PH 1111: PRINCIPLES OF PHYSICS: Mechanics
A TERM, 2007
KOLECI

NAME (please include last name): Solution
SECTION Number:

SAMPLE EXAM III (NOT THE ACTUAL EXAM!)

9 AM – 9:50 AM
CLOSED BOOK EXAM

PLEASE ANSWER ALL THREE QUESTIONS IN THE SPACE PROVIDED. QUESTIONS ONE AND TWO ARE WORTH 35 POINTS, EACH. QUESTION THREE IS WORTH 30 POINTS. PLEASE BE SURE TO SHOW ALL WORK AND JUSTIFY ALL YOUR ANSWERS. GRADING WILL BE BASED ON EVIDENCE OF YOUR UNDERSTANDING OF THE BASIC CONCEPTS AND PRINCIPLES— PLEASE PROVIDE THOROUGH SOLUTIONS TO THE PROBLEMS. GOOD LUCK!

Possibly Useful Information:

$A_{surface} = 4\pi r^2$ $\quad V_{sphere} = (4/3)\pi r^3$ $\quad C = 2\pi r$

$\rho = m/V$ $\quad x = x_o + v_o t + [\,(1/2)at^2]$ $\quad v = v_o + at$

$a = -9.80\ m/s^2$ $\quad v^2 = +\,v_o^{\,2} + 2a(x - x_o)$ $\quad \Sigma \mathbf{F} = m\mathbf{a}$

$a_c = v^2/r$ $\quad D = \tfrac{1}{2}(C\rho A v^2)$ $\quad W = \int \mathbf{F}\cdot\mathbf{s}$

$W = Fs\cos\theta$ $\quad K = \tfrac{1}{2}mv^2$ $\quad F_x = -kx$

$U_1 + K_1 = U_2 + K_2$ $\quad U_1 + K_1 + W_{other} = U_2 + K_2$

$\mathbf{F} = -[(\partial U/\partial x)\,\mathbf{i} + (\partial U/\partial y)\,\mathbf{j} + (\partial U/\partial z)\,\mathbf{k}]$ $\quad \mathbf{p} = m\mathbf{v}$

$\mathbf{J} = \int \mathbf{F}\,dt$ $\quad x_{cm} = (\Sigma m_i x_i)/(\Sigma m_i)$ $\quad s = r\theta$

$v = r\omega$ $\quad a = r\alpha$ $\quad K = (1/2)I\omega^2$

$I = \Sigma m_i r_i^{\,2}$ $\quad I = I_{cm} + mh^2$ $\quad I = \int r^2\,dm$

$\tau = rF\sin\theta$ $\quad \boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$ $\quad \Sigma\tau = I\alpha$

$W = \int \tau\,d\theta$ $\quad \mathbf{l} = \mathbf{r} \times \mathbf{p}$ $\quad l = I\omega$

$F = -(Gm_1 m_2)/r^2$ $\quad G = 6.67\times10^{-11} Nm^2/(kg)^2$ $\quad I_{solid\ sphere} = (2/5)mr^2$

$I_{hoop\ central\ axis} = mr^2$ $\quad I_{rod} = (1/12)ml^2$ $\quad I_{point\ mass} = mr^2$

$I_{solid\ cylinder} = \tfrac{1}{2}mr^2$ $\quad I_{spherical\ shell} = (2/3)mr^2$ $\quad l = rp\sin\theta$

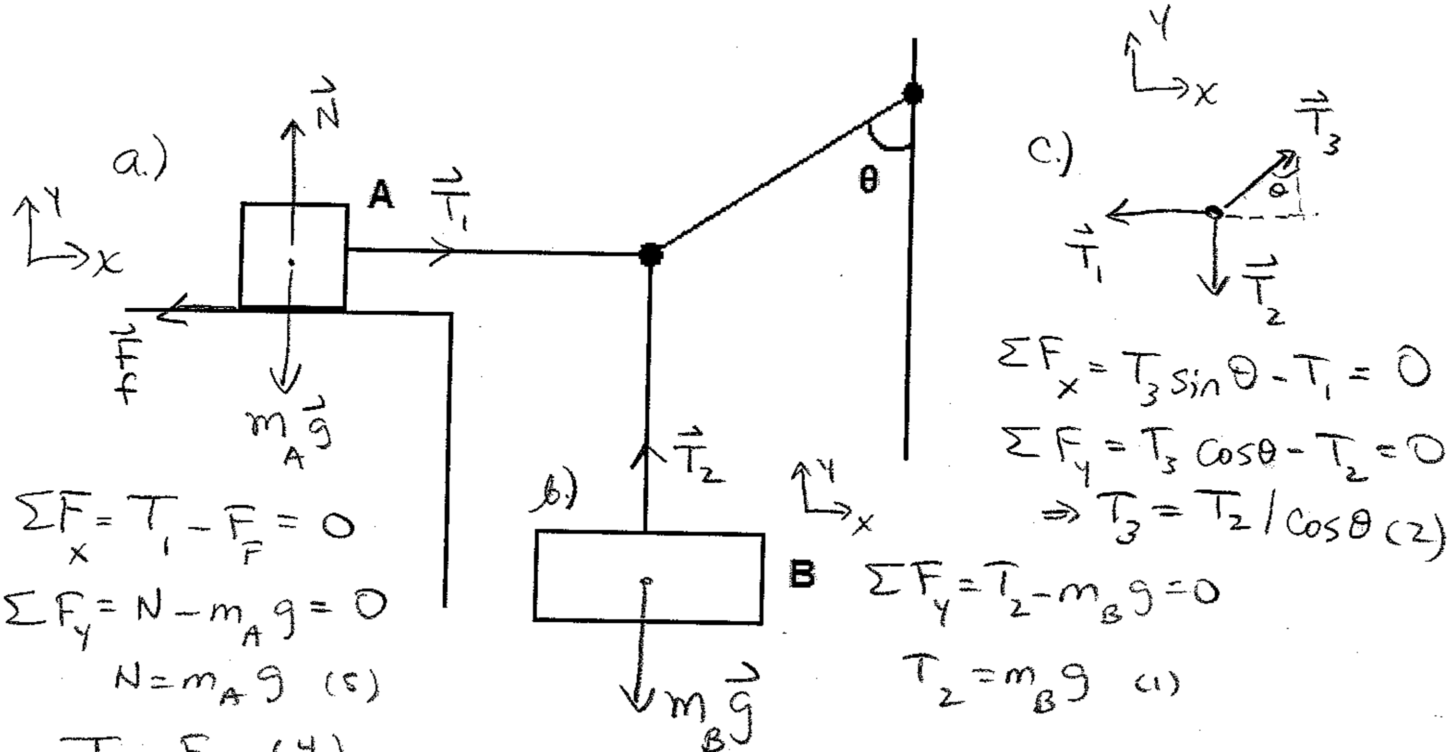
Table of Possibly Useful Integrals*

$\int x^m\,dx = [x^{m+1}/(m+1)] + C$ (note: $m \neq -1$)

*Note: These are indefinite integrals, and notice the constant of integration = C.

Problem	Score
1	
2	
3	
Net	

Problem One (*35 points*): As shown in the figure, a block A whose mass is m_A is in equilibrium, but it would slip if block B whose mass is m_B were any heavier. (a) Draw a Free Body Diagram (FBD) for block A (*5 points*). (b) Draw a FBD for Block B. (*5 points*) (c) Draw a FBD for the center knot. (*5 points*) (d) In terms of the given information, including the given θ, what is the coefficient of static friction between block A and the surface below it? (*20 points*)



a.)

$\Sigma F_x = T_1 - F_F = 0$

$\Sigma F_y = N - m_A g = 0$

$N = m_A g \quad (5)$

$T_1 = F_F \quad (4)$

b.)

$\Sigma F_y = T_2 - m_B g = 0$

$T_2 = m_B g \quad (1)$

c.)

$\Sigma F_x = T_3 \sin\theta - T_1 = 0$

$\Sigma F_y = T_3 \cos\theta - T_2 = 0$

$\Rightarrow T_3 = T_2 / \cos\theta \quad (2)$

d.) Substitute equation (2) into equation (1):

$T_3 = \dfrac{m_B g}{\cos\theta}$ from $\Sigma F_x = T_3 \sin\theta - T_1 = 0$ we get $T_1 = T_3 \sin\theta = \dfrac{m_B g}{\cos\theta} \sin\theta = m_B g \tan\theta$

From Equation 4, $F_F = T_1 = m_B g(\tan\theta)$

Since $F_F = \mu N$ and by equation (5), $N = m_A g$, we have

$$\mu = \frac{F_F}{N} = \frac{m_B g \tan\theta}{m_A g} = \boxed{\frac{m_B \tan\theta}{m_A}}$$

Problem Two, Part I (*15 points*): A certain physicist of mass M stands on the rim of a *frictionless* merry-go-round. The merry-go-round has radius R and moment of inertia I, and it is not moving. Suppose the physicist throws a rock of mass m horizontally in a direction that is tangent to the horizontal edge of the merry-go-round. The speed of the rock relative to the ground is v. (a) What is the resulting angular speed of the merry-go-round? (*10 points*)
(b) What is the resulting linear speed of the physicist? (*5 points*)

Part II (20 points): Suppose the same physicist in *Part I* (mass M) runs around the edge of a horizontal turntable mounted on a vertical frictionless axis through its center. The physicist's velocity relative to the earth has magnitude of αv m/s. The turntable is rotating in the opposite direction with angular velocity $\beta\omega$ relative to the earth. The radius of the turntable is r, and its moment of inertia about the axis of rotation is I_o. If the physicist comes to rest *relative to the turntable*, determine the final angular velocity of the system. (*20 points*)

Part I; a.) No External torques, angular momentum is Conserved. $L_0^{net} = L_f^{net}$ $L_0^{net} = mvR$

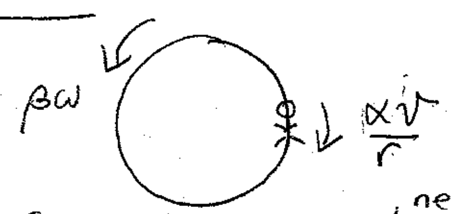
$$L_f^{net} = \underbrace{I_{MG}}_{\text{moment of Inertia of merry-go-round}}\omega + I_p\omega = I\omega + I_p\omega \qquad I_p = MR^2$$

$$L_f^{net} = I\omega + MR^2\omega \qquad L_f^{net} = (I + MR^2)\omega \qquad L_0^{net} = L_f^{net}$$

$$\Rightarrow mvR = (I + MR^2)\omega \Rightarrow \boxed{\omega = \frac{mvR}{(I + MR^2)}}$$

b.) $v = R\omega = \boxed{\dfrac{mvR^2}{(I + MR^2)}}$

Part II



Again, no external torques $L_0^{net} = L_f^{net}$

Let ccw = +
cw = −

$$L_0^{net} = \underbrace{I_0\beta\omega}_{\text{turntable}} - \underbrace{(Mr^2)\frac{\alpha v}{r}}_{\text{physicist}} = I_0\beta\omega - Mr\alpha v$$

$$L_f^{net} = I_0\omega_f + Mr^2\omega_f = (I_0 + Mr^2)\omega_f$$

$$L_f^{net} = L_0^{net} \Rightarrow (I_0 + Mr^2)\omega_f = I_0\beta\omega - Mr\alpha v \Rightarrow$$

$$\boxed{\omega_f = \frac{I_0\beta\omega - Mr\alpha v}{(I_0 + Mr^2)}}$$

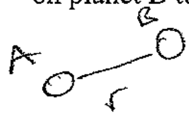
Problem Three: Conceptual Questions: Please answer the following possibly unrelated questions, using a minimum of mathematics *(5 points each, 30 points total)*.

a. What is the fundamental difference between an elastic collision and an inelastic collision?

elastic : KE conserved + Momentum conserved

inelastic : Only momentum is conserved.

b. Two planets, planet A and planet B, each of mass *M*, are separated by a distance *r*. Suppose the separation distance is now halved, what is the ratio of the <u>initial</u> gravitational force of planet A on planet B to that of the <u>final</u> gravitational force of planet A on planet B?



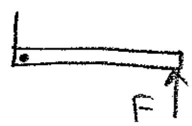
$r \Rightarrow \frac{r}{2} \Rightarrow F_G \rightarrow 4F_G$

$\frac{\text{initial } F_G}{\text{Final } F_G} = \frac{F_G}{4F_G} = \frac{1}{4}$

c. Write down the three conditions of static equilibrium.

$\Sigma F_x = 0, \Sigma F_y = 0, \Sigma \tau = 0$

d. A meter stick is hinged at the leftmost end and is free to rotate. Where should you apply a force of *F* Newtons to maximize the torque? Briefly explain.

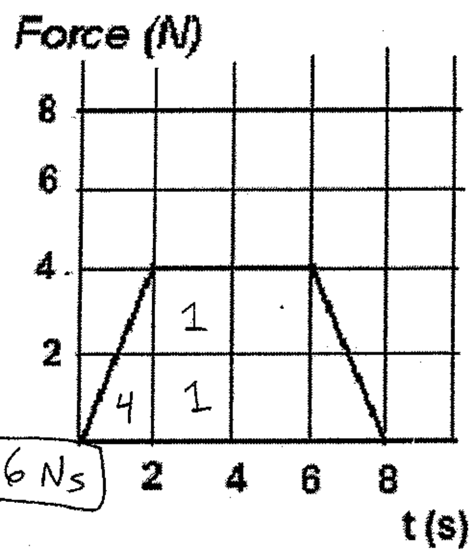


$\tau = rF\sin\theta$

τ maximized when $\theta = 90°$ and $r = 1$.

Apply perpendicular + at the end.

e. The following graph of *F vs.t*, describes the collision between two billiard balls. Determine the impulse of the object for the first four seconds (i.e. $t = 0$ m to $t = 4s$). (*2 points*) **AND** what is the change in momentum (for the first four seconds)? (*3 points*)



i.) $J = \int_0^4 F\,dt$ = area under curve $= 4+1+1 = \boxed{6\text{ Ns}}$

ii.) $J = \Delta p = 6$ Ns

f. **Assessment Questions:** A guaranteed five points for answers you provide!

- What was the <u>most</u> challenging (*aka: difficult*) topic we studied ? NA
- What was the <u>least</u> challenging (*aka: easiest*) topic we studied? NA
- What was <u>most</u> helpful, in preparation for this exam? NA
- What was <u>least</u> helpful, in preparation for this exam? NA
- What did you like most about our class? NA