NAME:

FINAL EXAM Physics 9A, Fall 2008

General Instructions/Information: This exam is closed book. Only a calculator is allowed. Please show all your work, and give units for all answers and on all graphs. Credit will only be given for complete solutions.

Possibly useful facts:
The acceleration of gravity at the earth's surface is g=9.8 m/s^2 downwards.
The universal gravitational constant is $G = 6.67 \times 10^{-11}$ in MKS units.
The mass of the earth is $M_{\rm earth} = 5.97 \times 10^{24}$ kg.
The mass of the sun is $M_{\rm sun} = 1.99 \times 10^{30}$ kg.
The radius of the earth is $r_{\rm earth} = 6.38 \times 10^{6}$ m.
The distance between the earth and the sun is $r_{\rm earth-sun} = 1.5 \times 10^{11}$ m.
Moment of inertia of uniform disk, mass m, radius r, rotating about its center: $I = \frac{1}{2}mr^2$.
Moment of inertia of uniform bar, mass m, length l, rotating about its center: $I = \frac{1}{12}ml^2$.

[20 points] 1. A 4 kg textbook is forced against a horizontal spring with force constant $k = 8000$ N/m, compressing the spring a distance 0.15 m. When released, the textbook slides on a horizontal table top with coefficient of kinetic friction $\mu_k = 0.10$. How far does the textbook move from the compressed position before coming to rest?

$E_{Spring}^{initial} = \frac{1}{2} m v_i^2 + \frac{1}{2} k x_i^2 = 0 + \frac{1}{2}(8000)(.15)^2 = 90\,J$

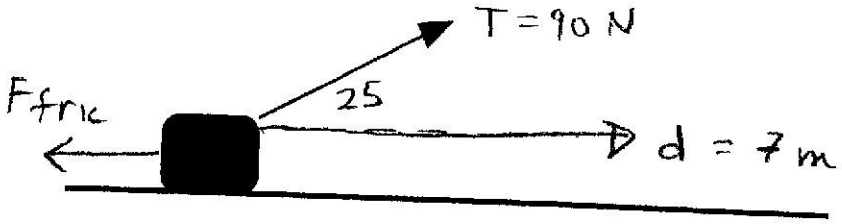
This is converted into KE. After release $x_f = 0$ and Spring PE = 0, $\therefore KE = \frac{1}{2} m v_f^2 = 90 \rightarrow v_f = 6.71$ m/s
(Problem doesn't ask for v_f)

Work done = change in KE = $0 - 90$ (↑ textbook at rest)

(↑) $F_{fric}\, d \cos 180$
$= N \mu_k d (-1)$
$= mg \mu_k d (-1)$

$d = 90 / 4(9.8)(.1) = 22.96$ m

[20 points] 2. An object of mass 8 kg is pulled by a rope with tension 90 N acting at an angle of 25 degrees from the horizontal. (See figure.) The coefficient of kinetic friction between the mass and the table on which it slides is $\mu_k = 0.25$. The object is pulled a distance 7 meters. a. What is the work done by the tension? b. What is the work done by friction? c. What is the work done by the normal force? d. If the object starts at $v_0 = 8$ m/s, what is its final velocity?



$N + 90\sin 25 - 8(9.8) = ma_y = 0$

$\therefore \quad N = 40.4\ N$

a) $W_T = Td\cos 25 = 90(7)\cos 25 = 571\ J$

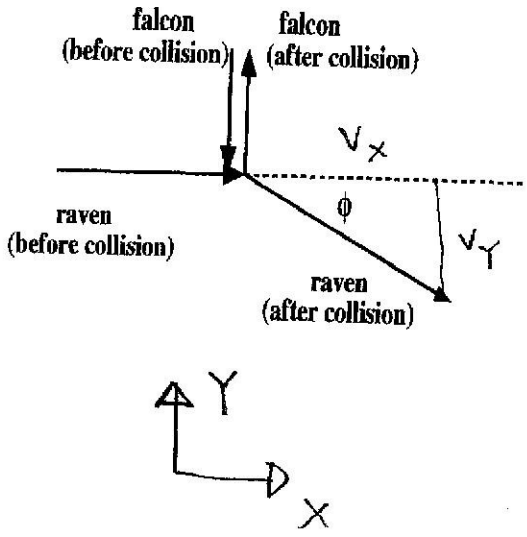
b) $W_{fric} = F_{fric}\, d\cos 180 = -\mu_k N d = -70.7\ J$

c) $W_N = Nd\cos 90 = 0$

d) $W_{TOT} = \Delta KE \qquad 571 - 70.7 + 0 = \frac{1}{2}8v_f^2 - \frac{1}{2}8(8)^2$

$\rightarrow \quad v_f = 13.75\ m/s$

[20 points] 3. To protect their young in the nest, peregrine falcons will fly into birds of prey such as ravens at high speed. In one such episode, a 0.60 kg falcon flying at 20 m/s hit a 1.50 kg raven flying at 9.0 m/s. The falcon hit the raven at right angles to its original path, and bounced back at 5.0 m/s. (a) By what angle ϕ did the falcon change the raven's direction of motion? (b) What was the raven's speed right after the collision?



Before: F (.6)(20), R (1.5)(9) — After: F (.6)(5), R (1.5)v_x

$x: \quad (.6)(0) + (1.5)(9) = (.6)(0) + (1.5)v_x$

$y: \quad (.6)(-20) + 1.5(0) = (.6)(5) + (1.5)v_y$

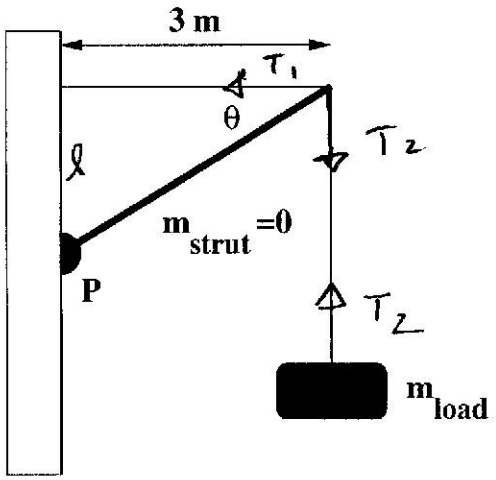
$v_x = 9\ m/s \quad \sim 5$

$v_y = -10\ m/s \quad \sim 5$

$\phi = \tan^{-1} 10/9 = 48^\circ \quad \sim 5$

$|v| = \sqrt{10^2 + 9^2} = 13.45\ m/s \quad \sim 5$

[25 points] 4. A massless strut is supported by a very light horizontal cable and a pivot P. A load of mass $m_{\text{load}} = 80$ kg is suspended from the end of the strut by another very light cable. The angle $\theta = 40°$. Find the tension in each cable and the magnitude and direction of the force exerted on the strut by the pivot. (See figure.)



From $\Sigma F_y = 0$ for the load:

$T_2 - 80(9.8) = 0$

$T_2 = 784$ N

From $\Sigma F_x = 0$ for strut

$F_p^x - T_1 = 0$

From $\Sigma F_y = 0$ for strut

$F_p^y - T_2 = 0 \rightarrow F_p^y = 784$ N

$\tan 40 = \ell/3$

From $\Sigma \tau = 0$ for strut (about point P)

$-T_2(3) + T_1(3\tan 40) = 0$

$T_1 = T_2/\tan 40 = 934$ N

$T_1 = 934$ N

$T_2 = 784$ N

$|F_p| = \sqrt{(F_p^x)^2 + (F_p^y)^2}$

$= 1219$ N

$F_p^x = 934$ N

$F_p^y = 784$ N

$\vec{F}_p$ makes angle $\tan^{-1}\frac{784}{934} = 40°$ with horiz

[20 points] 5. For a satellite to be in a circular orbit 780 km above the surface of the earth, (a) what orbital speed must it be given; and (b) what is the period of the orbit (in hours)?

$$\frac{GM_{earth} m_{sat}}{(R_e + 7.8\cdot 10^5)^2} = \frac{m_{sat} v^2}{(R_e + 7.8\cdot 10^5)}$$

$R_e \approx 6.38\cdot 10^6$

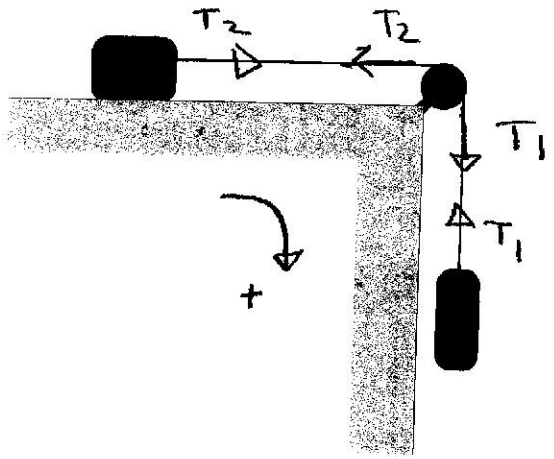
$v = 7458$ m/s

$v = \sqrt{\frac{GM_\oplus}{(6.38\times 10^6 + 7.8\times 10^5\,\text{m})}}$

$= \sqrt{\frac{GM_\oplus}{7.16\times 10^6\,\text{m}}}$

$T = \frac{2\pi(R_e + 7.8\cdot 10^5)}{v} = 6032$ s $= 1.68$ hrs

[30 points] 6. A 20 kg box resting on a horizontal, frictionless surface is attached to a 8 kg weight by a thin, light wire that passes over a frictionless pulley. (See Figure.) The pulley has the shape of a uniform disk of mass 4 kg and radius 0.3 m. After the system is released, find (a) the acceleration of the box; and (b) the tension in the wire on both sides of the pulley.



lower mass: $\sum F = ma$

$$-T_1 + 8(9.8) = 8a$$

pulley: $\tau = I\alpha$

$$T_1(.3) - T_2(.3) = \tfrac{1}{2}(4)(.3)^2\alpha \qquad (.3)\alpha = a$$

upper mass: $F = ma$

$$T_2 = 20a$$

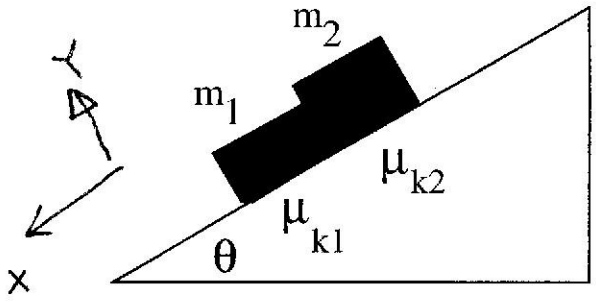
$$78.4 - T_1 = 8a$$
$$T_1 - T_2 = 2a$$
$$T_2 = 20a$$

$78.4 = 30a \rightarrow a = 2.45\ m/s$

$T_2 = 20a = 49\ N$

$T_1 = T_2 + 2a = 53.9\ N$

[25 points] 7. Two blocks m_1=5 kg and m_2=8 kg are sliding down an inclined plane tilted at an angle $\theta = 30°$ as shown in the figure. (a) Compute the acceleration of the masses when the coefficients of kinetic friction are $\mu_{k1} = 0.25$ between m_1 and the plane and $\mu_{k2} = 0.15$ between m_2 and the plane. What is the force (magnitude and direction) of block 2 on block 1? (b) What is the force (magnitude and direction) of block 2 on block 1 if the coefficients of friction are reversed, $\mu_{k1} = 0.15$ and $\mu_{k2} = 0.25$? To receive credit, you must *explain* your answer clearly.



We will use facts that
$N = mg\cos\theta$
and component of gravity down plane
is $mg\sin\theta$

m_1: $5(9.8)\sin 30 - 5(9.8)\cos 30(.25) + F_{2on1} = 5a$

m_2: $8(98)\sin 30 - 8(98)\cos 30(.15) + F_{1on2} = 8a$

$F_{1on2} = -F_{2on1}$

adding $24.5 - 10.6 + 39.2 - 10.2 = 13a$

$a = 3.3\ m/s$

$F_{2on1} = 5(3.3) - 24.5 + 10.6 = 2.6\ N$

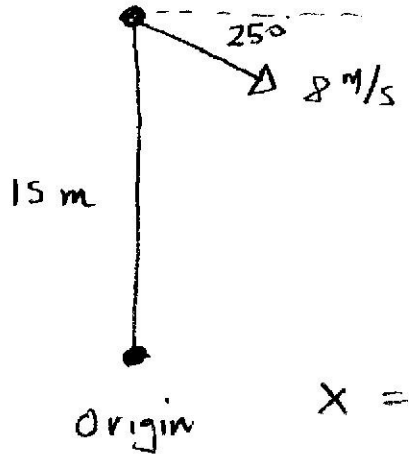
(down the plane / + direction / down)

If μ_K interchanged, m_1 accelerates faster than m_2.
They lose contact and $F_{2on1} = 0$.

Draw accurate

[20 points] 8. A snowball rolls off a barn roof that slopes downward at an angle of 25°. The edge of the roof is 15 m above the ground, and the snowball has a speed of 8 m/s as it rolls off the roof. (a) How far from the barn does the snowball strike the ground if it doesn't hit anything else while falling? (b) ~~Sketch~~ $x-t, y-t, v_x-t$, and v_y-t graphs for the motion; (c) A man 2 m tall is standing 3 m from the edge of the barn. Will he be hit by the snowball?

label with appropriate numbers



$$Y = Y_0 + v_{Y0}t + \tfrac{1}{2}a_y t^2$$

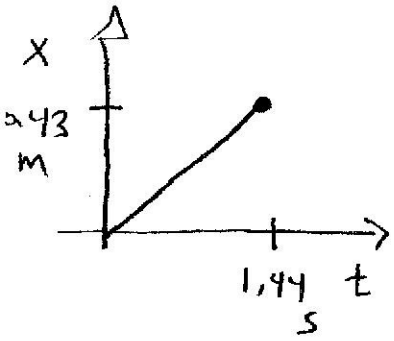
$$0 = 15 - 8\sin 25\, t + \tfrac{1}{2}(-9.8)t^2$$

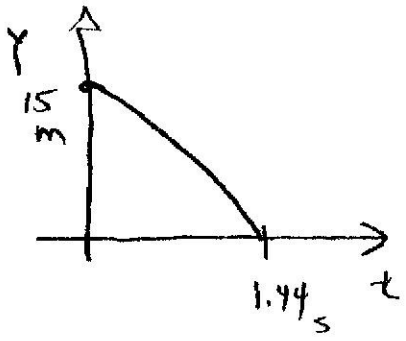
$$0 = 15 - 3.38t - 4.9t^2$$

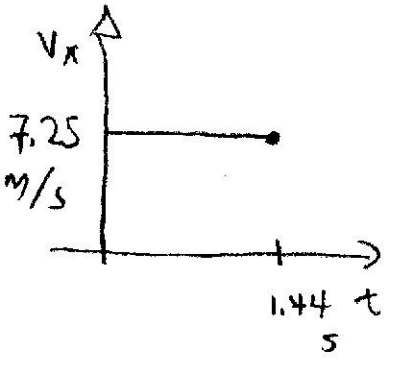
$$t = 1.44 \text{ sec}$$

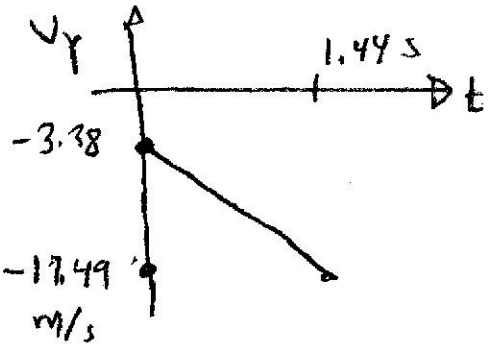
$$X = X_0 + v_{x0}t + \tfrac{1}{2}a_x t^2$$

$$= 0 + (8\cos 25)(1.44) + 0 = 10.43 \text{ m}$$









$X = 3$ when $t = 3/8\cos 25 = .1414$ sec

at that time $y = 15 - 3.38(.1414) - 4.9(.1414)^2 = 12.76$

Man is not hit