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. Define *solid*. What are its characteristics?

2. Define *fluid.*

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

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

5. 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. Define *diffusion.*

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

8. Define *temperature.*

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

10. Define *Kelvin*. What is the melting point and the boiling point of water in Kelvin?

11. Define *absolute zero.*

12. Which has greater kinetic energy: 0 ℃ ice or 0 ℃ water? Which has greater potential energy?

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

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

15. Define *thermal equilibrium.*

16. Define *heat.*

17. Define *internal energy.*

18. Define *phase change*.

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

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

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

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

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

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

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

26. Moses has 500 grams of gold.
    a. What is the specific heat capacity of gold in $\frac{J}{kg \times °C}$?
       http://hyperphysics.phy-astr.gsu.edu/hbase/Tables/sphtt.html

    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?

27. 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.

28. Aaron drops a 6 kg gold block with a temperature of 20°C into a tub with 2 kg of liquid water at 90°C. What will be the final temperature of the system?

29. Define *conduction, convection,* and *radiation.* Give an example of each.

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

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

32. Define *absorb*, *reflect* and *emit.*

33. Define *black body.*

34. 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?

35. Define *luminosity L*. Units?

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

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

38. 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*.