Name: ______________________

Class: ______________________

Due Date: ______________________

B.1 Thermal Energy Transfers

Understandings

- Molecular theory in solids, liquids, and gases.
- Density ρ as given by $\rho = \frac{m}{V}$.
- Kelvin and Celsius scales are used to express temperature.
- The change in temperature of a system is the same when expressed with the Kelvin or Celsius scales.
- The internal energy of a system is the total intermolecular potential energy arising from the forces between the molecules plus the total random kinetic energy of the molecules arising from their random motion.
- Temperature difference determines the direction of the resultant thermal energy transfer between bodies.
- A phase change represents a change in particle behavior arising from a change in energy at constant temperature.
- Quantitative analysis of thermal energy transfers Q with the use of specific heat capacity c and specific latent heat of fusion and vaporization of substances L as given by $Q = mc\Delta T$ and $Q = mL$.
- Conduction, convection, and thermal radiation are the primary mechanisms for thermal energy transfer.
- Conduction in terms of the difference in the kinetic energy of particles.
- Quantitative analysis of rate of thermal energy transfer by conduction in terms of the type of material and cross-sectional area of the material and the temperature gradient as given by $\frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{\Delta x}$.
- Qualitative description of thermal energy transferred by convection due to fluid density differences.
- Quantitative description of thermal energy transferred by convection due to fluid density differences.
- Quantitative analysis of energy transferred by radiation as a result of the emission of electromagnetic waves from the surface of a body, which in the case of a black body can be modeled by the Stefan-Boltzmann law as given by

$L = \sigma A T^4$ where L is the luminosity, A is the surface area, and T is the absolute temperature of the body.
- The concept of apparent brightness b.
- Luminosity L of a body as given by $b = \frac{L}{4\pi d^2}$.
- The emission spectrum of a black body and the determination of the temperature of the body using Wien's displacement law as given by $\lambda_{\text{max}} T = 2.9 \times 10^{-3}$ mK where λ_{max} is the peak wavelength emitted.

Equations

$$\rho = \frac{m}{V}$$

$$\overline{E_{\text{k}}} = \frac{3}{2} k_{\text{B}} T$$

$$Q = mc\Delta T$$

$$Q = mL$$

$$\frac{\Delta Q}{\Delta t} = kA \frac{\Delta T}{\Delta x}$$

$$L = \sigma A T^4$$

$$b = \frac{L}{4\pi d^2}$$

$$\lambda_{\text{max}} T = 2.898 \times 10^{-3} \text{ mK}$$

If you are interested in learning more about thermal physics then please read the book *Concepts in Thermal Physics* by Stephen J. Blundell and Katherine M. Blundell.

Visiting the coldest town in the world - Chilling Out | 60 Minutes Australia
60 Minutes Australia
https://www.youtube.com/watch?v=l1noUh2NrLI

The hottest place on Earth | 60 Minutes Australia
60 Minutes Australia
https://www.youtube.com/watch?v=bdeOZ6rJ36Q

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Use your favorite sources to answer the following questions

1. C: Define *solid*. What are its characteristics?

2. C: Define *fluid.*

3. C: Define *liquid*. What are its characteristics?

4. C: Define *gas*. What are its characteristics?

5. C: Define and give the units for each variable for density $\rho = \frac{m}{V}$. Is it a scalar or vector? Do not confuse density ρ with power P or momentum $\vec{p}$ or pressure p!

6. E: Determine the volume of a 1.00 kg gold bar if gold has a density of approximately 19,300 kg/m^3.

7. C: Define *diffusion.*

8. C: Which state of matter has the most potential energy: a solid, a liquid, or a gas?

9. C: Define *temperature.*

10. C: Define *Degrees Celsius*. What is the melting point and the boiling point of water in *degrees Celsius*?

11. C: Define *Kelvin*. What is the melting point and the boiling point of water in Kelvin?

12. C: Define *absolute zero.*

13. C: Which has greater kinetic energy: 0 °C ice or 0 °C water? Which has greater potential energy?

14. C: Define and give the units for each variable of the equation for *Boltzmann's constant* $k_\mathrm{B} = \frac{R}{N_\mathrm{A}}$.

15. C: Define and give the units for each variable for the equation for the internal energy of an ideal gas $\overline{E_\mathrm{k}} = \frac{3}{2} k_\mathrm{B} T = \frac{3}{2} \frac{R}{N_\mathrm{A}} T$.

16. C: Define *thermal equilibrium.*

17. C: Define *heat.*

18. C: Define *internal energy.*

19.C: Define *phase change*.

20.C: What does the equation $Q = mc\Delta T$ tell us? Define and give the units of each variable.

21.C: Define *melting*. Does an object gain potential energy or lose potential energy when it melts? What about kinetic energy?

22.C: Define *freezing*. Does an object gain potential energy or lose potential energy when it freezes? What about kinetic energy?

23.C: Define *vaporization/boiling*. Does an object gain potential energy or lose potential energy when it vaporizes/boils? What about kinetic energy?

24.C: Define *condensation*. Does an object gain potential energy or lose potential energy when it condenses? What about kinetic energy?

25.C: What does the equation $Q = mL_\mathrm{f}$ tell us? Define and give the units of each variable.

26.C: What does the equation $Q = mL_\mathrm{v}$ tell us? Define and give the units of each variable.

27.E: Moses has 500 grams of gold.

a. Go online to find the specific heat capacity of gold in its solid state in $\frac{\text{J}}{\text{kg}\times\text{K}}$.

b. How much energy will it take to increase the temperature of solid gold by 50°C?

c. How much energy will be lost by solid gold if its temperature decreases by 50°C?

28.E: How much energy will be needed to increase the temperature of 0.8 kg of solid ice from minus 30°C to steam at plus 140°C? Draw a temperature vs. energy graph of this process.

$c_{\text{solid}} = 2{,}108\ \frac{\text{J}}{\text{kg}\times\text{K}}$	$c_{\text{liquid}} = 4{,}186\ \frac{\text{J}}{\text{kg}\times\text{K}}$	$c_{\text{gas}} = 1{,}996\ \frac{\text{J}}{\text{kg}\times\text{K}}$
$L_{\text{f}} = 3.34\times10^{5}\ \frac{\text{J}}{\text{kg}}$	$L_{\text{v}} = 2.26\times10^{6}\ \frac{\text{J}}{\text{kg}}$	

29. E: Approximately how much energy will be needed to melt 1.25 kg of silver which is at a room temperature of 22.0 °C? The specific heat capacity of silver is approximately $236\ \frac{\mathrm{J}}{\mathrm{kg} \times {}^\circ\mathrm{C}}$, the latent heat of vaporization of silver is approximately 2.51×10^5 J, and the melting point of silver is approximately 962 °C.

30. E: Aaron drops a 6.00 kg gold block with a temperature of 20.0°C into a tub with 2.00 kg of liquid water at 90.0°C. What will be the final temperature of the system?

31.E: A ball of copper, which has a specific heat capacity of $c = 390.\frac{\text{J}}{\text{kg°C}}$, has a mass of 165 grams and is initially at a temperature of 115°C. This ball is quickly inserted into an insulated cup containing 125 ml of water at a temperature of 22.0°C.

a. What will be the final, equilibrium temperature of the ball and the water?

b. How much heat did the copper ball lose to the water?

c. How much heat did the water gain from the ball?

32.C: Define *conduction, convection,* and *radiation.* Give an example of each.

33.C: What is the difference between a *thermal conductor* and *thermal insulator*? Give an example of each.

34.C: Describe the equation $\frac{\Delta Q}{\Delta t} = kA\frac{\Delta T}{\Delta x}$.

35.E: A silver plate 3.00 cm thick has a cross-sectional area of $4{,}000.\,\mathrm{cm}^2$. One face is at 160.°C and the other is at 130.°C. How much heat passes through the plate each second? For silver, $k = 406\ \frac{\mathrm{W}}{\mathrm{mK}}$.

36.E: A metal plate 6.00 mm thick has a temperature difference of 48.0°C between its faces. It transmits 200. kcal/h through an area of $7.00\ \mathrm{cm}^2$. Calculate the thermal conductivity of this metal in $\frac{\mathrm{W}}{\mathrm{mK}}$.

37.E: Two metal plates are soldered together. It is known that $A = 70.0\ \text{cm}^2$, $L_1 = 2.00$ mm, $L_2 = 4.00$ mm, $T_1 = 110.$ °C, and $T_2 = 20.0$°C. For the plate on the left $k_1 = 45.0\ \frac{\text{W}}{\text{mK}}$ and for the plate on the right $k_2 = 85.0\ \frac{\text{W}}{\text{mK}}$. Determine the temperature of the soldered junction in K and the heat flow rate in J/s.

38.C: Define *absorb*, *reflect* and *emit.*

39.C: Define *black body.*

40.C: State the definition, equation, and units for *emissivity*. What is the *emissivity* of a really dark colored object? What is the *emissivity* of a really light colored object?

41.C: Define *luminosity L*. Units?

42.C: What does the *Stefan-Boltzmann law* tell us? State the equation and define each variable in the *Stefan-Boltzmann law*.

43.E: A spherical body of 5.00 cm in diameter is maintained at 700.°C. Assuming that it radiates as if it were a blackbody, at what rate (in Watts) is energy radiated from the sphere?

44.E: The average surface temperature of the Sun is 5.778×10^3 K and its average radius is 6.957×10^8 m. Assuming that it radiates as if it were a blackbody, at what rate (in Watts) is energy radiated from the sphere?

45.E: The radius of star X is four times that of star Y and its temperature is three times that of Y. Find the ratio of luminosity of Y to that of X.

46.E: A blackbody has a surface area of $4.00\ \text{m}^2$ and temperature of 450. K. The blackbody is in a closed room with room temperature of 293 K. How much energy does the blackbody lose per minute?

47.C: Define *apparent brightness b*. Units? What is the mathematical relationship between *apparent brightness b* and *luminosity L*?

48.E: The luminosity of the Sun is 3.846×10^{26} W and its distance from the Earth is about 1.50×10^{11} m. Determine the apparent brightness *b* of the Sun.

49.E: The apparent brightness of star X as observed from Earth is three times greater than that of star Y as observed from Earth. The luminosity of star X is two times greater than that of star Y. Determine the ratio of the distance of star Y to Earth to that of star X to Earth.

50.C: What does *Wien's displacement law* tell us? State the equation and define each variable for *Wien's displacement law*. Draw and label a graph describing *Wien's displacement law*.

51.E: The Sun emits electromagnetic waves with a maximum wavelength of 570. nm. According to this information what is the surface temperature of the Sun?

52.E: The maximum surface temperature of the red supergiant Betelgeuse is approximately 3.80×10^3 K. Determine the maximum wavelength emitted.