THERMODYANMICS
KRAEMER-LADERA-JEFFREY TRAIL SCRIMMAGE
NOV 4, 2017

NAME ______________________________

SCHOOL ______________________________

DO NOT TURN THE PAGE UNTIL YOU ARE INSTRUCTED TO DO SO.

AMBIENT TEMP________ VOLUME____________ STARTING TEMP ________________

Science Olympiad
Thermodynamics Team Checklist / Data Sheet

- ☐ 2.a. Competitors MUST bring: insulating device, 2 identical 250 mL Pyrex beakers, eye protection, plots, writing utensils
- ☐ 2.a. Competitors MAY bring: notes, parts/supplies, calcs
- ☐ 2.a. All reference materials secured in a 3-ring binder
- ☐ 2.d. The team's device, parts and any supplies must be impounded before the event starts.
- ☐ 2.d. Eye protection does not need to be impounded.
- ☐ 2.e. Competitors must wear eye protection during set up and loading devices with water.
- ☐ 3. Device fits in 20.0 x 20.0 x 20.0 cm cube
- ☐ 3.a. Only allowed materials used in device
- ☐ 3.c. Device can accommodate 250mL beaker
- ☐ 3.d. Device has hole >=1.5cm diameter, < cm above beaker
  12 cm
- ☐ 3.e. Device has no energy sources
- ☐ 3.f. Device is not significantly different from room temp

Team #: _______

Team Name:

____

Competitor Names:

____

Device Testing Data

Predicted Internal Beaker Temp	______
Final Internal Beaker Temp	______
Final External Beaker Temp	______
Ice Water Added (ml)	______

Multiple Choice
Identify the choice that best completes the statement or answers the question. Put answers on the answer sheet. (1/2 point each)

Write the letter that best answers the question or completes the statement on the line provided.

____ 1. From his observations of cannon drilling, Count Rumford concluded that heat could NOT be a form of

a. kinetic energy.
b. potential energy.
c. matter.
d. radiation.

____ 2. As the temperature of an object rises, so does the

a. kinetic energy of the object.
b. mass of the object.
c. thermal energy of the object.
d. potential energy of the object.

____ 3. Thermal energy depends on an object's

a. mass.
b. phase (sold, liquid, or gas).
c. temperature.
d. all of the above

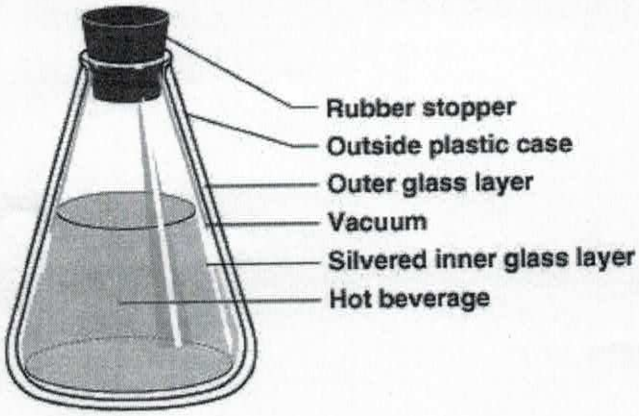


Figure 16-1

____ 4. The vacuum inside the thermos bottle shown in Figure 16-1 stops which type of thermal energy transfer to keep the liquid hot?

a. convection
b. conduction
c. radiation
d. both a and b

Team #: ________

____ 5. According to the first law of thermodynamics, the amount of work done by a heat engine equals the amount of

a. work done on the engine.
b. waste heat it produces.
c. thermal energy added to the engine minus the waste heat.
d. thermal energy added to the engine plus the waste heat.

____ 6. Disorder in the universe increases because

a. spontaneous changes produce more order in a system.
b. work produces disorder in a system.
c. work produces waste heat, which leaves a system.
d. all of the above

____ 7. What property of an object is related to the average kinetic energy of the particles in that object?

a. specific heat
b. mass
c. conductivity
d. temperature

____ 8. To which of the following does the first law of thermodynamics apply?

a. heating objects
b. transferring thermal energy
c. doing work on a system
d. all of the above

____ 9. The second law of thermodynamics states that thermal energy can flow from colder objects to hotter objects

a. by convection.
b. only if work is done on the system.
c. spontaneously.
d. when thermal expansion takes place.

____ 10. Which of the following happens in a steam engine?

a. Fuel is burned outside the engine
b. Heat is converted into work
c. Hot steam pushes a piston
d. all of the above

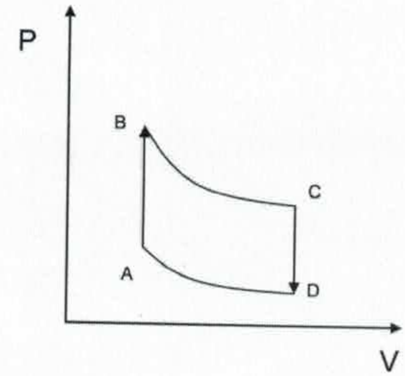
____ 11. A fluid that vaporizes and condenses inside the tubing of a heat pump is called the

a. compressor.
b. fuel.
c. refrigerant.
d. condenser.

Team #: ________

____ 12. In the figure, which process is no work done on or by the gas?

a) AB
b) BC
c) CD
d) DA
e) AB and CD
f) BC and DA



____ 13. In the figure, which process is work done by the gas?

a) AB
b) BC
c) CD
d) DA
e) AB and CD
f) BC and DA

____ 14. In the figure, for which process is the greatest amount of work performed (either on the gas or by the gas)?

a) AB
b) BC
c) CD
d) DA
e) AB and CD
f) BC and DA

____ 15. If 4 J of heat is added during process AB, and 2 J of heat is removed during process CD, what is the net work performed by a single cycle ABCDA?

a) 2 J of work output from the cycle
b) 2 J of work input to the cycle
c) 4 J of work output from the cycle
d) 4 J of work input to the cycle

____ 16. Two gas-filled rubber balloons that have equal volumes are located at the bottom of a dark, cold lake. The temperature of the water decreases with increasing depth. One balloon rises rapidly and expands adiabatically as it rises. The other balloon rises more slowly and expands isothermally. The pressure in each balloon remains equal to the pressure in the water just next to the balloon. Which balloon has the larger volume when it reaches the surface of the lake?

a. The balloon that expands adiabatically
b. The balloon that expands isothermally
c. Both balloons have the same volume
d. There is not enough information to answer

17-18. What is the average kinetic energy of a gas molecule at 20.0 degrees C ?

k=1.38X10^-23

19-20. "Room temperature" is generally defined to be 25 degrees C . (a) What is room temperature in F ? (b) What is it in K?

21-23. A 0.500 kg aluminum pan on a stove is used to heat 0.250 liters of water from 20.0 degrees C to 80.0 degrees C . How much heat is required?

c (water)= 4186 J/kg C)
c (aluminum) = 900J/kg C)

24-25. (a) Suppose there is heat transfer of 40.00 J to a system, while the system does 10.00 J of work. Later, there is heat transfer of 25.00 J out of the system while 4.00 J of work is done on the system. What is the net change in internal energy of the system?

(b) What is the change in internal energy of a system when a total of 150.00 J of heat transfer occurs out of (from) the system and 159.00 J of work is done on the system?

Thermodynamics
Kraemer 11/4
Key

Answer Sheet:

Multiple Choice:

1. __C___
2. __C___
3. __D___
4. __D___
5. __C___
6. __C___
7. __D___
8. __D___
9. __B___
10. __D___
11. __C___
12. __A___
13. __A__
14. __A__
15. __A___
16. ___B__

Key

17-18.

What is the average kinetic energy of a gas molecule at 20.0 C (room temperature)?

The known in the equation for the average kinetic energy is the temperature.

(13.57) Before substituting values into this equation, we must convert the given temperature to kelvins. This conversion gives

$\overline{\text{KE}} = \frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$ The temperature alone is sufficient to find the average translational kinetic energy. Substituting the temperature into the

$T = (20.0 + 273)\text{ K} = 293\text{ K}.$

Solution for (a)

translational kinetic energy equation gives

$\overline{\text{KE}} = \frac{3}{2}kT = \frac{3}{2}\left(1.38\times10^{-23}\text{ J/K}\right)(293\text{ K}) = \mathbf{6.07\times10^{-21}\ J}.$

19-20. **"Room temperature" is generally defined to be 25 degrees C . (a) What is room temperature in F ? (b) What is it in K?**

1. Choose the right equation. To convert from oC to oF , use the equation $T_{\text{oF}} = \frac{9}{5}T_{\text{oC}} + 32.$ (13.1)

2. Plug the known value into the equation and solve:

$T_{\text{oF}} = \frac{9}{5}25\text{C} + 32 = \mathbf{77F}.$

Solution for (b)

1. Choose the right equation. To convert from oC to K, use the equation $T_{\text{K}} = T_{\text{oC}} + 273.15.$

Key

(2)

2. Plug the known value into the equation and solve:

$T_K = 25C + 273.15 =$ **298 K.**

21-23.

A 0.500 kg aluminum pan on a stove is used to heat 0.250 liters of water from 20.0 degrees C to 80.0 degrees C . (a) How much heat is required?

1.Calculate the temperature difference: $\Delta T = T_f - T_i = 60.0oC$. (14.3)

2.Calculate the mass of water. Because the density of water is 1000 kg/m^3 , one liter of water has a mass of 1 kg, and

the mass of 0.250 liters of water is $m_w = 0.250 \text{ kg}$.

3.Calculate the heat transferred to the water. Use the specific heat of water in Table 14.1: $Q_w = m_w c_w \Delta T = (0.250 \text{ kg})(4186 \text{ J/kgoC})(60.0oC) = 62.8 \text{ kJ}$.

4.Calculate the heat transferred to the aluminum. Use the specific heat for aluminum in Table 14.1: $Q_{Al} = m_{Al} c_{Al} \Delta T = (0.500 \text{ kg})(900 \text{ J/kgoC})(60.0oC) = 27.0 \times 10^{3} = 27\text{kJ}$

=62.8+27.0 =89.8 kJ

24-25.

(a) Suppose there is heat transfer of 40.00 J to a system, while the system does 10.00 J of work. Later, there is heat transfer of 25.00 J out of the system while 4.00 J of work is done on the system. What is the net change in internal energy of the system?

(b) What is the change in internal energy of a system when a total of 150.00 J of heat transfer occurs out of (from) the system and 159.00 J of work is done on the system?

Key

Solution for (a)

The net heat transfer is the heat transfer into the system minus the heat transfer out of the system, or

$Q = 40.00 \text{ J} - 25.00 \text{ J} = 15.00 \text{ J}.$

Similarly, the total work is the work done by the system minus the work done on the system, or

$W = 10.00 \text{ J} - 4.00 \text{ J} = 6.00 \text{ J}.$ Thus the change in internal energy is given by the first law of thermodynamics:

$\Delta U = Q - W = 15.00 \text{ J} - 6.00 \text{ J} = 9.00 \text{ J}.$ We can also find the change in internal energy for each of the two steps. First, consider 40.00 J of heat transfer in and 10.00

J of work out, orNow consider 25.00 J of heat transfer out and 4.00 J of work in, or

$\Delta U_1 = Q_1 - W_1 = 40.00 \text{ J} - 10.00 \text{ J} = 30.00 \text{ J}.$ $\Delta U_2 = Q_2 - W_2 = -25.00 \text{ J} - (-4.00 \text{ J}) = -21.00 \text{ J}.$

The total change is the sum of these two steps, or

$\Delta U = \Delta U_1 + \Delta U_2 = 30.00 \text{ J} + (-21.00 \text{ J}) = \mathbf{9.00\ J.}$

Discussion on (a)

No matter whether you look at the overall process or break it into steps, the change in internal energy is the same.

Solution for (b)

Here the net heat transfer and total work are given directly to be $Q = -150.00 \text{ J}$ and $W = -159.00 \text{ J}$, so that $\Delta U = Q - W = -150.00 \text{ J} - (-159.00 \text{ J}) = \mathbf{9.00\ J.}$

Key

(4)