must decrease (fewer collisions with larger container)
(½x)

c. the temperature (in K) of the gas were doubled, without changing the number of molecules or the volume of the container?

$$\underset{\boxed{\uparrow}}{P}\underset{\leftrightarrow}{V} = \underset{\leftrightarrow}{n}\underset{\leftrightarrow}{R}\underset{\uparrow}{T}$$

Pressure must increase (more collisions with greater avg. KE)
(2x)

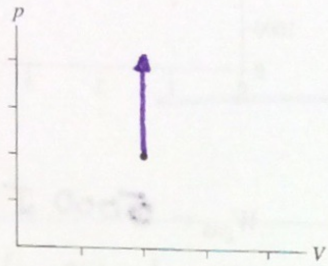
d. the rms speed of the molecules were doubled, without changing the number of molecules or the volume of the container?

RMS Speed $\propto \sqrt{T}$, so like last problem, but pressure would only increase by a factor of $\sqrt{2}$

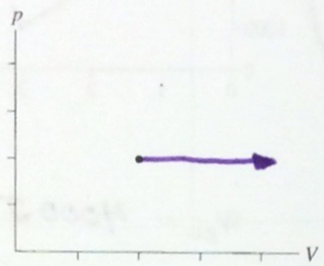
Whoops…if rms speed doubles, temperature would have to quadruple, so pressure would go up by 4x

11. The graphs below use a dot to show the initial state of a gas. Draw a pV diagram showing the following processes:

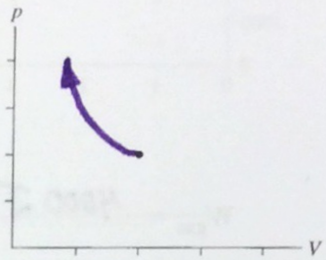
a. A constant-volume process that doubles the pressure.



b. An isobaric process that doubles the temperature.



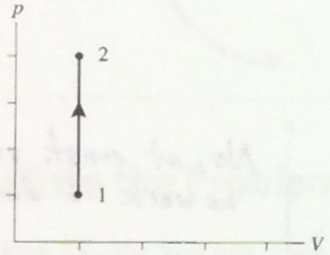
c. An isothermal process that halves the volume.



12. Interpret the pV diagrams shown below by

a. Naming the process.

b. Stating the *factors* by which p, V, and T change. (A fixed quantity changes by a factor of 1.)

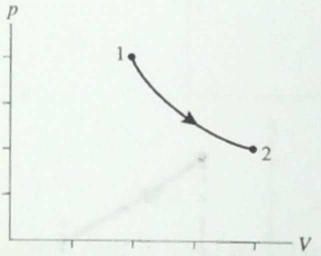


Process Isochoric

p changes by 3

V changes by 1

T changes by 3

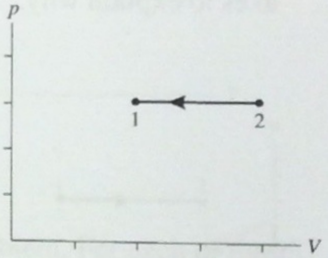


Process Isothermal

p changes by 1/2

V changes by 2

T changes by 1



Process Isobaric

p changes by 0

V changes by 1/2

T changes by 1/2

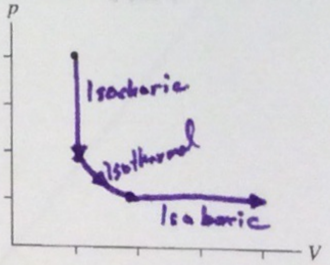
13. Starting from the initial state shown, draw a pV diagram for the three-step process:

i. A constant-volume process that halves the temperature.

ii. An isothermal process that halves the pressure, then

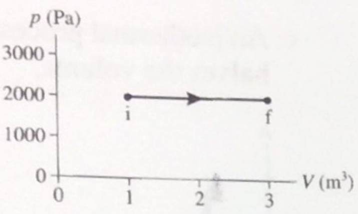
iii. An isobaric process that doubles the volume.

Label each of the stages on your diagram.

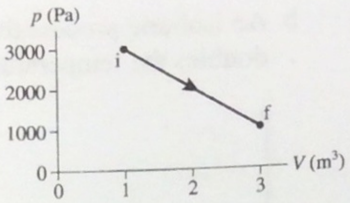


14. How much work is done by the gas in each of the following processes?

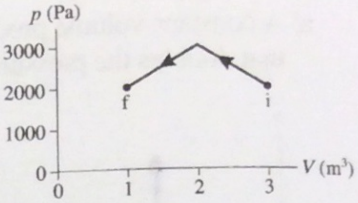
a.



b.



c.



W_{gas} = 4000 J

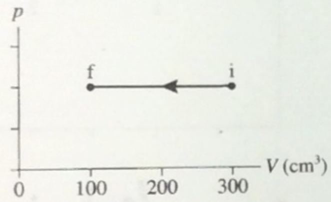
W_{gas} = 4000 J

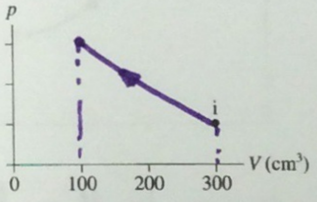
W_{gas} = 5000 J

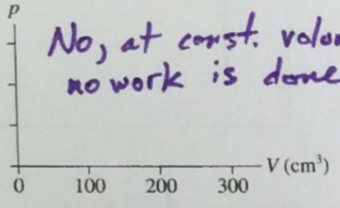
15. The figure below shows a process in which a gas is compressed from 300 cm^3 to 100 cm^3.

a. Use the middle set of axes to draw the pV diagram of a process that starts from initial state i, compresses the gas to 100 cm^3, and does the same amount of work on the gas as the process on the left.

b. Is there a constant-volume process that does the same amount of work on the gas as the process on the left? If so, show it on the axes on the right. If not, use the blank space of the axes to explain why.





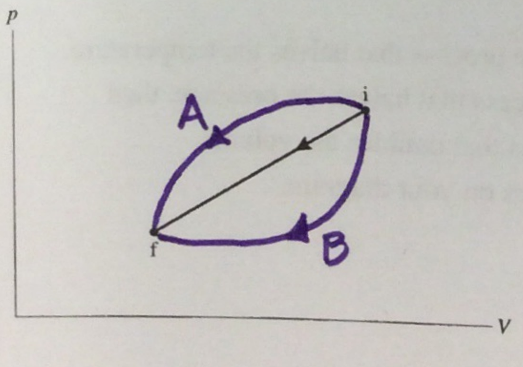


No, at const. volume, no work is done!

16. The figure shows a process in which work is done to compress a gas.

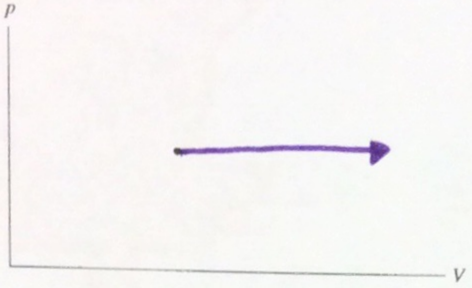
a. Draw and label a process A that starts and ends at the same points but does more work on the gas. More area

b. Draw and label a process B that starts and ends at the same points but does less work on the gas. Less area

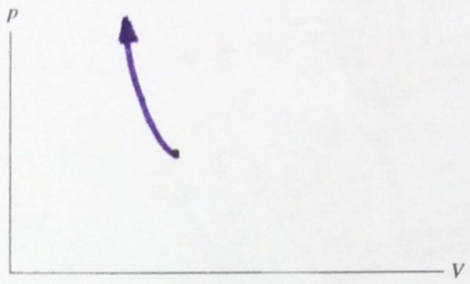


17. Starting from the point shown, draw a pV diagram for the following processes.

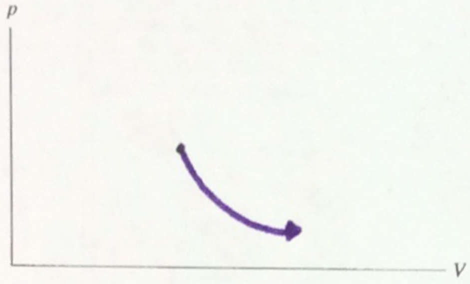
a. An isobaric process in which work is done *by* the system.



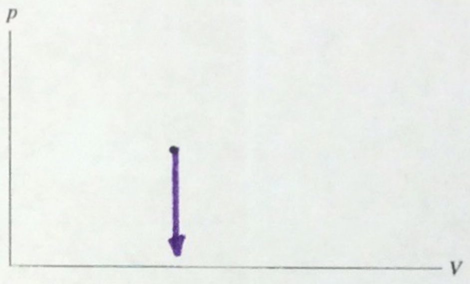
b. An adiabatic process in which work is done *on* the system.



c. An isothermal process in which heat is *added to* the system.



d. A constant-volume process in which heat is *removed from* the system.



You Write the Problem!

Exercises 18–20: You are given the equation that is used to solve a problem. For each of these:

a. Write a *realistic* physics problem for which this is the correct equation. Look at worked examples and end-of-chapter problems in the textbook to see what realistic physics problems are like.

b. Finish the solution of the problem.

18. $p_f = \dfrac{300\ \text{cm}^3}{100\ \text{cm}^3} \times 1 \times 2\ \text{atm}$

19. $(T_f + 273)\ \text{K} = \dfrac{200\ \text{kPa}}{500\ \text{kPa}} \times 1 \times (400 + 273)\ \text{K}$

20. $V_f = \dfrac{(400 + 273)\ \text{K}}{(50 + 273)\ \text{K}} \times 1 \times 200\ \text{cm}^3$