Exam 1 (October 3, 2013)

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 (5 pts, no justification necessary):

You are driving your car at 90 kilometers per hour down the highway. You follow a few meters behind a truck which is traveling in the same direction and speed as you. The truck is loaded with watermelons. Suddenly, one of the watermelons slips off the back of the truck. If air resistance is ignored (assume it is negligible),

a) the watermelon hits your car before it hits the ground.
b) the watermelon hits the ground before it hits your car.
c) you cannot determine whether the watermelon first hits the ground or your car without more information.

Problem 2 (12 pts, 3 pionts each, no justification necessary):

Below are four statements. Beside each statement, circle "true", "false", or "not known (meaning not possible to determine with the given information)" according to which answer you think best describes the accuracy of the statement according to Newton's Laws.

A body can have zero acceleration and a nonzero velocity. True / False / not known

A body can have zero velocity and nonzero acceleration. True / False / not known

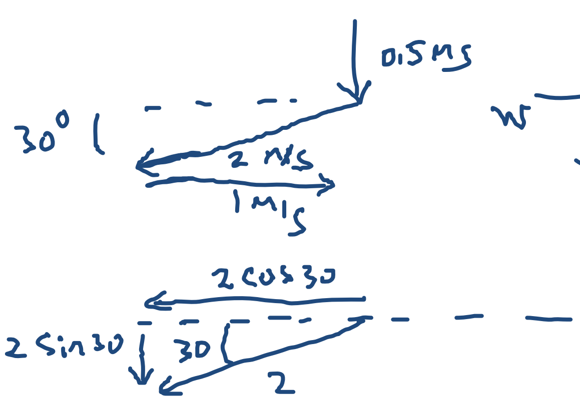
A body can be acted on by a force and have zero acceleration. True / False / not known

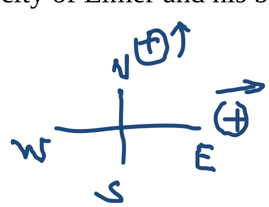
A body can be acted on by a force and have zero velocity. True / False / not known

Problem 3 (25 pts, 5 pts per part, show work):

Elmer, a very confused boat owner, takes his boat onto a river with the sail up *and* the boat motor running. The river flows due south at a constant 0.5 m/s. The wind blows in such a way that without the motor and the flowing river, the boat would move at a constant 2 m/s at an angle of 30 degrees ~~north of east~~ south of west. The boat is pointed due east so that if the river were not flowing and the wind not blowing, the boat would travel at a constant 1 m/s east due to being pushed by the motor. Assume the river is 100 m wide. *

a) What is the velocity of Elmer and his boat when they reach the middle of the river?



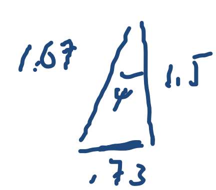


$$V_{NS} = -0.5\,m/s - \overbrace{2\sin 30}^{1} = -1.5$$

$$V_{EW} = -\underbrace{2\cos 30}_{1.73} + 1 = -0.73$$

$$|V| = \sqrt{1.5^2 + .73^2}$$

$$|V| = 1.7\,m/s$$



$$\tan\varphi = \frac{.73}{1.5}$$

$$\varphi = 26^\circ$$

Boat moves at 1.7 m/s at angle 26° West of south

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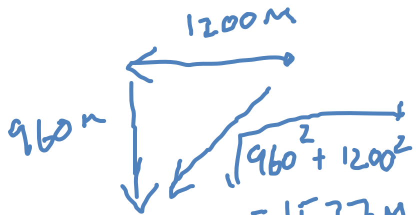
A week later Elmer takes his boat to a lake (where there is no flowing water). Starting in the middle of the lake at t=0, Elmer motors at 2 m/s due west for 10 minutes, then he motors due south at the same speed for 8 minutes.

b) What is Elmer's displacement at the end of the second (8 minute) leg of his trip relative to the center of the lake?

$10 \text{ min} \times \frac{60 \text{ sec}}{\text{min}} = 600 s \qquad (2 \text{ m/s})(600 s) = 1200 \text{ m}$

$8 \text{ min} \times \frac{60 \text{ sec}}{\text{min}} = 480 s \qquad (2 \text{ m/s})(480 s) = 960 \text{ m}$



$\sqrt{960^2 + 1200^2} = 1537 \text{ m}$

in a direction

~39° South of West

c) What is Elmer's average speed during the 18 minutes after he motored away from the center of the lake?

$\text{Ave speed} = \frac{(1200+960) \text{ m}}{(600+480) s} = \frac{2160 \text{ m}}{1080 s} = 2 \text{ m/s}$

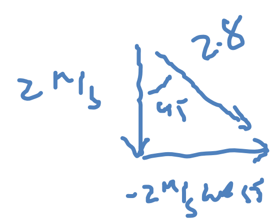
d) What is Elmer's average velocity during the same period?

$|\text{Ave velocity}| = \frac{1537 \text{ m}}{1080 s}$ {From (a)} $= 1.4 \text{ m/s}$

$\vec{V}_{ave} =$ 1.4 m/s in a direction 39° South of West

e) What is Elmer's average acceleration during the same period?

$\vec{a}_{Ave} = \frac{\Delta \vec{V}}{\Delta t} = \frac{\vec{V}_{Final} - \vec{V}_{init}}{\Delta t} = \frac{2 \text{ m/s south} - 2 \text{ m/s west}}{\Delta t}$ ← 1080 s

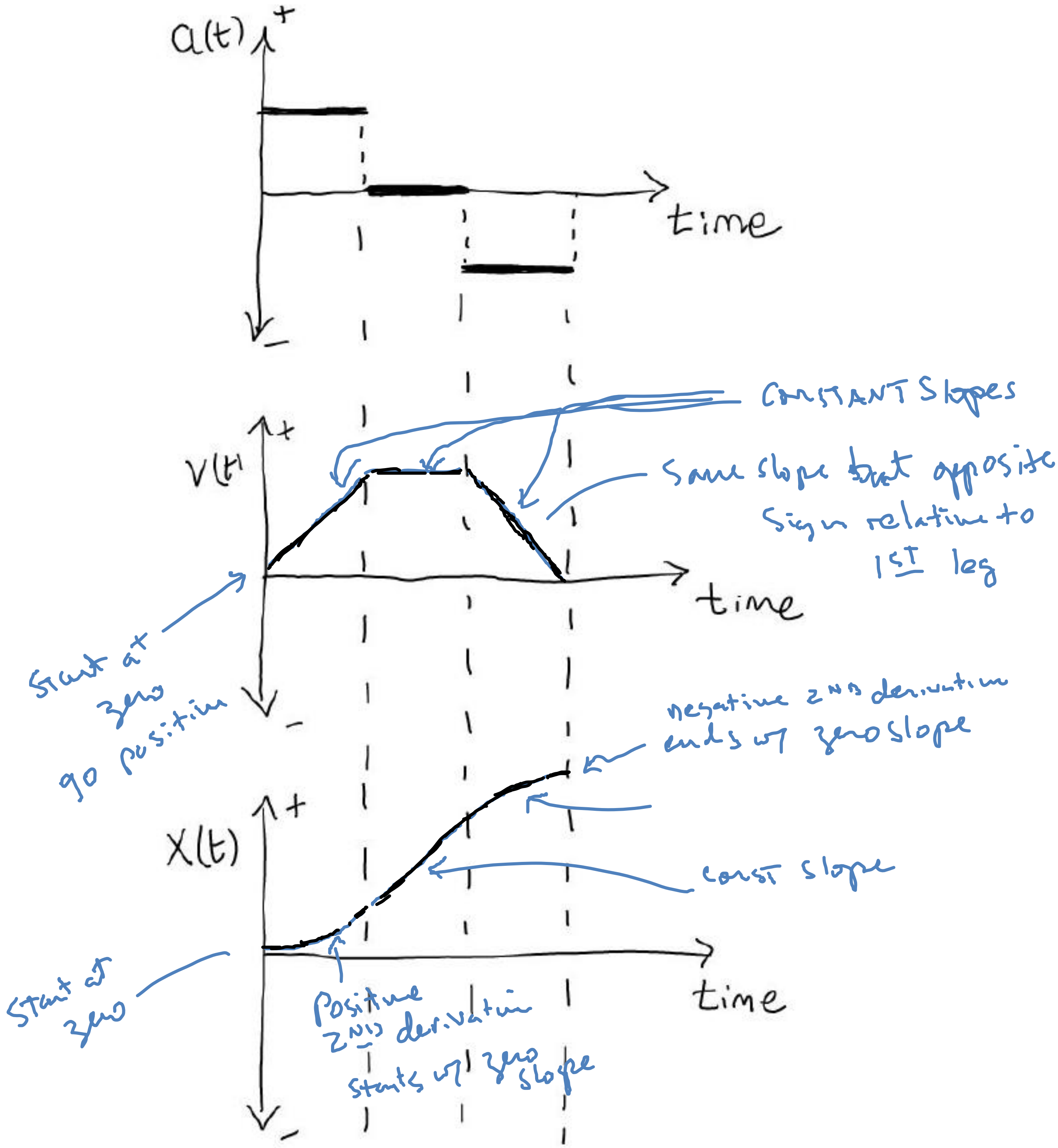


$\vec{a}_{ave} = .0026 \text{ m/s}^2$ in direction 45° east of South

Problem 4 (14 pts):

Jed Cool impressed his girlfriend by accelerating his Ford Fiesta in the positive x direction according to the acceleration-time graph shown below.

Assuming Jed starts out from rest at x=0 and t=0, provide qualitative graphs for Jed's velocity-time and postion-time graphs below:



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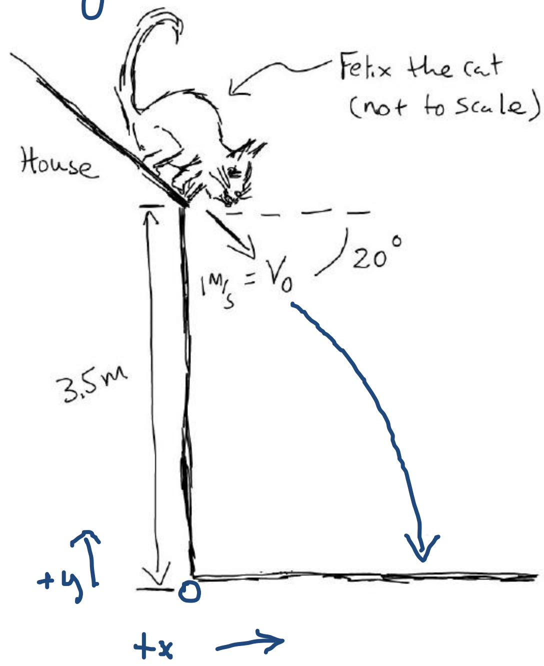

Problem 5 (22 pts, show work):

Felix the cat lounges at the edge of the roof of a house at a height of 3.5 m above the ground. He spots a mouse in the yard and pounces from the edge of the roof. To nab his snack, Felix pounces in such a way that he leaves the edge of the roof at an angle of 20 degrees down from the horizontal with an initial velocity magnitude of 1 m/s. How far from the house does Felix land? How long is he in the air?

$V_{0x} = V_0 \cos 20 = 0.94\ m/s$

$V_{0y} = V_0 \sin 20 = 0.34\ m/s$

$y = y_0 + V_{0y} t + \frac{1}{2} a_y t^2 \qquad a_y = -9.8\ m/s^2$

$0 = 3.5 - 0.34t - \frac{9.8}{2} t^2$

$t^2 + 0.07t - 0.71 = 0$

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

$t = \frac{-0.07 \pm \sqrt{.07^2 - 4(-.71)}}{2}$

$t = \frac{-0.07 \pm 1.69}{2} = \begin{matrix} -0.88\ s \\ 0.81\ s \end{matrix}$

root that makes sense here

Felix in air for 0.81 s

How far does he travel horizontally in this time?

$x = x_0 + V_{0x} t + \frac{1}{2} a_x t^2 \qquad a_x = 0$

$x = (0.94\ m/s)(0.81\ s)$

$x = 0.76\ m$

Felix lands 0.76 m from the house

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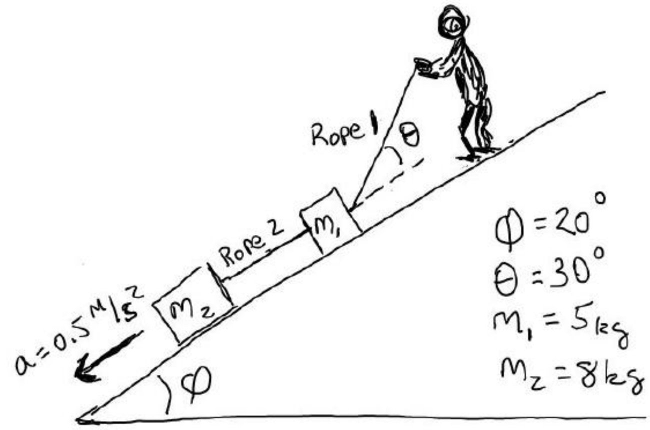
Problem 6 (22 pts, show work):

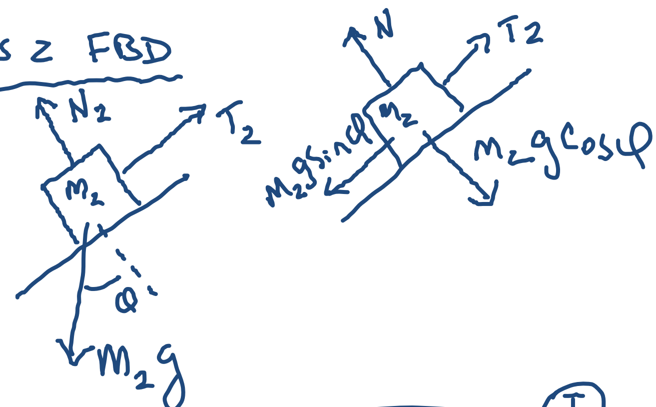
Biff Vanderbilt helps his fraternity brothers hauling supplies for the upcoming weekend party. In the process of doing this, Biff lowers cases of bottled tea and juice down an inclined plane, as shown in the sketch. Suppose the angle of the inclined plane with the horizontal is 20 degrees and that the angle of the rope Biff holds makes an angle of 30 degrees with respect to the surface of the inclined plane. Let the cases of tea and juice be represented by M_1(=5 kg) and M_2(=8kg), as in the sketch. Calculate the tension in each of the two ropes (labeled as rope 1 and rope 2 in the sketch) when Biff and the two cases move parallel to the surface of the plane downward with an acceleration of 0.5 m/s^2. Assume that you can ignore friction and assume the ropes are massless.



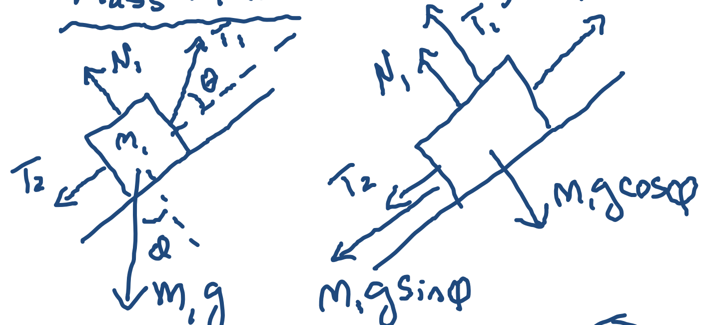
find T_1 and T_2

Choose coordinate ⊕ going down plane

Mass 2 FBD



Mass 1 FBD



$$\Sigma F_{\parallel M_2} = \boxed{M_2 a = M_2 g \sin\phi - T_2} \quad \text{I}$$

$$\Sigma F_{\perp M_2} = 0 = N_2 - M_2 g \cos\phi$$

$$\Sigma F_{\parallel M_1} = \boxed{M_1 a = T_2 + M_1 g \sin\phi - T_1 \cos\theta} \quad \text{II}$$

These two eqns not needed or useful in this particular problem

$$\Sigma F_{\perp M_1} = 0 = N_1 + T_1 \sin\theta - M_1 g \cos\phi$$

These two eqns → 2 eqns, 2 unknowns (T_1, T_2) solve

From I

$$T_2 = M_2 g \sin\phi - M_2 a$$

Sub in II

$$M_1 a = M_2 g \sin\phi - M_2 a + M_1 g \sin\phi - T_1 \cos\theta$$

$$T_1 = \frac{-a(M_1+M_2) + g \sin\phi (M_1+M_2)}{\cos\theta}$$

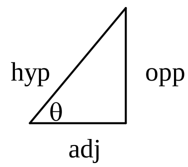
$$T_1 = \frac{-0.5(13) + 9.8 \sin(20)(13)}{\cos 30} \simeq \frac{37}{\cos 30} \cong \boxed{43 \text{ Newtons}} \; T_1$$

$$T_2 = (8)(9.8)\sin 20 - 8(0.5) \cong \boxed{23 \text{ Newtons}} \; T_2$$

1)	/5
2)	/12
3)	/25
4)	/14
5)	/22
6)	/22
tot	/100

$$\sin\theta = \frac{\text{opp}}{\text{hyp}}$$

$$\cos\theta = \frac{\text{adj}}{\text{hyp}}$$



$$\tan\theta = \frac{\text{opp}}{\text{adj}}$$

$$v = v_o + at$$

$$x = x_o + v_o t + \frac{1}{2}at^2$$

$$x = x_o + \left(\frac{v_o + v}{2}\right)t$$

$$v^2 = v_o^2 + 2a(x - x_o)$$

$$x - x_o = \int_{t_o}^{t} v\,dt$$

$$v - v_o = \int_{t_o}^{t} a\,dt$$

$$\sum \vec{F} = m\vec{a}$$

$$\vec{F} = \frac{Gm_1 m_2 \hat{r}}{r^2}$$

$$F_{centripetal} = \frac{mv^2}{r}$$

$$G = 6.67x10 - 11\ \text{Nm}^2/\text{kg}^2$$

$$\frac{d(x^n)}{dx} = nx^{n-1}$$

$$\int x^n dx = \frac{x^{n+1}}{n+1}$$

$$\text{circumference of circle} = 2\pi r$$

$$\text{area of circle} = \pi r^2$$

$$\text{quadratic equation} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$