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Probability of finding the speed of a particle in the range (v;v + dv)is :

$$v_{MP} = \left[\frac{2kT}{m}\right]^{\frac{1}{2}} \qquad v_{rms} = \left[\frac{3kT}{m}\right]^{\frac{1}{2}} \qquad v_{avg} = \left[\frac{8kT}{\pi m}\right]^{\frac{1}{2}} \qquad P(v)dv = 4\pi\left[\frac{1}{2\pi}\frac{m}{kT}\right]^{\frac{3}{2}} v^2 e^{-\frac{mv^2}{2kT}} dv$$

$$p = \frac{1}{3}\rho < v^2 > \qquad \rho = \frac{Nm}{V} \qquad \int_0^{+\infty} \frac{x^3}{e^x - 1} dx = \frac{\pi^4}{15}$$

Gaussian Integrals:

$$\int_0^{+\infty} e^{-ax^2} dx = \frac{1}{2}\sqrt{\frac{\pi}{a}} \qquad \int_0^{+\infty} x e^{-ax^2} dx = \frac{1}{2a} \qquad \int_0^{+\infty} x^2 e^{-ax^2} dx = \frac{1}{4}\sqrt{\frac{\pi}{a^3}}$$

$$\int_0^{+\infty} x^3 e^{-ax^2} dx = \frac{1}{2a^2} \qquad \int_0^{+\infty} x^4 e^{-ax^2} dx = \frac{3}{8}\sqrt{\frac{\pi}{a^5}}$$

ΔEint = Q + W $\qquad$ $pV=nRT$ $\qquad$ $W = -\int p dV$ $\qquad$ $\Delta S = \int \frac{dQ}{T}$

Change	ΔEint	W	Q	ΔS
P = const	$nC_v \Delta T$	$-p(V_f-V_i)$	$nC_p \Delta T$	$nC_p \ln\frac{T_f}{T_i}$
V = const	$nC_v \Delta T$	0	$nC_v \Delta T$	$nC_V \ln\frac{T_f}{T_i}$
T = const	0	$-nRT\ln\frac{V_f}{V_i}$	$nRT\ln\frac{V_f}{V_i}$	$nR\ln\frac{V_f}{V_i}$
Q = 0	$nC_v \Delta T$	$\frac{1}{\gamma-1}\left(p_f V_f - p_i V_i\right)$	0	0

$pV^\gamma = const.$ $\qquad$ $\gamma = \frac{C_P}{C_V}$ $\qquad$ $C_p - C_v = R$

$$\epsilon_{CRN} = \frac{W}{Q} = \left|\frac{Q_H - Q_L}{Q_H}\right| = 1 - \frac{T_C}{T_H} \qquad \textbf{COP} = \frac{\textbf{what we want}}{\textbf{what we pay for it}}$$

$\Delta L = \alpha L \Delta T$ $\qquad$ $\Delta S = \beta S \Delta T$ $\qquad$ $\Delta V = \gamma V \Delta T$

P = e σ A T^4; σ =5.67x 10^{-8}W/(K^4m^2) $\qquad$ $P = kA\left|\frac{dT}{dx}\right|$

Q = mcΔT $\qquad$ Q = Lm

c(water) = 4186 J/(kg C); $\qquad$ c(ice) = 2090 J/(kg C); $\qquad$ c(steam) = 2010J/(kg C)

L(fusion) =3.33x10^5 J/kg $\qquad$ L (vaporization) = 2.26x10^6 J/kg

density of Cu = 8940kg/m^3 ; $\qquad$ α(Cu)=17x$10^{-6}K^{-1}$; $\qquad$ c(Cu)= 385J/kgC ;

density of water =1000kg/m^3 $\qquad$ (unless different value is given in the problem)

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Part 1. In the scantron sheet to answer all MC questions below. (Best 6 count towards 48% of your test mark)

1. Short Finned Pilot Whale can dive to depths of 1.1 kilometers. What is the total pressure they experience at this depth? (take: ϱ = 1020 kg/m^3 and 10^5 N/m^2 = 1 ATM, g=9.81m/s^2.)

   A) 9 ATM B) 111 ATM C) 198 ATM D) 297 ATM E) 381 ATM

2. Two moles of ideal gas are kept inside sealed container at pressure of 15000Pa at temperature of 100C. What is the volume of that container?

   a) 413m^3 b) 413 l c) 1240 l d) 1240m^3 e) none of the above

3. A balloon filled with hydrogen has a volume of 2.0m^3 when its temperature is 300 K and its pressure is 1.0 atm. What volume (in m^3) would it have at a pressure of 0.11 atm and a temperature of 250 K ?

   A) 10 B) 12 C) 13 D) 15 E) none of the above

4. A 0.500 kg copper cup is at 280 K. If 2.5×10^4 J of energy is added to it, what is its final temperature in K? The specific heat of copper is $387 \text{ J/kg}\cdot°\text{C}$.

   A) 358 B) 392 C) 402 D) 409 E) none of the above

5. In the ideal gas described by the Boltzmann- Maxwell's distribution of speeds, the ratio of the number of molecules with the speed equal to v_{mp} , to the number of molecules with the speed of v_{rms} , is:

   A) $\frac{3}{2}e^2$ B) $\frac{2}{3}e^{\frac{1}{2}}$ C) $\frac{3}{2}e^{-\frac{1}{2}}$ D) $\frac{2}{3}e^{-1}$ E none of the above

6. A 10 kg sample of mercury is completely solidified and liberates 213.6 kJ of energy. What is the original temperature of the mercury? (The melting point of mercury is 234 K, the heat of fusion of mercury is 11.3 kJ/kg, and the specific heat of mercury is 140 J/kg•K.)

   A) 2K B) 85K C)306 K D) 334 K E) none of the above

7. In an adiabatic process 160 J of work are done on two moles of a gas. If the gas molecules have 5 degrees of freedom, how much does its temperature change?

   A) 3.21K B) 3.85K C) 9.6K D) 9.63K E) none of the above

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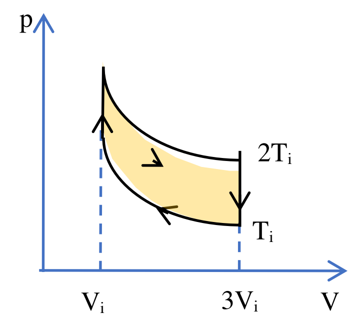
PART 2 **In examination booklets solve 4 out of 5 problems below. Each question has the same weight. (13p)**
For full marks you need a neat diagram (when applicable) and all steps to be clearly demonstrated.

1. a) A very powerful octopus uses one sucker of diameter 2.86 cm on each of the two shells of a clam in an attempt to pull the shells apart . Find the minimum force the octopus has to exert in salt water (42.3 m deep) to do this . (Take the salt water density =1kg/liter) (8p)

b) As a 1.00-mol sample of a monatomic ideal gas expands adiabatically, the work done on it is + 4 500 J. The initial temperature and pressure of the gas are 300 K and 1.60 atm. Calculate the final temperature, and the final pressure. (5p)

2. In the *Stirling engine*, fuel is burned externally to warm one of the engine's three cylinders. A fixed quantity of inert gas moves cyclically between the cylinders, expanding in the hot one and contracting in the cold one. Figure on the right represents a model for its thermodynamic cycle on p-V diagram. Consider *n* mol of an ideal monatomic gas being taken once through the cycle, consisting of two isothermal processes at temperatures $2T_i$ and T_i and two constant-volume processes. Determine, in terms of *n*, *R*, and T_i,
(a) the net energy transferred by heat to the gas in one cycle (7p)
(b) the net work done by the gas in one cycle (6p)



3. Given is one mole of CO_2 gas at 27°C. (Molar mass of CO_2 is 44g/mol).
a) Use Maxwell Boltzmann distribution to <u>write the case-specific full expression</u> for the number of N_2 molecules having speeds between 630m/s and 632m/s. (The expression has to contain data specific for this problem – but there is no need to finish the calculations!) (6P)
b) Find the most probable velocity of CO_2 at the temperature of 27°C (2P)
c) At what temperature would the rms velocity of CO_2 gas molecules be the same as in part (b)? (3P)
d) Demonstrate that the most probable velocity of ideal gas molecules is indeed equal to $v_{MP}= (2\,kT/m)^{½}$ (2P)

4. Present detailed <u>proofs of the following</u> :

i)using the summary of thermodynamic processes table (from your formula sheet) and known Laws of Thermodynamics prove that $C_p=C_v+R$. (4P)

ii) Starting from the first principles, show that pV^{γ}=const for adiabatic transformation. (where $\gamma = \frac{C_p}{C_V}$) (9P)

5. A copper-made 2.00-kg "Archimedes" cylinder (with its altitude equal to its diameter) is taken from a forge at 850°C and dropped into 5.00 kg of water at 10.0°C.

Assuming that no energy is lost by heat to the surroundings, determine

a) the final temperature of the "water + cylinder" system. (7p)
b) the ratio of the total power radiated by the copper before and after equilibrium was established (3p)
c) the change of the surface of the copper cylinder as result of its temperature change . (3p)

density of Cu =8.94g/cm^3 ; α(Cu) = $17\cdot10^{-6}$ K^{-1} c(Cu)=385 J/(kgC)
The specific heat of water/ice/steam as well as latent heats are given on the formula sheet.