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PHYS 121 **EXAM III** **April 27, 2012**
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Name: Soln

(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!

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

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Problem 1a

What is the difference between force and torque? Support your answers with examples.

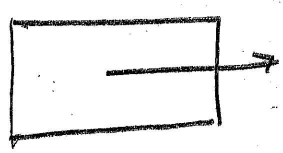
(10)

Force causes linear acceleration and hence Translation

$$M\vec{a} = \sum \vec{F_i}$$

Driving a nail

Rigid Body



$\vec{F}$ $\quad M\vec{a}_{CM} = \vec{F}$.

Torque ($\vec{\tau}$) causes angular acceleration and hence rotation about an axis. To have $\vec{\tau}$ you must apply $\vec{F}$ at some distance $\vec{r}$ from axis, and $\vec{F}$ must be perpendicular to $\vec{r}$.

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

$$I\vec{\alpha} = \sum \tau_i \text{ for rigid body.}$$

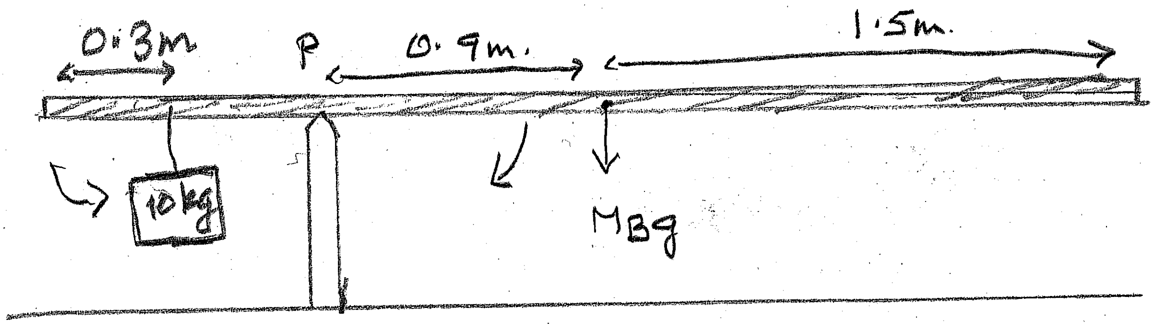
Screw Driver applies torque.

Opening door causes torque

Problem 1b

A uniform bar of length 3*m* is placed on a vertical support located at 0.6*m* from the left end. If hanging a mass of 10kg at a distance of 0.3m from the end brings the bar into equilibrium in the horizontal position. What is the mass of the bar? Why?

(15)



For Eqm of a rigid Body

Total force $\sum \vec{F_i} = 0$

Total Torque $\sum \vec{\tau_i} = 0$.

Take Torques about P

Torque due to $M_B g$ is −ive.

" " " $10g$ is +ive.

$-M_B g \times 0.9 + 10 \times 9.8 \times 0.3 = 0$

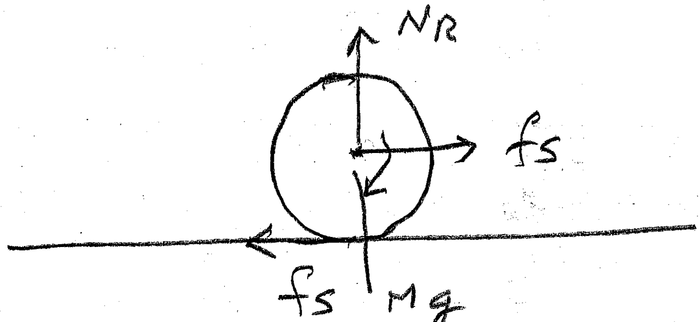
$-M_B \times 9.8 \times 0.9 + 10 \times 9.8 \times 0.3 = 0$

$M_B = \frac{10 \times 0.3}{0.9} = 3.33\,kg$

Problem 2a

You are stopped at a red light on a horizontal road when the coefficient of static friction is 0.5. When the light turns green, what is the maximum acceleration at which you can take off? Why?

(15)



$N_R - Mg = 0$

To get going you engage engine to wheel which puts a torque $\vec{\tau}$ on it. wheel tries to turn pushing with f_s on the road. where

$$f_s \leq \mu_s N_R.$$

static friction.

~~Road~~ By Newton's 3rd law, road pushes wheel forward,

$$M\vec{a} = f_s$$

$$M\vec{a} \leq \mu_s N_R \hat{x}$$

$$M\vec{a} \leq \mu_s Mg \hat{x}$$

$$\vec{a} \leq \mu_s g \hat{x}$$

$$a_{max} = 0.5 \times 9.8 = 4.9 m/s^2$$

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Problem 2b

What is the relationship between the angular momentum (magnitude) and the rotational kinetic energy of a rigid body? Why?

(10)

$$\vec{L} = I\vec{\omega}$$

$$K_{rot} = \frac{1}{2} I \omega^2$$

Magnitude

$$L = I\omega$$

$$L^2 = I^2\omega^2$$

$$\frac{L^2}{I} = I\omega^2$$

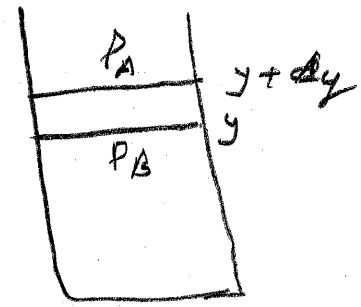
$$\frac{L^2}{2I} = \frac{1}{2} I\omega^2 = K_{rot}.$$

Problem 3a

Near Earth, why does the pressure in a gas or liquid reduce with height above the surface of earth?

(5)

Consider a layer lying between y & y + Δy. If it is to be in Em total force on it must be zero. Earth pulls it down $\underset{\rightarrow}{W_g} = -Mg\hat{y}$. P_A must be less than P_B to give an upward force to balance $\underset{\rightarrow}{W_g}$



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Problem 3b
A gas is contained in a stationary enclosure at a temperature of 500K. What is the average velocity of the particles in it? Why?

(5)

The motion is random therefore average velocity is zero

$\langle \underline{v} \rangle = 0$

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Problem 3c

Why does a gas exert pressure on the walls of its container?

(15)

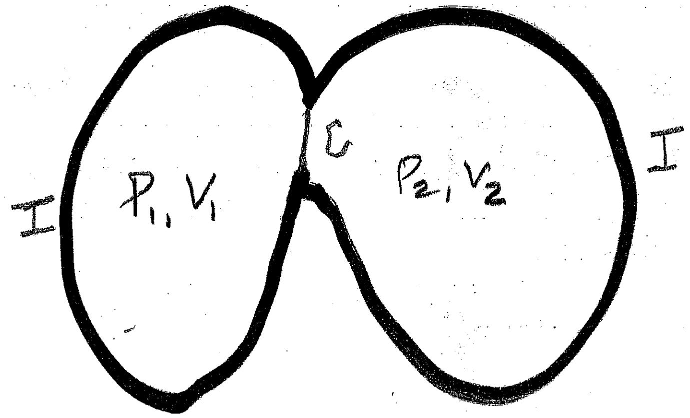
1. The atoms are in random motion
2. Each time an atom bounces off a wall it delivers momentum $2mv$ to the wall because collision is Elastic.
3. If there are N_c collisions per second on a wall of area A, wall experiences a force

$$2mv\,N_c$$

4. Pressure is force/Area.

Problem 4a
Consider the setup of two thermodynamic systems which are isolated from the surroundings but have a conducting wall between them. Use it to develop the concept of temperature.

(15)



Let the initial pressures and volumes be P_1, V_1 and P_2, V_2 respectively

There are two possibilities

Expt

① There is no change when Expt begins although,

$$P_1 \neq P_2, \quad V_1 \neq V_2.$$

② Both systems change but after a while changes stop. Again the new values

$$P_2' \neq P_1', \quad V_1' \neq V_2'$$

Conclusion ① When there is no change systems must be in equilibrium (not dynamic).

② P & V are irrelevant for this Ξm.

③ We need a new parameter whose equality ensures Ξm. This is temperature so we call it thermal Ξm

and state: Two systems can be in Ξm if and only if they have same TEMPERATURE

Problem 4b

A $100cm^3$ beaker of Aluminum (Coefficient of linear expansion $\alpha = 23\times10^{-6}C^{-1}$) is filled to the brim with water ($\gamma = 210\times10^{-6}C^{-1}$) at 15°C. Next, it is warmed to a temperature of 90°C. How much water, if any, will overflow in this experiment? Why?

(10)

Both the beaker & water will expand.

Beaker

$$V_B = V_0\left[1+\alpha(\theta-\theta_0)\right]^3$$

$$= V_0\left[1+3\alpha(\theta-\theta_0)\right]$$

$\alpha \rightarrow$ linear

3α - volume

Water

$$V_W = V_0\left[1+\gamma(\theta-\theta_0)\right].$$

$$V_W - V_B = V_0\left[(\gamma-3\alpha)(\theta-\theta_0)\right]$$

$$= 100\left[(210-69)\times10^{-6}\times75\right]\ cm^3.$$

$$= (100\times75\times141\times10^{-6})\ cm^3$$

$$= 10.575\times10^{-4}\ cm^3 = 1.05\ cm^3$$