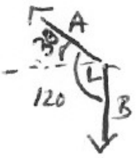
P113 University of Rochester NAME Soln key - Sly
S. Manly Fall 2003

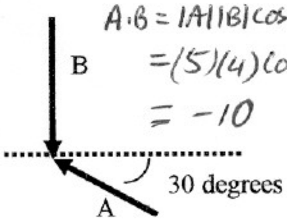
Exam 2 (November 13, 2003)

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.

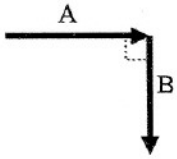
Problem 1 (12 pts~~, no partial credit~~):

Consider the two vectors A and B. Vector A has a magnitude of 5 units. Vector B has a magnitude of 4 units. Indicate on each sketch below the value of the vector dot (scalar) product, A•B.

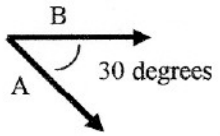




$A \cdot B = |A||B|\cos\theta$
$= (5)(4)\cos(120)$
$= -10$



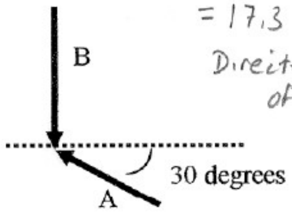
$A \cdot B = 0$

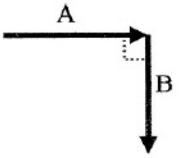


$(A \cdot B) = |A||B|\cos 30$
$= (5)(4)\cos 30 = 17.3$

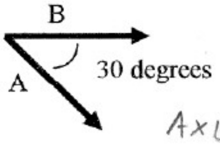
Consider the two vectors A and B. Vector A has a magnitude of 5 units. Vector B has a magnitude of 4 units. Indicate on each sketch below the value and direction of the vector cross product, A×B.

$A \times B = |A||B|\sin(120)$
$= 17.3$ units
Directed out of paper





$A \times B = |A||B|\sin 90$
$= 20$ units
directed into paper



$A \times B = |A||B|\sin 30$
$= 10$ units
directed out of paper

Problem 2 (8 pts, no partial credit):

Seeking enlightenment and the keys to physics nirvana, Alice ascends a mountain via a short, steep trail. Bob ascends the same mountain using the ski lift access road, which is a long, winding road with a gentle slope. They meet at the top of the mountain and meditate before doing the week's problem set. Which of the following statements is true?

- **a) Alice does more work against the force of gravity than Bob.**
- **b) Bob does more work against the force of gravity than Alice.**
- **c) Alice and Bob each do the same amount of work against the force of gravity during the ascent.**
- **d) To compare the work done against gravity by the two knowledge–starved students we must know the lengths of the paths they each took.**
- **e) To compare the work done against gravity by the two knowledge-starved students we must know the height of the mountain.**

No requirement for justification on this problem.
However the justification is that gravitation is a conservative force. The potential Energy of Alice and Bob depends only on the end Position. It is path independent.

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1)	/12
2)	/8
3)	/10
4)	/15
5)	/18
6)	/17
7)	/20
tot	/100

Problem 3 (10 pts):

Two objects are sliding initially at the same speed across a wooden surface. The coefficient of kinetic friction between the first object and the surface is twice that between the second object and the surface. The distance traveled by the first object before it stops is S. The distance traveled by the second object is

- **a) S**
- **b) 4S**
- **c) Impossible to determine without knowing the masses involved**
- **d) S/2**
- **e) 2S**

Show your work/reasoning

use work-Energy

$\frac{1}{2}mv^2 = \mu_1 m_1 g s_1$ $\Rightarrow 1 = \frac{\mu_1 s_1}{\mu_2 s_2}$

$\frac{1}{2}Mv^2 = \mu_2 M_2 g S_2$ $1 = \frac{2\mu_2 s_1}{\mu_2 s_2}$

$s_2 = 2s_1$

Think abt Acceleration

$m_1 a_1 = \mu_1 M_1 g$ $\quad m_2 a_2 = \mu_2 M_2 g$

$a_1 = \mu_1 g$ $\quad a_2 = \mu_2 g$

$\frac{a_1}{a_2} = \frac{\mu_1}{\mu_2} = \frac{2\mu_2}{\mu_2} = 2 \Rightarrow a_1 = 2a_2$

or $a_2 = a_1/2$

Problem 4 (15 pts):

When a good tennis player serves the ball, they strike the ball with the racquet extended as far up in the air as they can reach. The coach will tell them to toss the ball high and then stretch high as they strike the ball. Briefly explain why this is so. ***(Briefly discuss referring to physics concepts we have studied recently. Feel free to make and refer to sketches as needed.)***

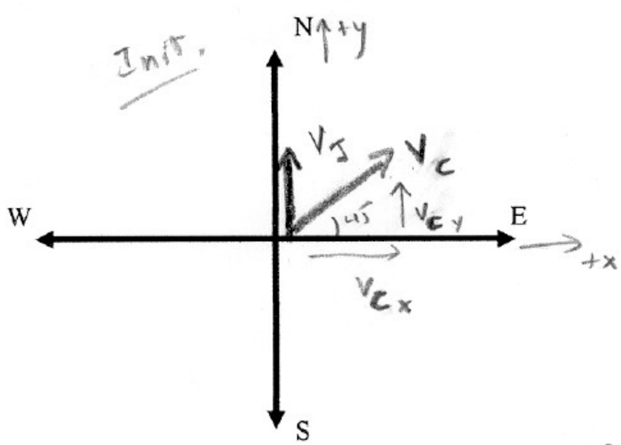
The Primary reason for this (that is related to our studies) is that the Arm and raquet move with a given angular velocity. The head of the racquet farthest away from the body/shoulder will move with the largest linear velocity due to the $v = r\omega$ scaling that relates the angular and linear variables. If one hits the ball with a fast moving racquet then the ball moves away much faster and is much harder for the opponent to hit. If you hit the ball with less arm extension the linear velocity of the racquet head will be less due to the smaller radius for the circular motion.

Another reason (Not impt. for your physics Answer) that you want extension is that it provides a much better Angle to get the ball over the net and into the Appropriate part of the court.

Problem 5 (18 pts):

Jed Cool went for a drive while pondering what to do for his class physics project. Unfortunately, Jed was a bit too excited about the project. He was in deep thought about it and didn't pay attention to the road. As Jed moved due north on a level road he struck another car moving due northeast at an intersection (it was moving 45 degrees east of north). Jed's car has a mass of 2000 kg. The car Jed struck has a mass of 2300 kg. Jed was traveling at 20 m/s at the time of the collision. The car Jed struck was traveling at 32 m/s at the time of the collision. The two cars collided violently sticking together. How fast and in what direction were the cars moving immediately after the crash?

Two dimensional Momentum Conservation Problem.



$$\vec{P}_{init} = \vec{P}_{Final}$$

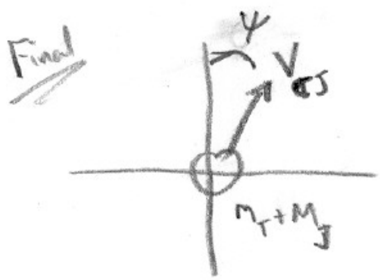
$$\Sigma P_{init_x} = \Sigma P_{Final_x}$$

$$M_c V_{c_x} = (M_c + M_J) V_{cJ_x}$$

$$M_c V_c \cos 45 = (M_c + M_J) V_{cJx}$$

$$(2300)(32)\cos 45 = (2000 + 2300)\, V_{cJx}$$

$$V_{cJx} = 12.1 \text{ m/s}$$

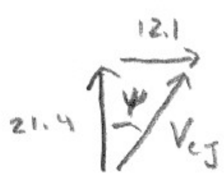


$$\Sigma P_{init_y} = \Sigma P_{Final_y}$$

$$m_J V_J + M_c V_{cy} = (M_J + M_c) V_{cJ_y}$$

$$(2000)(20) + (2300)(32)\sin 45 = (2000 + 2300)\, V_{cJ_y}$$

$$V_{cJ_y} = 21.4 \text{ m/s}$$



$$V_{cJ} = \sqrt{12.1^2 + 21.4^2} = 24.6 \text{ m/s}$$

$$\tan\psi = \frac{12.1}{21.4} \Rightarrow \psi = 29.5^\circ \text{ East of North}$$

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Problem 6 (17 pts):

Spaceman Spiff flies his spacecraft near two planets whose centers of mass are separated by a distance d. He finds that when he is at a position P between the two planets (as shown below) the gravitational field is zero, i.e. there is no net gravitational force on Spiff and his spacecraft. Spiff determines through a careful measurement that the point P lies at a distance X=5d/6. "Ah ha!" Spiff declares. "Now I know the mass of the large planet (M) in terms of the mass of the small planet (m)!"

a) Duplicate Spiff's calculation here. That is to say, calculate how much more massive is the large planet than the small planet in terms of multiples of the small planet's mass.

grav. field = zero at pt P $\Rightarrow$
m_s = Spiff's spacecraft's mass

$$\frac{GMm_s}{X^2} = \frac{Gmm_s}{(d-x)^2}$$

$$\frac{M}{x^2} = \frac{m}{(d-x)^2}$$

$x = \frac{5d}{6}$

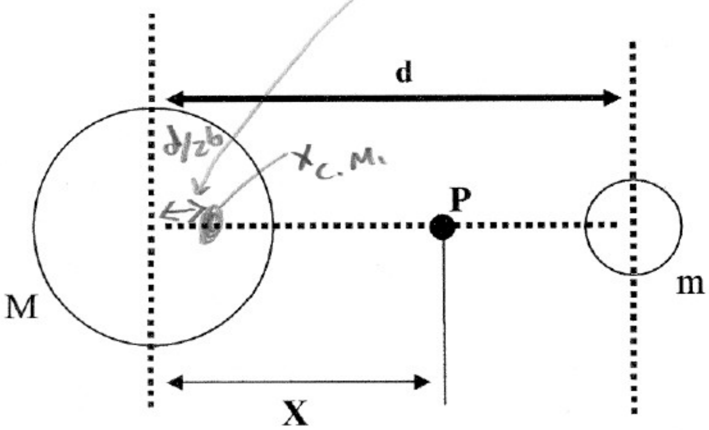
$$\frac{M}{\left(\frac{5}{6}d\right)^2} = \frac{m}{\left(\frac{1}{6}d\right)^2} \Rightarrow \frac{M}{25} = m$$

or $M = 25m$

b) Given your answer in part (a), calculate the position of the center of mass of the two planet system along the line joining the centers of the planets in terms of d. for simplicity, assume the center of the large planet defines the zero position on the axis joining the planet centers.

$$X_{CM} = \frac{\Sigma m_i x_i}{\Sigma M_i} = \frac{M(0) + md}{M + m}$$

$$X_{C.M.} = \frac{md}{25m + m} = \frac{d}{26}$$



Problem 7 (20 pts):

$\Rightarrow 5.1\,\text{kg}$ $\Rightarrow 2\,\text{kg}$

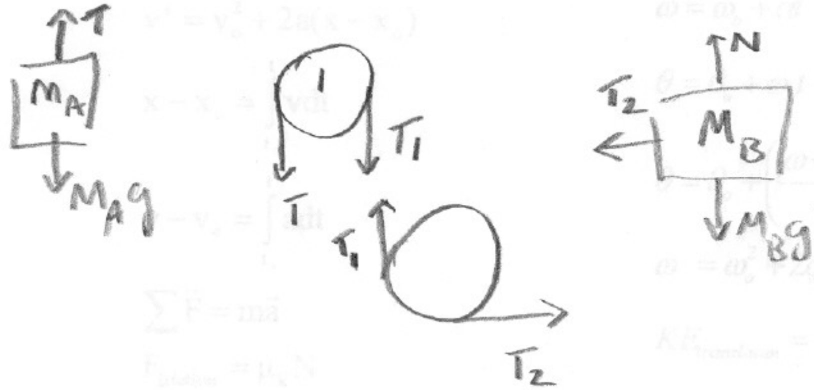
Mass A weighs 50 Newtons and mass B weighs 20 Newtons. Masses A and B are attached via a massless string that passes across two frictionless pulleys as shown in the sketch below. Each pulley consists of a uniform wheel of radius R=0.3 meters and mass M=2 kg. Mass B rests on a frictionless horizontal surface. The pulleys are fixed to a wall so they do not translate but are allowed to rotate.

If the system starts from rest and is released, what is the acceleration of mass A?

What is the maximum tension in the string?

Indicate on the sketch the approximate location where the tension in the string is maximum.

Assume the moment of inertia of each pulley wheel is (1/2)MR²



① $M_A g - T = M_A a$

$TR - T_1 R = I_1 \alpha_1 = \frac{1}{2} M R^2 \frac{a}{R}$

② $T - T_1 = \frac{M}{2} a$

$T_1 R - T_2 R = I_2 \alpha_2 = \frac{1}{2} M R^2 \frac{a}{R}$

③ $T_1 - T_2 = \frac{M}{2} a$

④ $T_2 = m_B a$

④ in ③ $T_1 = \frac{M}{2} a + M_B a = \left(\frac{M}{2} + M_B\right) a$

Sub into ②

$$T = \frac{M}{2} a + \frac{M}{2} a + M_B a = (M + M_B) a$$

Sub into ①

$$M_A g - (M + M_B) a = M_A a$$

$$a = g\left(\frac{M_A}{M_A + M + M_B}\right) = (9.8)\frac{5.1}{(5.1 + 2 + 2)} = 5.4\,\text{m/s}^2$$

$T = (2+2)\,5.4 = 21.6\,\text{N}$ = Max Tension

$T_1 = (1+2)\,5.4 = 16.2\,\text{N}$

$T_2 = (2)\,5.4 = 10.8\,\text{N}$