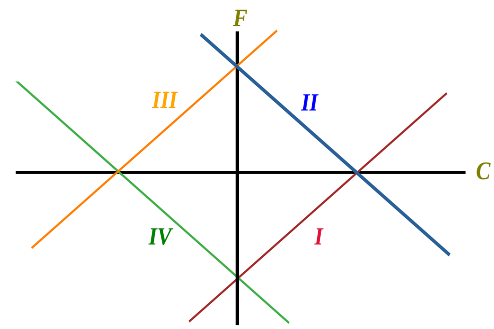
Sem-II - Thermal Physics

(Instructor: AKB, Department of Physics, Asutosh College)

Assignment I: Thermo-Calorimetry & Kinetic Theory

Submission due date: 15/05/2025

Q.1) (a) At what temperature do the Fahrenheit and Celsius scale display the same reading? **(b)** In figure shown beside, identify which line represents $\frac{C}{5} = \frac{F-32}{9}$? Justify your answer. **(c)** In a constant volume gas thermometer, pressure of air at $0°C$ is $80cm$ and at $100°C$ is $109.3cm$. Calculate the temperature of a hot bath in which when the thermometer is immersed shows a pressure of $100cm$.



Q.2) (a) Air in a Wilson's cloud chamber at $20°C$ is abruptly expanded to 1.4 times its initial volume. Calculate the final temperature. Given γ of air is 1.4. **(b)** At $10^6 dynes/cm^2$ pressure, a gas with $\gamma = 1.4$ expands isothermally until its volume is double of the initial volume. After that, it adiabatically expands until its volume is redoubled. Calculate the final pressure of the gas.

Q.3) (a) Calculate the number of molecules/cc of an ideal gas at $27°C$ and at pressure of $20mm$ of mercury. Given, density of mercury is $13.6gm/cc$ and mean kinetic energy of a molecule at $27°C$ is $4 \times 10^{-21} Joules$. **(b)** At what temperature will the root mean squared velocity of a gas will become half of its value at $0°C$?

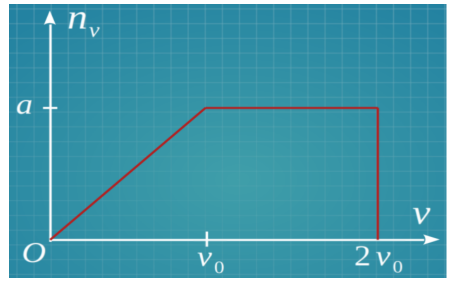
Q.4) (a) At what value of speed c will the Maxwell's velocity distribution F_c will yield same magnitude for a mixture of Hydrogen and Helium gases at $27°C$? **(b)** Find $\langle \frac{1}{c} \rangle$ using F_c. **(c)** Molecular mass of an ideal gas of Oxygen is 32. Calculate average velocity ($\bar{c}$), root mean square velocity (c_{rms}) and most probable velocity (c_m) of the gas at $27°C$. **(d)** Convince yourself that $\frac{RT}{M} = \frac{P}{\rho}$ where symbols have their usual meaning. Using that, calculate $\bar{c}, c_{rms}, c_m$ of the molecules of the gas at density $1.293 \times 10^{-3} gm/cc$ at $76cm$ of Mercury pressure. **(e)** The quantity $(c - \bar{c})^2 = c^2 - 2c\bar{c} + \bar{c}^2$ is the *squared deviation* of atomic speed from the average speed. Calculate the average value of this using F_c and obtain the root mean squared deviation. **(f)** Show also that their exists 57% probability for the molecules to have emerged with a speed greater than v_m.

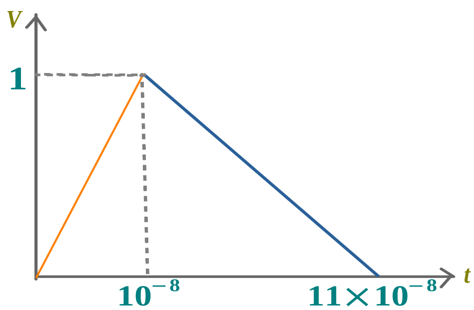
Q.5) (a) According to the Drude-Jellium model for a metal at temperature T, a conduction electron gets collided with an ion at time $t = 0$. Assuming that the temporal distribution of the electron to have another collision with an ion at time t is Poissonian,

$$p(t) = \frac{1}{\tau} e^{-t/\tau},$$

evaluate **(i)** the average, **(ii)** the (mean) square, and **(iii)** standard deviation (SD) of the time interval for the electron to have its next collission. Taking the obtained SD as the time uncertainty, estimate the quantum mechanical energy uncertainty and compare that with the energy uncertainty obtained classically (Maxwellian).

Q.6) Consider an imaginary speed distribution of an electron gas in a metal shown above, that consist of N conduction electrons with the number of electrons within velocity range v and $v + dv$ is given by $dn_v = n_v dv$. **(i)** Express the parameter 'a' that represents the maximum of n_v in terms of N and v_0. **(ii)** Mathematically obtain the distribution function $n_v(v)$ and **(iii)** using that, calculate $\bar{v}$ and v_{rms}. **(iv)** What fraction of the total electrons will have velocity between $3v_0/2$ and $2v_0$?





Q.7) Consider a saw-tooth waveform signal shown beside, that grows linearly from $0V$ to $1V$ in $10ns$ and then decays linearly to $0V$ over a period of $100ns$. Obtain mathematically the waveform and using that, find the $r.m.s.$ voltage in units of mV.

Q.8) **(a)** Estimate the size of a Helium atom assuming its mean free path is $28.5 \times 10^{-6} cm$ at N.T.P. and density is $0.178 gm/liter$ at N.T.P. and the mass of Helium atom is $6 \times 10^{-24} gm$. **(b)** The diameter of a gas molecule is $3 \times 10^{-8} cm$. Calculate the mean free path at N.T.P. Given $k_B = 1.38 \times 10^{-16} ergs/^\circ C$. **(c)** Find the diameter of a molecule of Benzene if its mean free path is $2.2 \times 10^{-8} m$ and the number of Benzene molecules per unit volume is $2.79 \times 10^{25} molecules/m^3$.