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PHYS 121 **EXAM 3** **April 29, 2009**
Prof. S. M. Bhagat

Name: SOLUTION.

(Sign in ink, print in pencil)

Notes

1) There are four (4) problems in this exam. Please make sure that your copy has all of them.

2) Please show your work indicating clearly what formula you used and what the symbols mean. Just writing the answer will not get you full credit. In stating vectors give both magnitude and direction.

3) Write your answers on the sheets provided.

4) Do not forget to write the units.

5) Do not hesitate to ask for clarification at any time during the exam. You may buy a formula at the cost of one point.

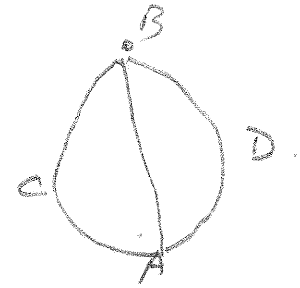
God Bless You!

$$k_B = 1.383x10^{-23}\ J/K$$
$$N_A = 6.02x10^{23}$$
$$m_p = 1.6x10^{-27}\ kg$$

Problem 1a: What is a conservative force? (6)

For a conservative force the work done is independent of the path and is determined only by the end-points of the displacement

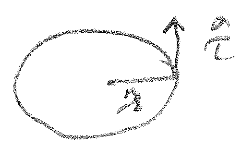
$\Delta W_{AB} = \Delta W_{ACB} = \Delta W_{ADB}$.



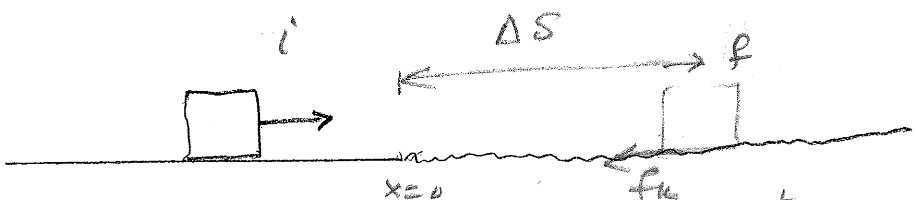
Problem 1b: The centripetal force can be provided by friction, tension, spring force. Why are they regarded as "no-work" forces in this situation? Explain. (4)

When friction, tension, spring force provide the force $\vec{F}_c$ they must be along $-\hat{r}$. The displacement is along the tangent $\hat{t}$. So

$\Delta W = \vec{F} \cdot \Delta \vec{s} = 0$



Problem 1c: A mass of 10kg travelling at 2m/s $\hat{x}$ on a smooth horizontal surface when it runs into a rough patch where the coefficient of kinetic friction $\mu_k = 0.6$. how far will it travel before it comes to a stop? (15)



Conservation of Energy, external force is present so

$$K_f + U_f = K_i + U_i + W_{NCF}$$

(W_{NCF}: Non-Conservative Force)

Here $K_i = \frac{1}{2} \times 10 \times 2^2$ J

$= 20J$

$U_i = 0$.

$K_f = 0, U_f = 0$.

$W_{NCF} = -f_k \Delta S = -\mu_k M g \Delta S$.

$0 + 0 = 20J - \mu_k M g \Delta S$

$$\Delta S = \frac{20}{\mu_k M g} = 0.34m$$

Problem 2a: Two objects of masses M and 3M have the same kinetic energy which one will have the larger linear momentum (magnitude) and by what factor? Why? (5, 5)

$K = \frac{p^2}{2M}$ let $M_1 = M$, $M_2 = 3M$.

$K_1 = \frac{p_1^2}{2M_1}$, $K_2 = \frac{p_2^2}{2M_2}$

$K_1 = K_2$

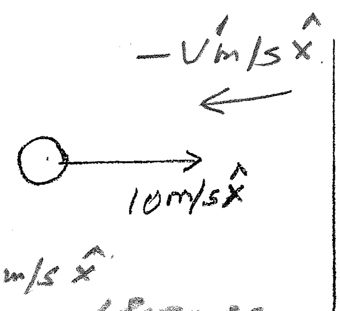
so $\frac{p_1^2}{2M_1} = \frac{p_2^2}{2M_2}$

$\frac{p_2}{p_1} = \sqrt{\frac{M_2}{M_1}} = \sqrt{3}$

So 3M has the larger momentum by a factor of $\sqrt{3}$.

Problem 2b: An object of mass 0.25kg travelling horizontally at 10m/s $\hat{x}$ collides with a vertical wall. What is the change in the momentum of the wall if the collision is (i) totally elastic, (ii) totally inelastic? Why? (15)

Let vel. of object after collision be $-v'$ m/s $\hat{x}$.



Then $\Delta \vec{p}_{obj} = (-Mv - Mv')$ m/s $\hat{x}$
$= -M(v+v')$ m/s $\hat{x}$

Lin Mom^m conservation requires
$\Delta \vec{p}_{wall} = -\Delta \vec{p}_{obj} = +M(v+v')$ m/s $\hat{x}$

However, wall has large mass so change in kin of wall $\Delta K_{wall} = \frac{(\Delta p_{wall})^2}{2M_{wall}} \to 0$.

i) If collision is totally Elastic, kin. Energy is conserved. Since $\Delta K_{wall} = 0$, $\Delta K_{obj} = 0$, so $v' = v$; $\Delta \vec{p}_{wall} = 2mv\hat{x} = (2 \times 0.25 \times 10)$ kg-m/s $\hat{x}$
$= 5$ kg-m/s $\hat{x}$

(ii) If collision is totally Inelastic, object sticks to wall $v' = 0$

$\Delta \vec{p}_{wall} = mv\hat{x} = 2.5$ kg-m/s $\hat{x}$

Problem 3a: When a planet goes around the sun the force keeping it in orbit is

$$\underset{\rightarrow}{F_G} = \frac{-GM_{sun}M_P}{Rp^2}\hat{r}$$

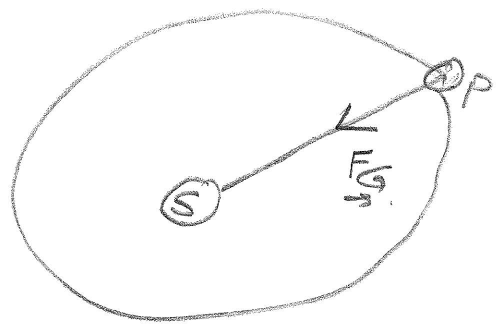
Why is the angular momentum of the planet, about an axis through the Sun, constant? (10)

If $\vec{\tau}_{ext}$ on planet is zero, its angular momentum will be constant

Now $\vec{F}_G \parallel \hat{r}$

and torque on planet due to $\vec{F}_G$ would be

$\vec{\tau}_G = [\vec{r} \times \vec{F}_G] = 0$!



Problem 3b: Why does a gas exert pressure on the walls of its container? Explain. (10)

First At a finite temperature atoms of gas are in random motion

Second Each time an atom of mass m and velocity $\vec{v}$ bounces off a wall and the collision is totally Elastic and wall picks up momentum

$\Delta \vec{p}_{wall}$ (Single Coll) $= 2m\vec{v}$

Third Let us calculate the no. of collisions that a wall of Area A has every sec.

Let this # be N_s then

$\Delta \vec{p}_{wall}$ (Per sec) $= 2m\vec{v} N_s$

But $\frac{\Delta \vec{p}}{\Delta t} = \langle \vec{F} \rangle$ ← average force.

$P = \frac{F}{A}$!

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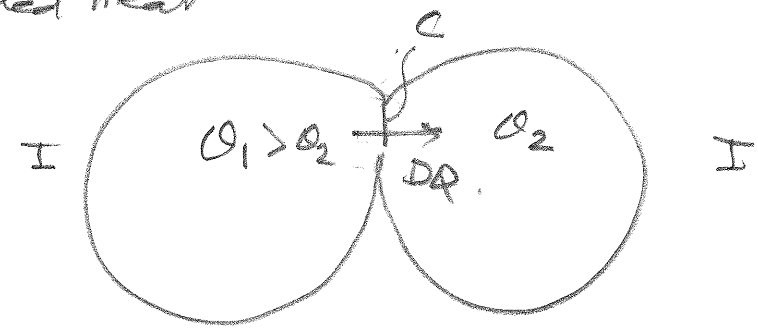
Problem 3c: A gas is in a stationary container at T= 700k. What is the average velocity of its atoms? Why? (5)

Since the atoms are in random motion

$$\langle \vec{v} \rangle = 0.$$

Problem 4a: What is heat energy? (5)

Exchange of energy between two systems when they are at different temperatures and have a conducting wall separating them is called Heat



Problem 4b: What is the difference between specific heat and latent heat? (5)

If there is a change of temperature, the scale is set by specific heat

$$DQ = mc\Delta T.$$

If there is a change of state, without change of temperature, the scale is set by latent heat

$$DQ = mL$$

[Actually, as we know now neither of them should be called "Heat", they refer to Internal Energy changes]

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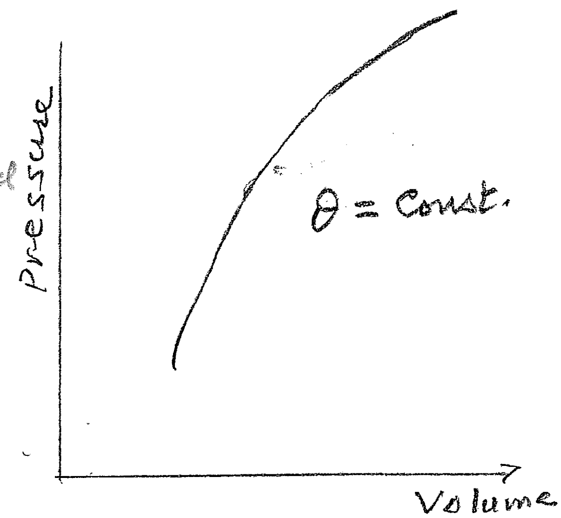
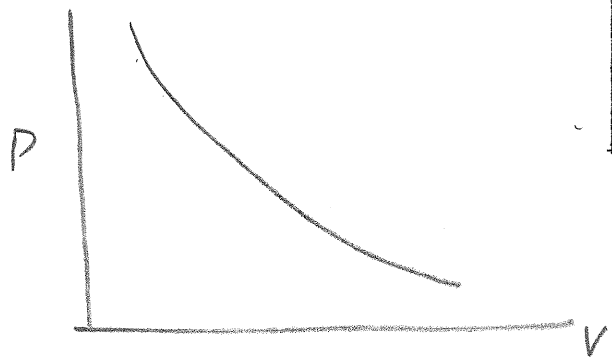
Problem 4c: What is wrong with the picture (below) which is intended to show variation of pressure with volume in an ideal gas at constant temperature? (10)



If temperature is constant, pressure must be inversely proportional to volume. The correct picture is



Problem 4d: Write down the dimensions of

(i) Angular momentum

(ii) Temperature (5)

Angular momentum $l = mrv$ $\quad M^1 L^2 T^{-1}$

Temperature θ $\quad \theta^1$