P113 University of Rochester NAME Soln key - Slm
S. Manly Fall 2004

Exam 2 (October 28, 2004)

Please read the problems carefully and answer them in the space provided. Write on the back of the page, if necessary. Show all your work. Partial credit will be given unless specified otherwise.

Problem 1 (10 pts, justify):

Two unequal masses hang from either end of a massless cord that passes over a frictionless pulley. Which of the following is true about the gravitational potential energy (U) and the kinetic energy (K) of the system after the masses are released from rest?

a) $\Delta U<0$ and $\Delta K>0$.
b) $\Delta U=0$ and $\Delta K>0$.
c) $\Delta U<0$ and $\Delta K=0$.
d) $\Delta U=0$ and $\Delta K=0$.
e) $\Delta U>0$ and $\Delta K<0$.

$\Delta PE = mgx$ (+)

$\Delta PE = Mgx$ (−)

$KE_{init} = 0$

$KE_{final} > 0$

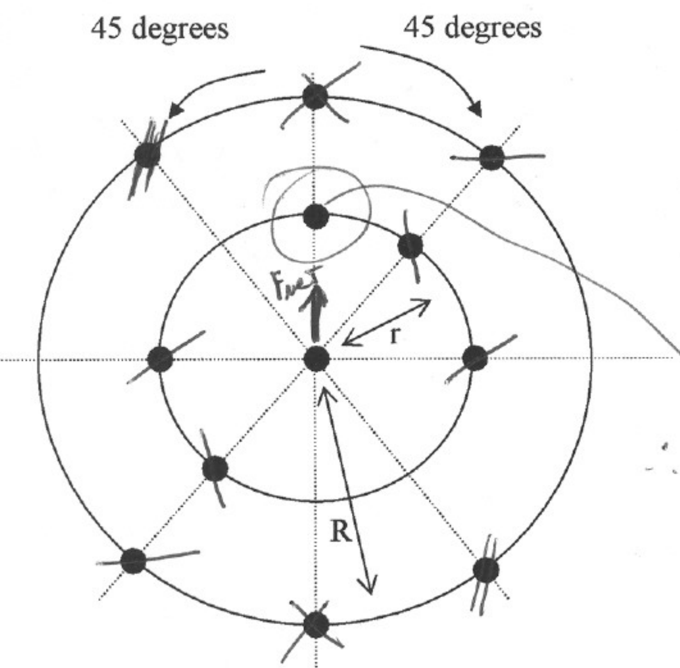
$\Delta KE > 0$

Total ΔPE is negative

$M > m$

Problem 2 (10 pts, justify):

A central particle is surrounded by two circular rings of particle, at radii r and R, with R>r. All the particles have mass m. What are the magnitude and direction of the net gravitational force on the central particle due to the particles in the rings? Give your answer in terms of m, r and R and indicate the direction on the sketch.



Vector Nature of Attractive force Means Masses that are Symmetrically placed w/ respect to center will have forces that cancel out

Leaves only

∴ Net grav force on central Mass is

$$\frac{Gm^2}{r^2} \text{ up}$$

1)	/10
2)	/12
3)	/13
4)	/10
5)	/13
6)	/12
7)	/15
8)	/15
tot	/100

Problem 3 (10 pts, justify):

A golf ball and a ping pong ball are dropped in a vacuum chamber on the surface of the Earth. When the have fallen halfway to the floor, they have the same

a) speed — only depends on acceleration
b) potential energy
c) kinetic energy All depend on mass
d) momentum
e) speed, potential energy, kinetic energy, and momentum.

Problem 4 (15 pts):

A cannon is situated on a railcar as shown in the sketch below. The cannon fires a shell (or cannonball) with a mass of 50 kg with a velocity of 400 m/s at an angle of 60 degrees with the horizontal. Assume the cannon and railcar combination has a mass of 11000 kg both before and after the cannon is fired. What is the recoil velocity of the railcar+cannon immediately after it is fired. Ignore friction and air resistance in this problem.

$\vec{p} = m\vec{v}$

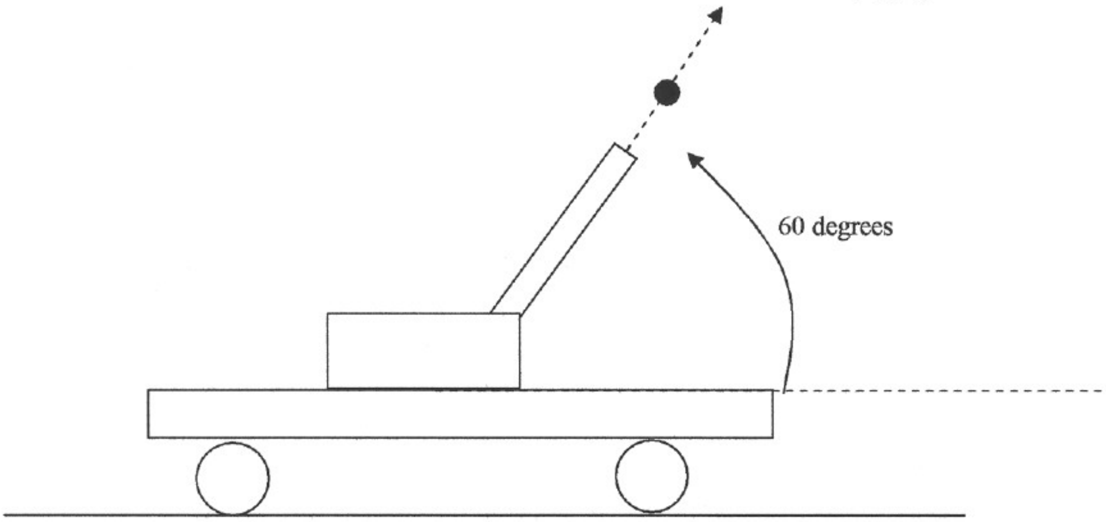
$P_x = P\cos 60$

$$\sum_x \vec{P}_{init} = \sum_x P_{final}$$

$$0 = m_{shell} V_{shell} \cos 60 - M_{rail} V_{rail}$$

$$(11000) V_{rail} = (50)(400) \cos 60$$

$$V_{rail} = 0.91 \ m/s \text{ to left}$$



Problem 5 (12 pts):

Imagine that you go home for Thanksgiving break and one evening during dinner your Mom confides that she is in the midst of a mid-life crisis. She has decided to pursue the study of physics, which is a passion she has always held deeply but put off formal study because she had kids. After dinner she pulls you aside and says, "Honeymunchkins, since we are both studying physics right now, I wanted to ask you a question. Something has been confusing me. In the book on gravitation I've been reading recently, they keep using the letter `g' for different things and I am confused."

Write a brief note that would help your mother understand the different meanings and the use of the symbols "G", "g", and "$\vec{g}$" in physics and this course.

Mom! I'm thrilled to see your interest in physics. I know we will have so much fun through the years through engaging in stimulating and exciting conversations about physics. This is <u>so</u> wonderful.

As for your question...

"G" is a CONSTANT that sets the strength of the gravitational force. Gravity is an attractive force that is quantified by the relation

$$\vec{F} = -\frac{G M_1 M_2}{r^2}\hat{r}.$$

G has units of $\frac{N \cdot m^2}{kg^2}$ so that the equation makes sense. G is determined by experiment and is a universal constant that tells us how strong gravitation is relative to other forces.

"g" is the (magnitude of the) acceleration due to gravity near the surface of the earth.

$$|\vec{F}| = \frac{G M_E m}{R_E^2} = mg \quad \text{where } g \equiv \frac{G M_E}{R_E^2} = 9.8\ m/s^2.$$

"$\vec{g}$" might be interpreted as the vector acceleration due to gravity near the surface of the Earth. However, $\vec{g}$ is usually reserved ~~for~~ as the symbol for the gravitational "field" or Force per unit mass at a given point. The force on a mass at a given point is the mass times the gravitational field, $\vec{g}$. $\vec{F} = m\vec{g}$. When used in this way "$\vec{g}$" has nothing to do with (necessarily) being near the surface of the Earth. Hope that helps Mom!!

Love, your Honeymunchkins

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Problem 6 (12 pts):

After an argument during graduation weekend, Billy-Joe Benson climbs the flagpole at the base of the quad in order to search for beloved girlfriend in the crowd. After he spots her, he slides down the pole in a hurry to chase her and make up. Billy-Joe has a mass of 70 kg and slides 12 meters down the pole. He is moving at a speed of 3 m/s just before hitting the ground.

How much work is done by the force of gravity during Billy-Joe's slide down the pole?

F_g Work done by gravity $= mgh = (70)(9.8)(12) = 8232\ J$

h

What is the average frictional force acting on Billy-Joe during his descent?

$E_{START} = E_{end}$

$\hookrightarrow mgh = KE + W_{FRICT}$

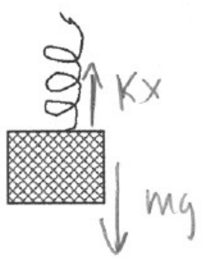
$8232\ J. = \frac{1}{2}(70)(3)^2 + W_{Fric}$

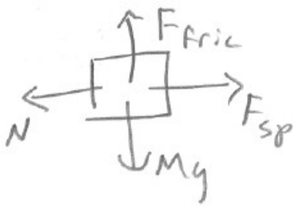
$W_{Fric} = 7917\ J = (\text{Ave Frict force})\, 12$

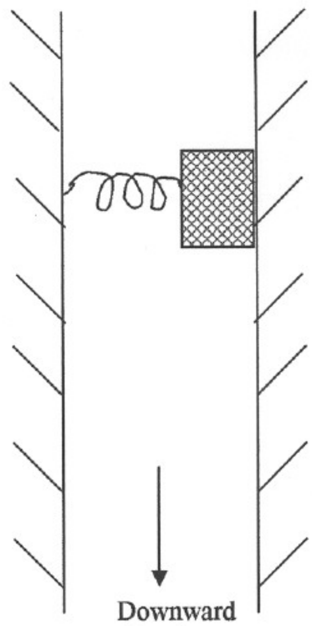
$\text{Ave } F_{Friction} = 660\ N$

Problem 7 (15 pts):

Terrance decides to hide his nosey wife's Christmas present in the chimney by using a spring to shove it against one wall, as shown in the right-hand sketch below. First, Terrance finds a spring that he thinks will work. The extension of the chosen spring is 0.3 m beyond its natural length when the Christmas present (of mass 1.5 kg) is hung (motionlessly) from it as shown in the left-hand sketch below. When the present is secured in the chimney (as shown in the right-hand sketch), the spring is compressed by 0.2 m from its natural length. What is the minimum coefficient of static friction between the present and the chimney wall that would allow Terrance to hide the present in this fashion?







$Mg - Kx = 0$

$K = \frac{Mg}{x}$

$= \frac{(1.5)(9.8)}{0.3} = 49\ \frac{N}{M}$

$\Sigma F_y = 0$

$F_{Fric} - Mg = 0$

$N = F_{sp} = 0.2\,K$

$\mu_s N = Mg$

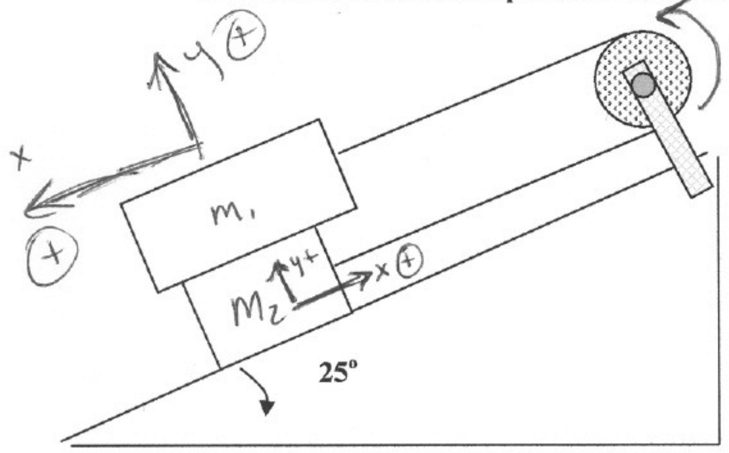
$(0.2)(49)\mu_s = (1.5)(9.8)$

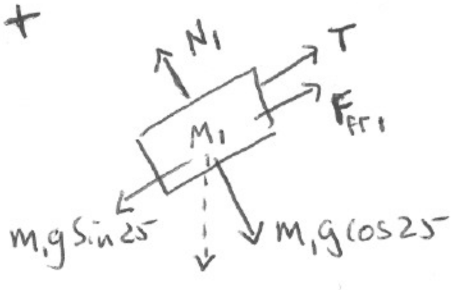
$\mu_s = 1.5$

Problem 8 (16 pts):

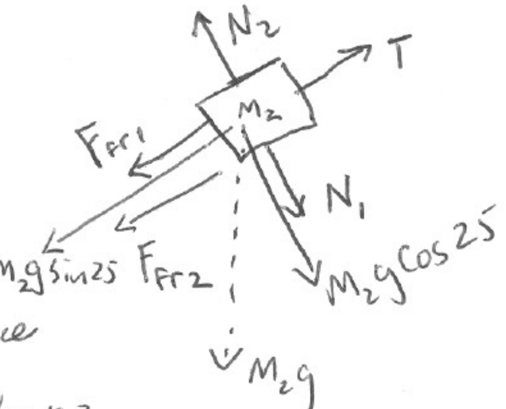
0.02

The figure below shows a 10 kg block (mass m_1) sliding on a 5 kg block (mass m_2) supported on an inclined plane. ~~The coefficient of static friction, μ_s, between the two blocks, as well as the lower block and the inclined plane is 0.3.~~ The coefficient of kinetic friction, μ_k, between the two blocks, as well as the lower block and the inclined plane is ~~0.2~~. Assume the blocks start from rest in the configuration shown below. Find the acceleration of each block and the tension in the rope that connects the two blocks in the moments after the blocks are released. Assume the rope is massless and that the pulley is massless and frictionless.





FBD's



$F_{Fr1} \equiv$ Friction between block surfaces

$F_{Fr2} \equiv$ Friction between lower block and inclined plane surface

N_1 = Normal force between block 1 and block 2

N_2 = Normal force between block 2 and plane

Mass 1: $\sum F_y = 0 = N_1 - M_1 g\cos 25 \Rightarrow N_1 = M_1 g \cos 25$

$\sum F_x = m_1 a = m_1 g \sin 25 - T - F_{Fr1} = M_1 g \sin 25 - T - \mu_k m_1 g \cos 25 = M_1 a$

$41 - T - 1.78 = 10a$

$39.2 - T = 10a$

Mass 2: $\sum F_y = 0 = N_2 - N_1 - M_2 g \cos 25$

$N_2 = (M_1 + M_2) g \cos 25$

2 eqns
2 unknowns
$\Rightarrow$ solve for T, a

$\sum F_x = m_2 a = T - F_{Fr1} - m_2 g \sin 25 - F_{Fr2}$

$m_2 a = T - \mu_k m_1 g \cos 25 - m_2 g \sin 25 - (M_1 + M_2)\mu_k g \cos 25$

$m_2 a = T - \mu_k g \cos 25 (2M_1 + M_2) - m_2 g \sin 25$

$5a = T - 4.44 - 20.7$

$5a = T - ~~65.1~~\ 25.1$

$a = 0.94\ m/s^2$

$T = 29.8\ N$