P113 University of Rochester
S. Manly Fall 2000

NAME Soln key – Slm

Exam 2 (October 19, 2000)

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.

Problem 1 (25 pts):

In an M-TV spring break special airing from Cancun, three "beautiful people" contestants play tug of war on an ice skating rink. Each contestant pulls on a (massless) rope tied to a full beer keg which weighs 60 kg. The first contestant pulls with a constant force of 15 newtons due north. The second pulls with a constant force of 10 newtons due east. The third pulls with a constant force of unknown magnitude at an angle of 30 degrees south of west. The keg slides across the ice without friction. The students have shoes that enable them to pull on the ropes without sliding. At the end of the competition, the keg was measured to have moved 5 meters due west. You can assume the direction and magnitude of the forces on the keg are constant throughout the motion.

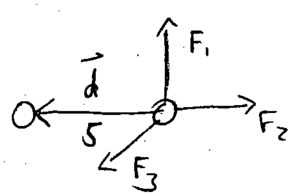
(a) What force does the third contestant apply to the keg? 30 newtons 30 degrees south of west

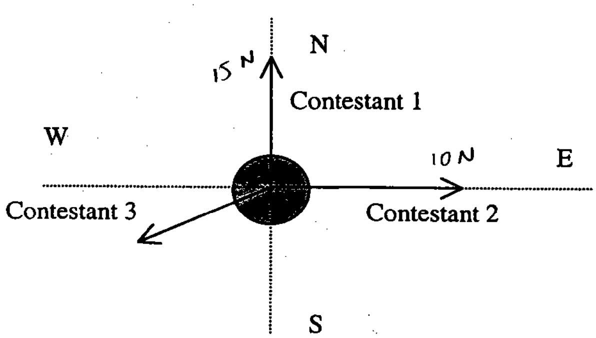
(b) How much work is done on the keg by contestant one? No work, $\vec{F}_1 \cdot \vec{d} = 0$

(c) How much work is done on the keg by contestant two? $W_2 = \vec{F}_2 \cdot \vec{d} = -(10)(5) = -50$ J

(d) How much work is done on the keg by contestant three? $W_3 = \vec{F}_3 \cdot \vec{d} = 30\cos(30)(5) = 130$ J

(e) What is the net work is done on the keg? $130 - 50 + 0 = 80$ J

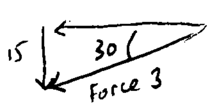




$\Sigma F_y = 0$ because keg moves west

$\therefore \quad 15\text{ N} = |\vec{F}_3| \sin 30$

$|\vec{F}_3| = \frac{15}{\sin 30}$ newtons



$|\vec{F}_3| = 30$ newtons

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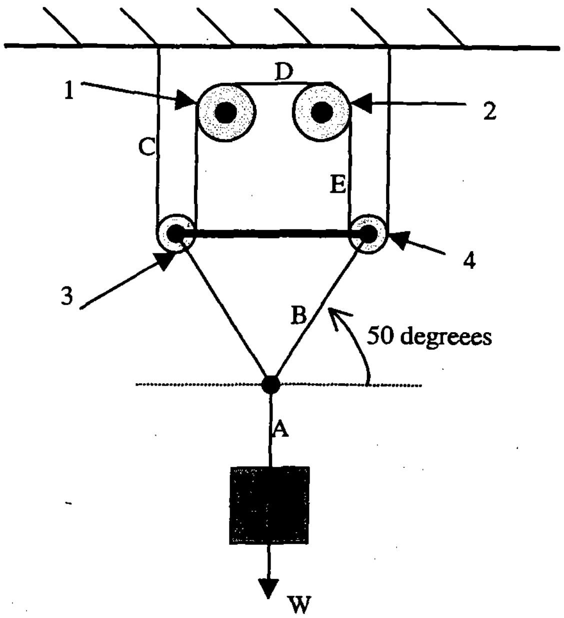
Problem 2 (20 pts):

Joe Sevenio, worldly New York cabbie, likes playing with pulleys in his spare time. He decided to hang a mass of weight W on the configuration of massless and frictionless strings and pulleys pictured below. Pulleys 1 and 2 are fixed to the wall. They rotate freely but cannot move horizontally or vertically. Pulleys 3 and 4 are attached by a massless rigid rod. Other than that they are free to move horizontally and vertically. All the strings and pulleys lie in a vertical plane (which is the plane of the paper in the drawing). In terms of W, what is the tension in the string at each point A, B, C, D, and E as shown in the figure below?



Tension at

Point A = W

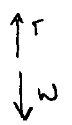
Point B = $W/(2\sin 50)$

Point C = $W/4$

Point D = $W/4$

Point E = $W/4$

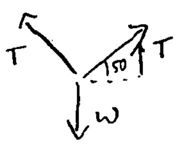
PT A:



$\sum F_y = 0 = T - W$

$T = W$

PT B:



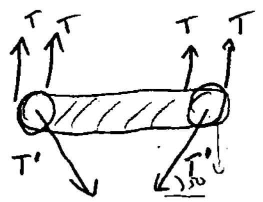
$\sum F_y = 0 = 2T\sin 50 - W$

$W = 2T\sin 50$

$T = W/2\sin 50$

PT C, D, E: All one string

Tension is the same at Points C, D, E.



T = Tension at pts C, D, E

T' = Tension at pt B

$\sum F_y = 0 = 4T - 2T'\sin 50$

$4T = 2\frac{W}{2\sin 50}\sin 50 = W$

$T = W/4$

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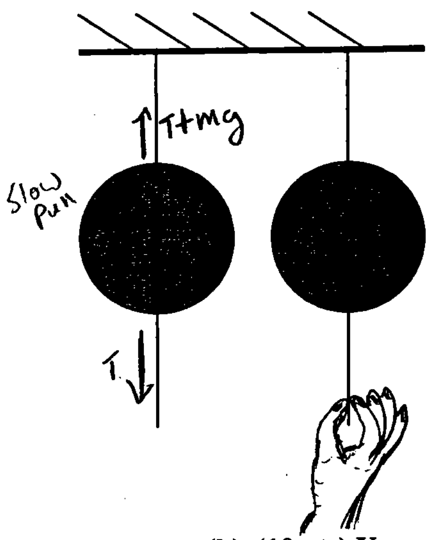
1)	/25
2)	/20
3)	/30
4)	/25
5)	/20
tot	/120

Problem 3 (30 pts):

(a) (10 pts) In a physics class demo, the wonderful professor asks the class to consider two identical balls of mass M attached to identical strings above and below as shown in the figure below. The (still wonderful) professor asks two diligent, hard-working students (who happen to love physics class) to come up and pull on the bottom strings until something breaks. The first student pulls on bottom string of the left ball with slowly increasing force. Finally, the top string breaks. The second student yanks hard on the bottom string on the right ball and finds that the bottom string breaks. After repeating the experiment several times, the class arrives at the general conclusion that pulling on the bottom string with slowly increasing force causes the top string to break and yanking hard on the bottom string causes the bottom string to break. Please explain why this is to be expected based on your knowledge of Newton's laws?



For the slow pull the tension in the top string is equal to the tension in the bottom string plus the weight of the ball. Since the tension in the top string is greater that string will break. For the yank the tension in the bottom string will cause the ball (mass) to accelerate. However, because of the mass of the ball the acceleration is finite ($F = Ma$). This leads to a time lag before the top string experiences the tension that the bottom string sees. Therefore the bottom string snaps first (Inertia).

(b) (10 pts) Your roomie locks you out of your dorm room. In frustration, you push very hard against the door for a few minutes. Unfortunately, the door does not budge. Have you done any work? Explain.

No work $\int \vec{F} \cdot d\vec{s} = 0$ because $d\vec{s} = 0$

(c) (10 pts) Explain why wrecks involving fast automobiles usually occur in or around curves in the road.

The transverse force of friction holds the car on the road and accelerates the car transversely in a curve. If the radius of curvature is such that $m\frac{v^2}{R} > F_{friction}$, the frictional force will be insufficient to hold the car in the curve $\Rightarrow$ the car slides off the road and wrecks. For motion in a straight line, the friction does not play a role.

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Problem 4 (25 pts):

Arlene Bond (the sister of James, of course) has a job as a human cannonball with the circus. She likes the job. In fact, she gets a bang out if it. At any rate, Arlene made me promise not to tell you her weight. However, her mass is 55 kg. The cannon consists of a large spring (with constant k=1000 N/m) inside a cylinder. Before Arlene is "shot" out of the cannon, the spring is compressed 3 meters. She gets inside the cannon and sits on the compressed spring. She is shot out of the cannon as the spring released and allowed to uncoil.

Suppose Arlene is shot out of the cannon at an angle of 50 degrees with the floor (upward, of course).

(a) What is Arlene's kinetic energy when she leaves the cannon (assuming the end of the uncompressed spring is even with the top of the cannon)?

$$\frac{1}{2}mv^2 = KE = \Delta PE_{spring} + \Delta PE_{grav} = \frac{1}{2}kx^2 - mgh$$

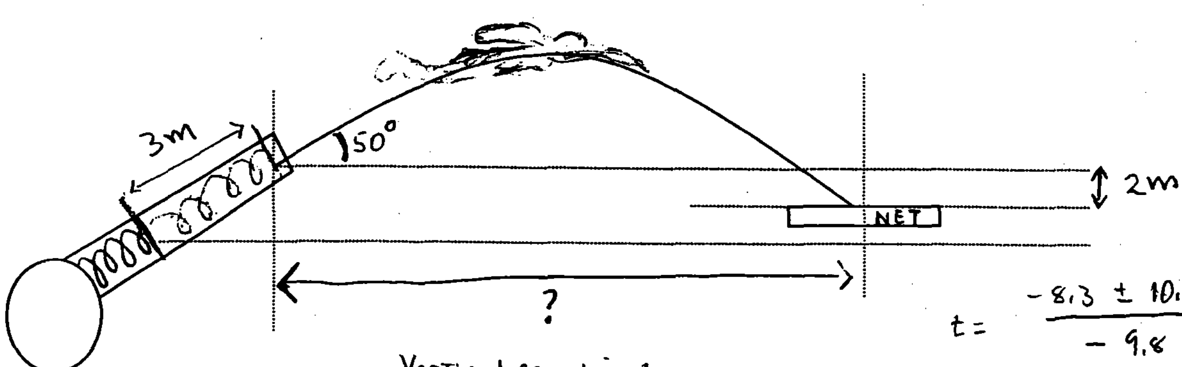
$$\frac{1}{2}mv^2 = KE = \frac{1}{2}(1000)(3)^2 - (55)(9.8)(3)\sin 50 =$$

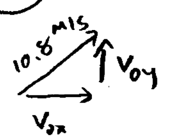
$$KE = 4500\ J - 1288\ J = \boxed{3262\ J}$$

(b) What is her velocity as she leaves the top of the cannon?

$$\frac{1}{2}mv^2 = 3262\ J \qquad v = \sqrt{\frac{(3262)(2)}{55}} = \boxed{10.8\ m/s}$$

(c) Suppose the net that catches Arlene is at a height 2 meters below the top of the cannon. How far from tip of the cannon should the net be placed (Horizontally) ?





$V_{ox} = V_0 \cos 50° = 6.9\ m/s$

$V_{oy} = V_0 \sin 50° = 8.3\ m/s$

Horizontal Eqn:

distance = V_{ox}(time of flight)

Vertical equation:

$$y = y_0 + V_{oy}t + \frac{1}{2}at^2$$

$$-2 = 0 + 8.3t - \frac{1}{2}(9.8)t^2$$

$$0 = 2 + 8.3t - 4.9t^2$$

$$t = \frac{-b \pm \sqrt{b^2+4ac}}{2a}$$

$$t = \frac{-8.3 \pm \sqrt{(8.3)^2+(4)(4.9)(2)}}{-2(4.9)}$$

$$t = \frac{-8.3 \pm 10.4}{-9.8} = \begin{matrix} +1.9\ s \\ -0.2\ s \end{matrix}$$

ignore negative root

Horizontal distance

$= (6.9\ m/s)(1.9\ s)$

$\boxed{= 13.1 \text{ meters to net}}$

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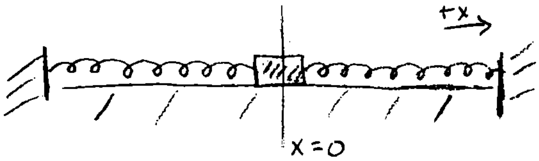
Problem 5 (20 pts)::

Consider a mass sandwiched between two collinear springs that are arranged along the x-axis such that there is no force on the mass when it is centered at x=0. Assume the mass slides on a frictionless surface and that both springs have a spring constant k.

Horizontal

(a) What is the force on the mass as a function of x and k (for reasonable x that is smaller than the spring length)?



$$F(x) = \underbrace{-kx}_{\text{Spring 1}} \underbrace{-kx}_{\text{Spring 2}} = -2kx$$

at ⊖ x Force is in Positive direction $F = -\frac{dU}{dx}$ $\therefore \frac{dU}{dx}$ is ⊖

at ⊕ x Force is in negative direction $F = -\frac{dU}{dx}$ $\therefore \frac{dU}{dx}$ is ⊕

consistency checks

(b) Qualitatively graph the potential energy function of the system as a function of x.

eqn above is like a single spring w/ $k = 2k$

$\therefore PE = \frac{1}{2}kx^2 = \frac{1}{2}2kx^2 = kx^2$