Phys2053 **FINAL EXAM** Time 9:00-11:00 AM
Physics Department
Instructor Anand Yethiraj.
ANSWER ALL FIVE QUESTIONS **[100 points total]**. You may use a calculator.

(I) Short Questions [20 points]
Answer the following questions in the box provided. Where asked, provide a reason for your answer in one sentence (in the second box).

(1) If you were to consider helium gas and nitrogen gas at the same temperature:
(a) which gas would have a higher root-mean-square velocity and why?

(b) which gas would have a higher root-mean-square *momentum* and why?

(2) You need to pick up a very hot cooking pot in your kitchen. You have a pair of hot pads. To be able to pick up the pot most comfortablyshould you soak them in tap water or keep them dry?

Answer:

Reason:

(3) Select T-True, F-False. (If the first is F the second T and the rest F, write FTFF).

For one mole of an ideal gas:

(i) During adiabatic compression, thechange in internal energy equals zero.

(ii) In a reversible isothermal expansion, heat is transferred to the gas.

(iii) Temperature decreases in a isobaric expansion.

(iv) Entropy increases in a reversible iso-volume pressure increase.

Answer:

(4) If an airstream from a hair dryer is directed over a ping-pong ball, the ball can be levitated.

Explain why:

(5) Can a heat pump have a coefficient of performance less than unity?

Answer:

Reason:

(II) [20 points] FLUIDS

(1) (5 points) A very powerful vacuum cleaner has a hose 2cm in diameter. With no nozzle on the hose, what is the mass of the heaviest brick that the vacuum cleaner could lift?

(2) (5 points) Water flows through a fire hose of inner diameter 6 cm at a rate of 0.012 m^3/s. The fire hose ends in a nozzle of inner diameter 2 cm. What is the speed with which the water exits the nozzle?

(3) (5 points) Assume your eardrum has a diameter of 0.5 cm. Calculate the force that sea water exerts on your eardrum at a depth (below sea level) of 100 m.

(4) (5 points) The retarding force on a sphere of radius R that moves with speed v through a fluid of viscosity η is $F=6\pi\eta Rv$. This is known as Stokes law. A sphere with mass density ρ_s falls through water whose density is ρ. The forces on the sphere are the viscous force, the buoyant force and the gravitational force.

(a) Set up the force balance and derive a formula for the *terminal velocity* v_t, which is the velocity when the net force is zero (i.e. the sphere is not accelerating).

(b) Use the equation obtained in (a) to find the terminal velocity for a $1\,mm$ diameter glass sphere ($\rho_{glass}=2000\,kg/m^3$).

(III) [20 points]
A 10cm x 10cm x 10cm cube contains air (assume an ideal gas of equivalent molar mass 28.9 g/mol) at atmospheric pressure and temperature 300K.

(a) Find the mass of the gas.

(b) Calculate the root-mean-square velocity of the gas molecules.

(c) Find the ***force*** exerted by the gas on each surface of the cube.

(d) Comment on the physical reason why such a small amount of air can exert such a large force.
[Force is momentum transfer per unit time]

(IV)[20 points]

(1)(10 points)

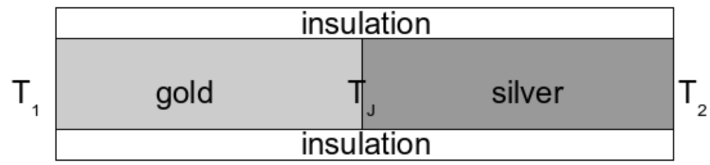
How much work (in joules) is required to compress 5.0 moles of an unknown gas ($\gamma = 1.4$) that is initially at 20 °C and 1 atm., to one tenth of the original volume V_i

(a) by an adiabatic process ? (Hint: Begin by calculating V_i .)

(b) by an isothermal process

(c) Is the final pressure in the adiabatic process greater than, less than, or equal to the final pressure in the isothermal process?

(2) (10 points)
A bar of gold is in thermal contact with a bar of silver of the same length L and area A. One end of the compound bar is maintained continuously at $T_1 = 350\,K$, the other end is at a constant temperature of $T_2 = 300\,K$.



What is the temperature of the junction T_J (in K) ? You may neglect heat loss or heat transfer through the insulation. [Do not put in numbers until you have an equation for T_J .]

(V) [20 points]

(1) (5 points)

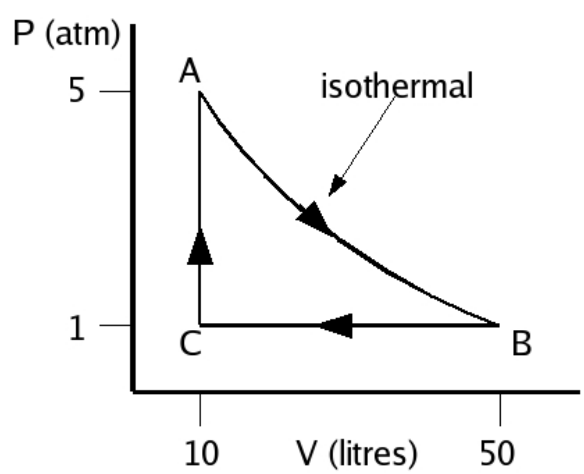
How much work is required, using an ideal Carnot refrigerator, to change 0.5 kg of water at 10 ºC to ice at -20 ºC? Assume that the freezer compartment is held at -20 ºC and that the refrigerator exhausts energy into a room at 20 ºC.

(2) (15 points)

A 1 mole sample of an ideal monatomic gas is taken through the cycle shown in the figure. The process A to B is a reversible isothermal expansion.

Calculate (obtain numerical values for):

(a) the entropy change in process A-B



(b) the temperatures (in K) T_A , T_B , T_C .

(c)net work done **on** the gas

(d) the energy added **to** the gas by heat Q_h

(e) the efficiency of the cycle

EQUATIONS:

i) $F_{visc} = -\eta A \frac{dv}{dy}$

ii) $\Delta p = \frac{2\gamma}{R}$

iii) $\frac{dV}{dt} = v_1 A_1 = v_2 A_2$

iv) $\Re = \frac{vL\rho}{\eta}$

v) $p + \frac{1}{2}\rho v^2 + \rho g y = constant$

vi) $pV = N k_B T = nRT$

vii) $v_{rms} = \sqrt{\frac{3k_B T}{m_0}} = \sqrt{\frac{3RT}{M}}$

viii) $v_{mp} = \sqrt{\frac{2k_B T}{m_0}} = \sqrt{\frac{2RT}{M}}$

ix) $Q = mL$

x) $Q = mc\Delta T$

xi) $W = -\int_{initial}^{final} p\, dV$

xii) $pV^{\gamma} = K$, where $\gamma = \frac{C_P}{C_V}$

xiii) $S_B - S_A = \int_A^B \frac{dQ_{rev}}{T}$

xiv) $e = \frac{|W|}{|Q_h|}; e_{Carnot} = 1 - T_c / T_h$. $COP_{refrigerator} = \frac{|Q_c|}{|W|}$. $COP_{heat\ pump} = \frac{|Q_h|}{|W|}$

xv) $P_{conduction} = kA\frac{\Delta T}{\Delta x}$, $P_{radiation} = \epsilon \sigma A T^4$

CONSTANTS:

$R = 8.31\, J/(mole.K)$ and
$k_B = R/(6.02\times10^{23}) = 1.38\times10^{-23}\, J/K$
$g = 9.8\, m/s^2$
1 kPa = 1000 N/m^2.
1 atmosphere corresponds to a pressure of 101.3 kPa.

A cubic-metre of water contains 1000 litres.
The density of water: $\rho_{water} = 1000$ kg/m^3.
The density of sea-water: $\rho_{sea-water} = 1030$ kg/m^3.
$c_{water} = 4186\, J/kg.K$; $L_{water-ice} = 3.33\times10^5\, J/kg$; $c_{ice} = 2090\, J/kg.K$
Viscosity of water at 20 ºC: $1.0\times10^{-3}\, Pa.s$.

Thermal conductivity of gold: 314 *W/m.K*
Thermal conductivity of silver: 427 W/m.K