Thermodynamics

Fill in the blank (1pt)

1. The Newton temperature scale is made up of 20 different points
2. When Antonine Lavoisier began his study of combustion, he noticed that metals would increase in weight upon being burned in air
3. The engine cycle used in most modern jet turbines is the Brayton cycle
4. William Thomson coined the functional term *thermo-dynamics* in his 1858 paper titled "An Account of Carnot's Theory of the Motive Power of Heat"
5. At room temperature, mercury is the only metal to be in liquid form
6. The highest density of water occurs at roughly what degree celsius 4°C (nearest whole number)
7. The most efficient thermodynamic engine can never be realistically achieved due to the constraint of time
8. Absolute hot is the concept of the highest temperature that can be achieved, it is also known as Planck temperature.
9. In solar panels, the photoelectric effect is the primary method that allows conversion of solar energy to electrical energy
10. The relationship between molar heat capacity at constant pressure and molar heat capacity at constant pressure is at a difference of $8.314\ \frac{J}{mol*K}$ (numerical value with units)
11. The book *Reflections on the Motive Power of Fire* was written by Sadi Carnot
12. An ice cube melts slower in hot water than in cold water
13. The British Thermal Unit is defined as the energy required to heat 1 pound of water 1 degree Fahrenheit(temperature scale).

14. A reversible adiabatic process is a process in where the state variable, entropy, remains constant
15. A linear gas molecule with 5 atoms has 10 theoretical vibrational degrees of freedom
16. Boyle's law can be used to help extrapolate absolute zero degrees using a pressure gauge and and temperature differences
17. The Kelvin is to Celsius as Rankine is to Fahrenheit
18. Nernst is the scientist most responsible for the 3rd law of thermodynamics
19. The measure of useful work available in a system is also known as Helmholtz free energy
20. Constant pressure calorimetry typically measures enthalpy while constant volume calorimetry typically measures internal energy
21. The Maxwell Juttner distribution is similar to the Maxwell-Boltzmann distribution, except considering relativistic effects as well
22. A singular dice has 6 microstates
23. This dice has an entropy of $2.47 * 10^{-23} J/K$ (boltzmann constant 1.38*10^-23 J/K)
24. The efficiency of a diesel engine is theoretically controlled by the compression ratio and cut-off ratio
25. 100g of 0 °C ice is heated by 30000J, the end result is a bucket with ice and water (ice only, ice and water, water only)
26. The name of the relationship between the different forms of ice (I, II, III etc.) is called polymorphs
27. The boiling of water in a pot utilizes conduction (method of heat transfer)

FRQ

1. A long copper rod is used to conduct heat between two objects. The rod has a heat transfer coefficient of 20 J/ (m * K * s) with a length of 30 m and a surface area of .05 m^2. One object starts at a temperature of 20°C and the other starts at a temperature of 80°C with heat capacities of 100kJ/K. Determine the time in seconds until they are 2°C apart? (5 points)

- $\frac{dQ}{dt} = \frac{kA(\Delta T)}{d}$ $\therefore dQ = C\,dT$ $\quad 2\,dT = d(\Delta T)$

  $dQ = \frac{C\,d(\Delta T)}{2}$

- $\frac{C\,d(\Delta T)}{2\,dt} = \frac{kA(\Delta T)}{d}$ $\quad$ - $\frac{d(\Delta T)}{(\Delta T)} = \frac{2kA}{Cd}\,dt$

- $\int_{60}^{2} \frac{d(\Delta T)}{\Delta T} = \frac{2kA}{Cd} \int_{0}^{t} dt$

- $\ln\left(\frac{2}{60}\right) = \frac{2(20)(.05)}{100000 \cdot 30}\,t$

$t = 5.10 \times 10^{6}$ seconds

2. A blackbody radiates at max wavelength of 800nm, using Wien's Law, what is the temperature of this blackbody? (3 points)

$\lambda_{max} = \frac{b}{T}$

$800 * 10^{-9} m = \frac{2.8977729 \times 10{-}3\ m \cdot K}{T}$

$T = 3622.22K$

3. Explain the rationale of the ultraviolet catastrophe and eventual solution (4 points)

Classical physics can be used to derive an equation which describes the intensity of blackbody radiation as a function of frequency for a fixed temperature--the result is known as the Rayleigh-Jeans law. Although the Rayleigh-Jeans law works for low frequencies, it diverges as $\underline{\nu^2}$; this divergence for high frequencies is called the ultraviolet catastrophe.

Max Planck explained the blackbody radiation in 1900 by assuming that the energies of the oscillations of electrons which gave rise to the radiation must be proportional to integral multiples of the frequency, i.e.,

$$E = nh\nu$$

Using statistical mechanics, Planck derived an equation similar to the Rayleigh-Jeans equation, but with the adjustable parameter

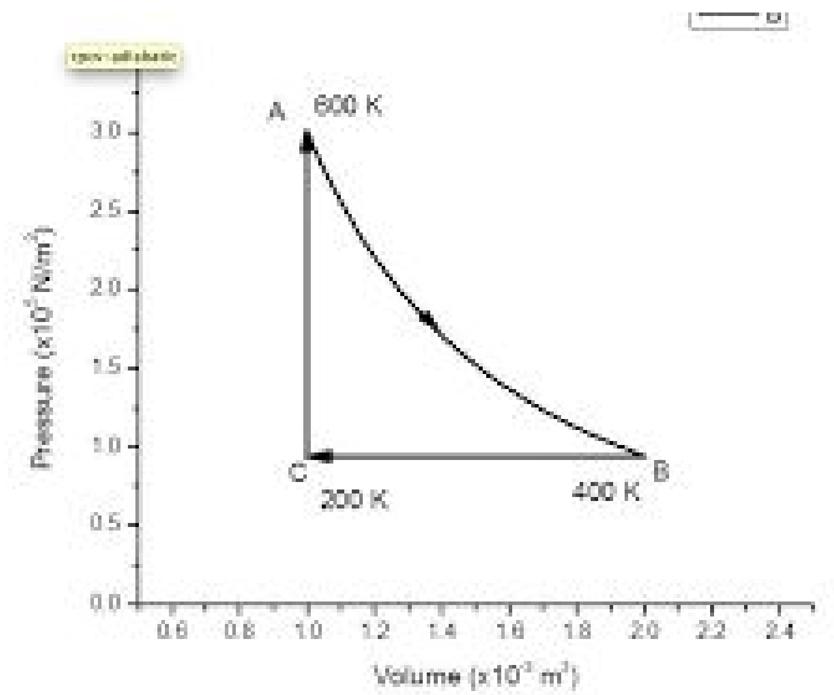
h. Planck found that for $h = 6.626 \times 10^{-34}$ J s, the experimental data could be reproduced.

4. A small 15W lightbulb burns at 5000K in a room. Assuming the filament is a perfect radiator, determine the area of the burning filament (4 points)

   $\frac{P}{A} = \varepsilon\sigma T^4$

   $\frac{15}{A} = (1) * 5.6703 * 10^{-8}(\frac{W}{m^{2} * K^{4}}) * (5000K)^4$

   $A = 4.23 * 10^{-7} m^2$



5. What is the theoretical carnot efficiency of this engine with the given temperatures? (2 points)

$\eta = 1 - \frac{T_c}{T_H}$

$\eta = 1 - \frac{200K}{600K}$

$\eta = \frac{2}{3}$

6. What is the actual efficiency of this engine assuming 1 mol of monoatomic gas? (4 points)

$W = -P(\Delta V) + nRT\,ln(\frac{V_2}{V_1})$

$W = -(10^5 Pa)(10^{-3} m^3) + (1mol)(8.314\frac{J}{mol*K})(600K)ln(\frac{2m^3}{1m^3})$

$W = 3357.69J$

$Q_{in} = (\frac{3}{2})nR(\triangle T) + (-w_{isothermal})$

$Q_{in} = (\frac{3}{2})(1mol)(8.314\frac{J}{mol*K})(600K - 200K) + (1mol)(8.314\frac{J}{mol*K})(600K)ln(\frac{2m^3}{1m^3})$

$Q_{in} = 8446.10J$

$\eta = \frac{W}{Q_{in}} = \frac{3357.69J}{8446.10J} = 39.75\%$

7. What is the degrees of freedom of a gas mixture of inert O_2, CO_2, He, and Ne? (3 points)

$degrees\ of\ freedom = number\ of\ components\ -\ number\ of\ phases\ + 2$

$degrees\ of\ freedom\ = 3 - 1 + 2$

$degrees\ of\ freedom = 4$

8. The sun is 5778K and 695,700 kilometres, assuming it is an ideal radiator, what is the power of the sun? (4 points)

$\frac{P}{A} = \varepsilon\sigma T^4$

$P\ = A\varepsilon\sigma T^4$

$P\ = (\frac{4}{3})(695700000m)^2\pi(1)(5.6703 * 10^{-8}(\frac{W}{m^{2*}K^4}))(5778K)^4$

$P\ = 1.43 * 10^{41}\,W$

9. Prove that in an isothermal process, $W = nRT\,ln(\frac{V}{V_1})$ (5 points)

$$w = -\int_{V_1}^{V_2} P\,dV \quad \text{---------- (i)}$$

By ideal gas equation

$PV = nRT$

$$P = \frac{nRT}{V}$$

Substitute in (i), we get.

$$w = -\int_{V_1}^{V_2} \frac{nRT}{V}\,dV$$

$$w = -nRT \int_{V_1}^{V_2} \frac{dv}{V}$$

$$w = -nRT\,[\ln V]_{V_1}^{V_2} \quad \left[\because \int \frac{dx}{x} = \ln x\right]$$

$$w = -nRT\,[\ln V_2 - \ln V_1]$$

$$w = -nRT \ln \frac{V_2}{V_1}$$

$$\boxed{w = -2.303\, nRT \log \frac{V_2}{V_1}} \qquad [\ln x = 2.303 \log x]$$

Since $P_1V_1 = P_2V_2$

$$\frac{V_2}{V_1} = \frac{P_1}{P_2}$$

$$\boxed{w = -2.303\, nRT \log \frac{P_1}{P_2}}$$

10. 2 objects are heated separately and placed in a vat of water. Object 1, 20g, has specific heat capacity of .5J/g°C and is heated to 90°C. Object 2, 20g, has a specific heat capacity of .25J/g°C and is heated to 75°C. The vat of water, 100g, has a specific heat capacity of 4.18J/g°C and starts at 20°C. To the nearest whole degree, what is the final temperature of the system at equilibrium? (4 points)

$$m_1C_1(T_1 - T_f) + m_2C_2(T_2 - T_f) = -m_wC_w(T_w - T_f)$$

$$20g(0.5\frac{J}{g*°C})(90°C - T_f) + 20g(.25\frac{J}{g*°C})(75°C - T_f) = -100g(4.18\frac{J}{g*°C})(20°C - T_f)$$

$$900J - 10(T_f)\frac{J}{°C} + 375J - 5(T_f)\frac{J}{°C} = -8360J + 418(T_f)\frac{J}{°C}$$

$$9635J = 433(T_f)\frac{J}{°C}$$

$$T_f = 22.25°C$$