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PHYS 121 **EXAM II** **March 30, 2012**
Prof. S. M. Bhagat

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.

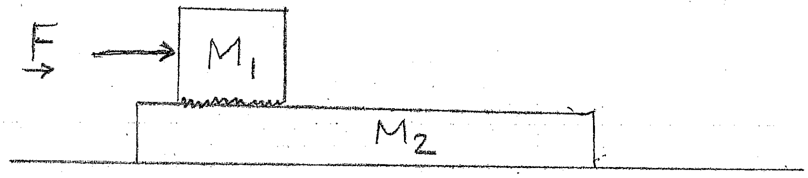
4) Do not forget to write the units.

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.

Best of Luck! God Bless You!

Problem 1a Consider the set-up below: The coefficient of static friction between M_1 and M_2 is $\mu_S = 0.2$ while M_2 is lying on a smooth frictionless table. If $M_1 = 1$kg and $M_2 = 5$kg, what is the maximum acceleration M_1 can have so they both move together? Why?

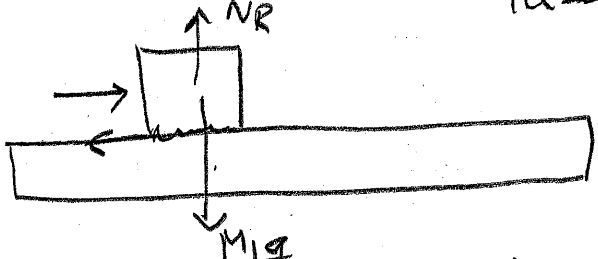
(15)



Newton's Law

$M\vec{a} = \sum \vec{F_i}$ at that pt. at that time

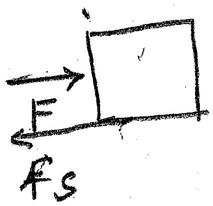
Forces



$f_s \leq \mu_s N_R.$

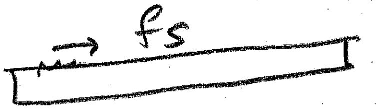
$\equiv m$ along y so $N_R = M_1 g.$

M_1:



$M_1 a = F - f_s.$

M_2



$M_2 a = f_s$

$M_2 a \leq \mu_s M_1 g$

so $a \leq \frac{\mu_s g M_1}{M_2}$

$\vec{a}_{max} = \frac{0.2 \times 9.8 \times 1}{5} \, m/s^2 \, \hat{x}$

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Problem 1b Two objects of masses M and 5M have the same linear momentum (magnitude), which one will have the larger kinetic energy and by what factor? Why?

(6)

Kinetic Energy $K = \frac{p^2}{2M}$

$K_1 = \frac{p_1^2}{2M_1}$

$K_2 = \frac{p_2^2}{2M_2}$

$\frac{K_1}{K_2} = \frac{p_1^2}{p_2^2} \cdot \frac{M_2}{M_1}$ $M_1 = M$, $M_2 = 5M$.

$p_1 = p_2$ $\frac{K_1}{K_2} = \frac{M_2}{M_1} = \frac{5M}{M} = 5.$

Smaller Mass has larger K by a factor of 5.

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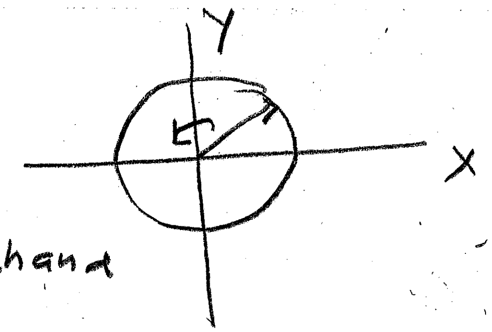
Problem 2a An object of mass 0.5kg is moving uniformly counterclockwise in the xy-plane, making 15 revs per minute. The radius of the circle (which is centered at zero) is 4m. What is

(i) The angular velocity?

If the object is at $\underset{\sim}{r} = 4m\hat{y}$ at t = 0 what will its

(ii) Velocity and acceleration be at t = 3sec. Why? (6,6,6)

15 revs in 60 secs

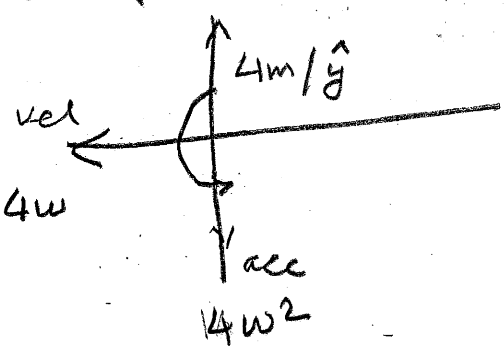


T = 4 secs

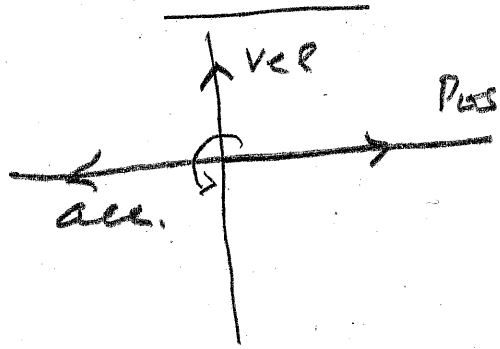
$\underset{\rightarrow}{\omega} = \frac{2\pi}{4}$ rad/s $\hat{z}$ [rt hand rule ccw angles are positive].

$\underset{\rightarrow}{r} = R\hat{r}$, $\underset{\sim}{v} = \omega R\hat{\tau}$ $\underset{\rightarrow}{a} = -R\omega^2\hat{r}$

t=0 Pos



t = 3sec



$\underset{\rightarrow}{V}(3sec) = \frac{4 \times 2\pi}{4}$ m/s $\hat{y}$

$\underset{\rightarrow}{a_c}(3sec) = -4 \times \left(\frac{2\pi}{4}\right)^2$ m/s^2 $\hat{x}$

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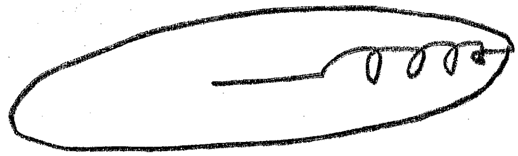
Problem 2b In 2a, the centripetal force is provided by a spring. Is the spring stretched or squeezed? Why? If the spring constant is 10^4 N/m what is the change in the length of the spring? Why? (4,7)

centripetal force $\vec{F}_c = -MR\omega^2 \hat{r}$ –

spring force

$\vec{F}_{sp} = -k \Delta r \hat{r}$



Δr must be +ive to generate $\vec{F}_c$

spring stretches.

$k \Delta r = MR\omega^2$

$\Delta r = \frac{MR\omega^2}{10^4}$ m

$= 0.5 \times 4 \times \left(\frac{2\pi}{4}\right)^2 \times \frac{1}{10^4}$ m

$= 4.9 \times 10^{-4}$ m $= 0.49$ mm

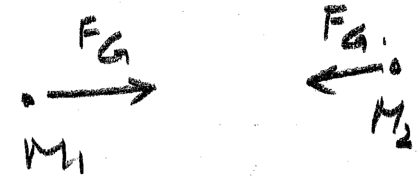
Problem 3a Newton's law of Gravitation is written as

$$\underset{\rightarrow}{F}_G = -\frac{GM_1M_2}{r^2}\hat{r}$$

Why is there a negative sign on the right side of this equation? (5)

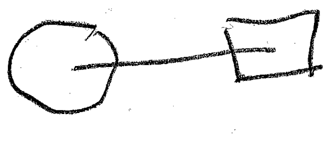
This is an attractive force. It pulls M_1 & M_2 toward one another.

Actually two forces



Problem 3b Why are astronauts in stable orbit said to be "weightless"? (Please do not say, they are in free fall.) (15)

Satellite is in stable orbit b/c Earth provides centripetal force



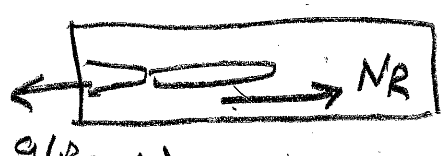
$\underset{\rightarrow}{F}_c = -M_{sat} R_{sat} \omega_{sat}^2 \hat{r} = -M \underset{\rightarrow}{a}_c \hat{r}$

and Earth gives

$\underset{\rightarrow}{F}_G = -\frac{G M_E M_{sat}}{R_{sat}^2}\hat{r} = -M_{sat}\, g(R_{sat})\hat{r}$

So $g(sat) = a_c(sat)$.

Astronaut inside satellite



So $N_R - Mg(R_{sat}) = -M a_c$.

$N_R = M[g(R_{sat}) - a_c] = 0.$

centripetal acc = grav. acc.

Problem 3c If you were located at the center of the earth, what would your weight be? (we assume that earth is a uniform solid sphere), why? (5)

Inside a solid sphere

$$\vec{F}_G = -\frac{4\pi}{3} G\rho r m \hat{r}$$

where ρ is the density

Hence at $r=0$, $F_G = 0$.

Your weight is zero at the center of Earth.

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Problem 4a Why is there a minus sign in the equation for the change in potential energy

$$\Delta P = -\underset{\rightarrow}{F}_{cons} \bullet \underset{\rightarrow}{\Delta S}$$

(5)

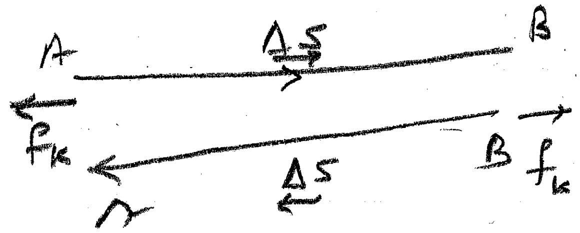
Potential Energy: work stored in system when it is assembled in presence of conservation force $\vec{F}_{cons}$

The force which performs the assembly must be equal and opposite to Fcons otherwise the mass being assembled will accelerate and acquire Kinetic Energy.

Problem 4b Why is not possible to define potential energy for the force of kinetic friction?

(5)

Friction force is not conservative. work done on a closed loop is not zero



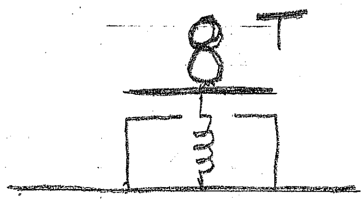
$\Delta W_{AB} = -f_k \Delta S_{AB}$

$\Delta W_{BA} = -f_k \Delta S_{BA}$

So $\Delta W_{AB} + \Delta W_{BA} = -2 f_k \Delta S_{AB}$

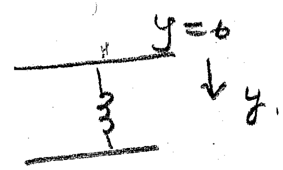
← NOT ZERO!

Problem 4c The toy T is placed on a platform as shown. You push down on the spring by 1mm and let go. If T has a mass of 10^{-3} kg and goes up to 3m before falling back what is the spring constant? Why? (neglect any friction) (15)



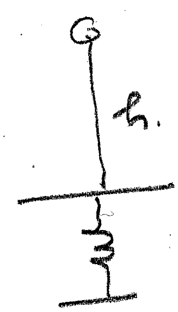
No NCF so Conservation of Mech Energy Eqn. is

$$K_f + P_f = K_i + P_i$$



$K_i = 0$,

$P_i = -Mgy + \frac{1}{2}ky^2$.



$K_f = 0$

$P_f = Mgh$.

Hence

$$Mgh = \frac{1}{2}ky^2 - Mgy$$

$$k = \frac{2Mg(h+y)}{y^2} = \frac{2 \times 10^{-3} \times 9.8 \times 3}{10^{-6}} \text{ N/m}$$

$$\simeq 60{,}000 \text{ N/m}$$

$y \ll h$.