PHYSICS 2110
Exam I

September 27, 2001

Name (please print)________________________________ Seat Number ____________

Student ID Number ________________________________ Class meeting time: ________

INSTRUCTOR (circle one) Nesaraja Murdock Kozub

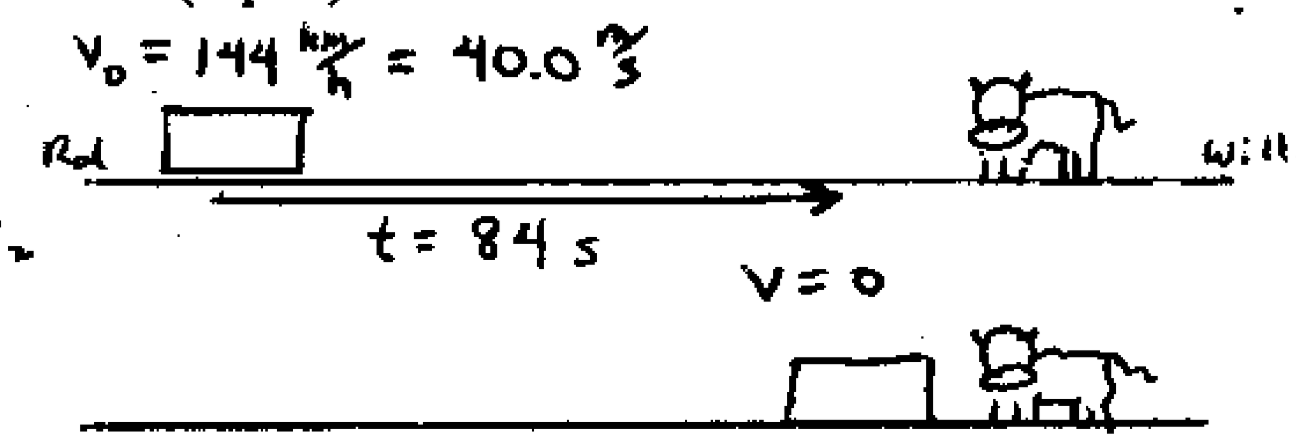
REMEMBER: *YOU MUST SHOW YOUR WORK AND/OR EXPLAIN YOUR REASONING TO RECEIVE CREDIT! Write down given quantities and identify the quantities requested in the problem.* ***Draw pictures***—*they will help you visualize the system.* ***Write down the formula(s)*** *you are using and, again,* ***show your work!*** *Finally, in numerical results,* ***don't forget the units*** *and* ***watch the significant figures!***

QUESTION NUMBER	POSSIBLE SCORE	YOUR SCORE
1	10	________
2	10	________
3	10	________
4	10	________
5	12	________
6	9	________
7	19	________
8	14	________
9	6	________
	TOTAL	________

1. Amtrak's 20th-Century Limited is en route from Raleigh, NC to Williamsburg, VA at 144 km/h, when the engineer spots a cow on the track. The train brakes to a halt in 1.4 min with constant deceleration, stopping just in front of the cow.

a) What is the magnitude of the train's acceleration in m/s^2? (4 pts.)

We are given that a_x is constant, so we can use



$$a_x = \frac{V - V_0}{t} = \frac{0 - 40.0 \frac{m}{s}}{84\ s} = -0.48 \frac{m}{s^2}$$

$$|a_x| = 0.48 \frac{m}{s^2}$$

b) What is the direction of the acceleration (i.e. towards Raleigh or towards the cow)? (2 pts.)

a_x is negative, meaning that $\vec{a}$ is directed backward, i.e. to Raleigh, NC

c) How far in meters was the train from the cow when the engineer first applied the brakes? (4 pts.)

Again, as a_x is constant, we can use

$$x = \tfrac{1}{2}(v_0 + v)\,t = \tfrac{1}{2}(40.0 \tfrac{m}{s} + 0)(84\ s) = 1.7 \times 10^3\ m$$

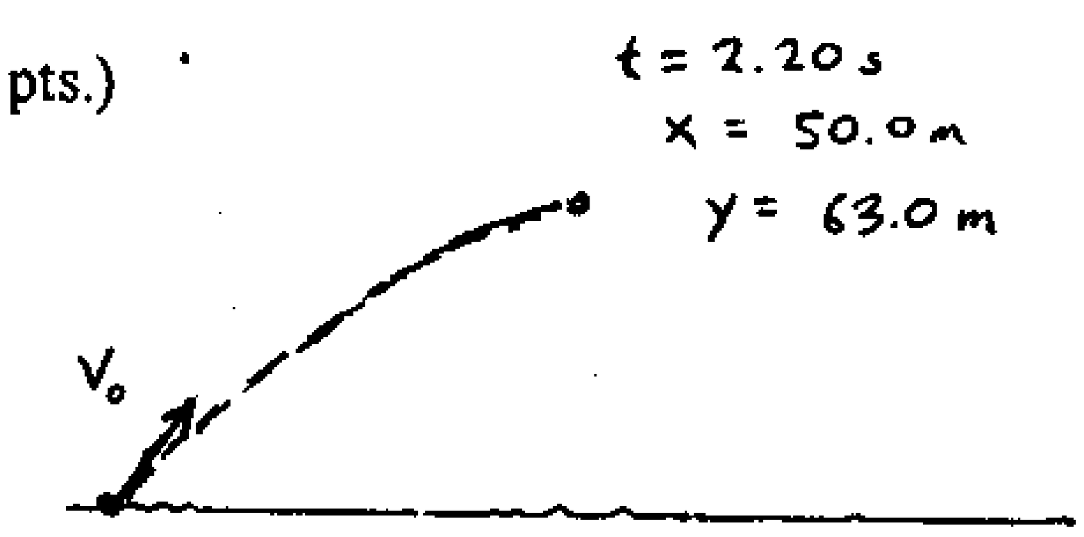
2. A projectile is shot from a canon and 2.20 seconds after being projected from ground level, the projectile is displaced 50.0 m horizontally and 63.0 m vertically above its point of projection.

a) What is the horizontal component of the initial velocity? (2 pts.)

At $t = 2.20 s$ we know that $x = 50.0\ m$.

Since $x = V_{0x} t$ then

$$V_{0x} = \frac{50.0\ m}{2.20\ s} = 22.7 \frac{m}{s}$$



b) What is the vertical component of the initial velocity? (2 pts.) Choose $x_0 = 0$ $y_0 = 0$

At $t = 2.20 s$ we know that $y = 63.0\ m$.

Since $y = V_{0y} t + \frac{1}{2} a_y t^2$ and $a_y = -9.80 \frac{m}{s^2}$ then

$$V_{0y}(2.20 s) = 63.0\ m - \tfrac{1}{2}(-9.80 \tfrac{m}{s^2})(2.20\ s)^2 = 86.7\ m$$

$$\Rightarrow V_{0y} = 86.7\ m / 2.20\ s = 39.4 \frac{m}{s}$$

c) At what instant does the projectile achieve its maximum height? (3 pts.)

Max ht. achieved when $V_y = 0$, so since $V_y = V_{0y} + a_y t$ then

$$0 = (39.4 \tfrac{m}{s}) + (-9.80 \tfrac{m}{s^2})\,t$$

$$t = \frac{39.4 \frac{m}{s}}{9.80 \frac{m}{s^2}} = 4.02\ s$$

d) What is the maximum height reached? (3 pts.)

What is the value of y when $V_y = 0$? Can use $V_y^2 = V_{0y}^2 + 2 a_y y$

$$y = \frac{V_y^2 - (V_{0y})^2}{2 a_y} = \frac{(39.4 \frac{m}{s})^2}{2(9.80 \frac{m}{s^2})} = 79.3\ m$$

3. A communication satellite is in a circular orbit about the Earth at an altitude h of 4.50×10^3 m from the surface of the Earth. If the radius of the Earth is 6.37×10^3 km and the satellite makes one revolution every 95.5 min, what are

a) the speed of the satellite (m/s)? (5 pts.)

Radius of the orbit of the satellite is

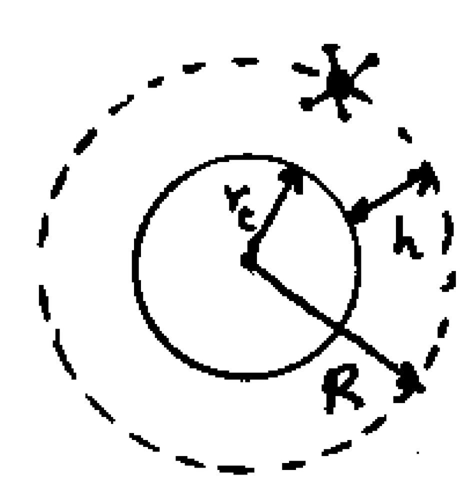
$R = h + r_e = (4.50 \times 10^3 + 6.37 \times 10^6)\ m$

$= 6.37 \times 10^6\ m$

Circumference of orbit is

$C = 2\pi R = 4.01 \times 10^7\ m$ Period is $T = 95.5\ min = 5.73 \times 10^3\ s$

Speed is $v = C/T = (4.01 \times 10^7 m)/(5.73 \times 10^3 s) = \boxed{6.99 \times 10^3\ m/s}$



b) centripetal acceleration (m/s^2)? (5 pts.)

Centripetal accel. is

$$a_c = \frac{v^2}{R} = \frac{(6.99 \times 10^3\ m/s)^2}{(6.37 \times 10^3\ m)} = \boxed{7.67\ m/s^2}$$

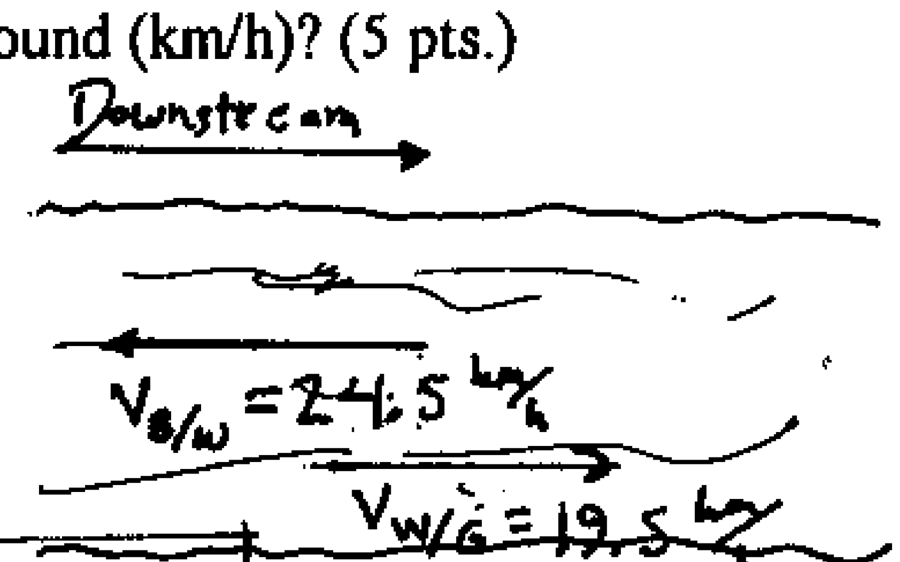
4. Captain Earl James is steering his boat upstream at 24.5 km/h with respect to the water of a river. The water is flowing at 19.5 km/h with respect to the ground.

a) What is the velocity of the boat with respect to the ground (km/h)? (5 pts.)

Given velocities are

$V_{B/w} = -24.5\ \frac{km}{hr}$ (Downstream $\equiv +$)

$V_{w/G} = +19.5\ \frac{km}{hr}$



Then

$V_{B/G} = V_{B/w} + V_{w/G} = -24.5\ \frac{km}{hr} + 19.5\ \frac{km}{hr}$

$= \boxed{-5.0\ \frac{km}{hr},\ \text{i.e. } 5.0\ \frac{km}{hr}\ \text{upstream}}$

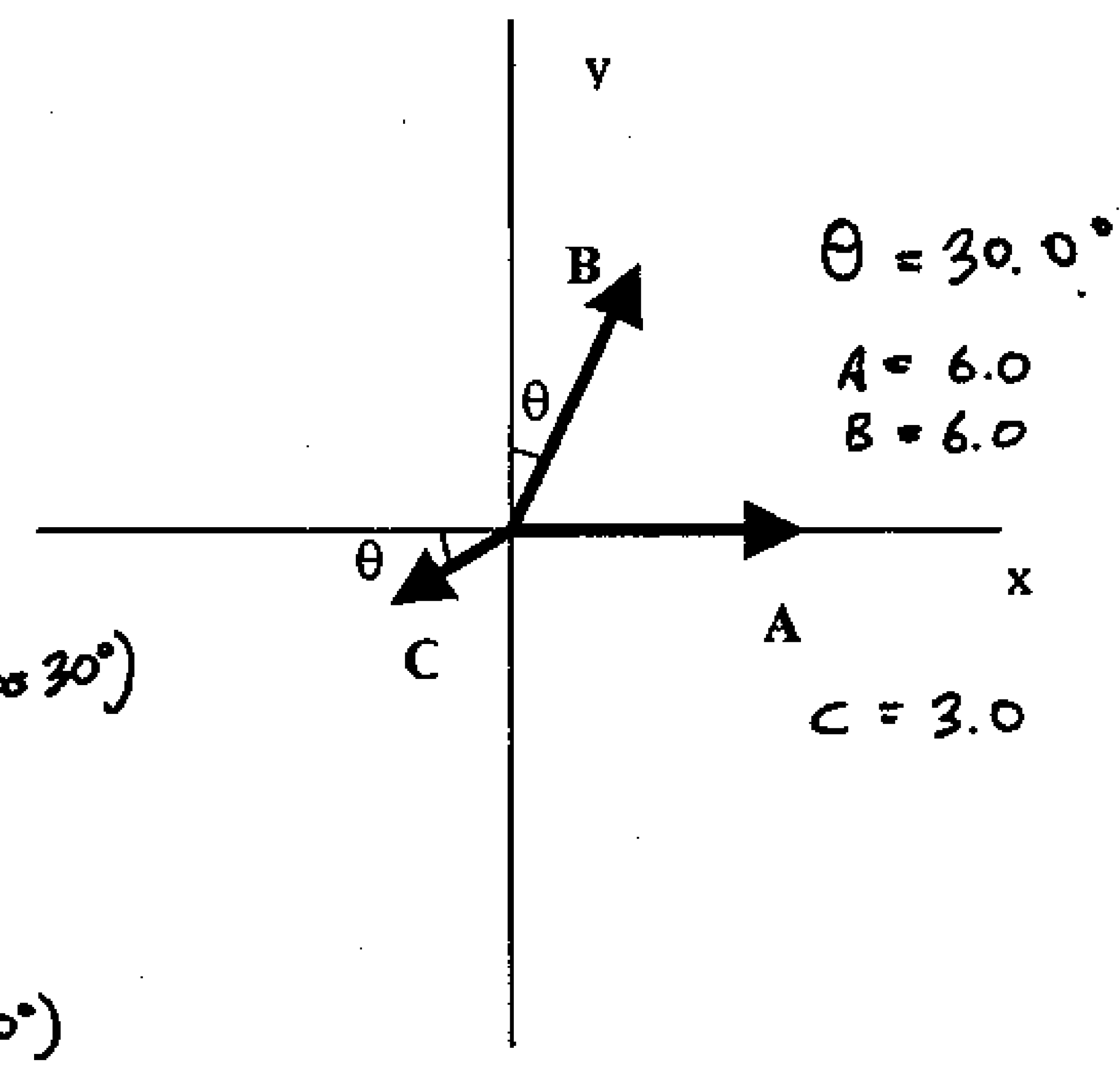
b) A child on the boat walks from front to rear at 16.5 km/h with respect to the boat. What is the child's velocity with respect to the ground (km/h)? (5 pts.)

Now we have $V_{c/B} = +16.5\ \frac{km}{h}$ (positive because front of boat is pointed upstream) then

$V_{c/G} = V_{c/B} + V_{B/G} = +16.5\ \frac{km}{h} - 5.0\ \frac{km}{h} = 11.5\ \frac{km}{h}$

or, $11.5\ \frac{km}{h}$ downstream

5. In the figure, vectors **A** and **B** are each 6.0 units long and vector **C** is 3.0 units long. The angle θ is 30.0°.
   (a) Calculate the magnitude of the vector **D**=**A**+(3.0)**B**-(2.0)**C** and the angle between **D** and the x-axis. (8 points)



Get the x and y components of $\vec{D}$

$D_x = A_x + (3.0)B_x - (2.0)C_x$

$= 6.0 + (3.0)(6.0)(\sin 30°) - (2.0)(3.0)(-\cos 30°)$

$= 20.2$

$D_y = A_y + (3.0)B_y - (2.0)C_y$

$= 0.0 + (3.0)(6.0)\cos 30° - (2.0)(3.0)(-\sin 30°)$

$= 19.$

Then $D = \sqrt{D_x^2 + D_y^2} = 28$

Take $\vec{D}\cdot\hat{i} = D_x = 20.2$

also $= (D)(1)\cos\phi = (28)\cos\phi$ where ϕ is angle between $\vec{D}$ and x axis.

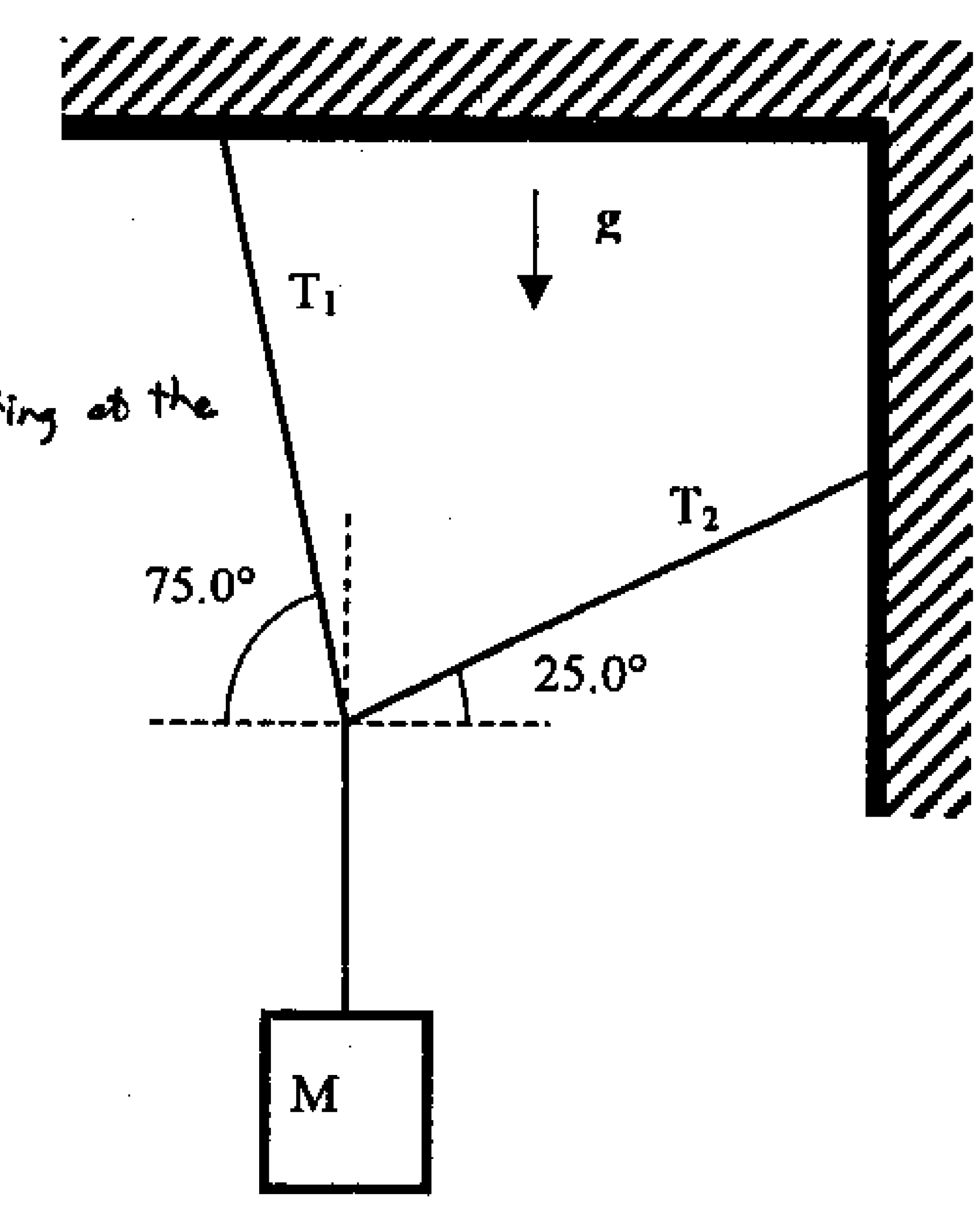
Then $\cos\phi = 0.72 \implies \phi = 44°$

   (b) Calculate the dot product **B**•**C**. (4 points)

Angle between $\vec{B}$ and $\vec{C}$ is $30° + 90° + 30° = 150.0° \equiv \phi$

So $\vec{B}\cdot\vec{C} = BC\cos\phi = (6.0)(3.0)\cos 150° = -16$

6. The system shown is in equilibrium. $\vec{a} = 0$ for mass M
   (a) Calculate the tensions T_1 and T_2 in the strings if the mass M is 1.50 kg. (6 points)



The lowest string supports mass M so its tension is $T_3 = Mg = 14.7\ N$. Then considering forces acting at the junction (which must sum to zero) we have:

x: $-T_1\cos 75° + T_2\cos 25° = 0$

So $T_2 = \frac{\cos 75.0°}{\cos 25.0°}T_1 = 0.286\,T_1$

y: $T_1\sin 75.0° + T_2\sin 25.0° - 14.7\ N = 0$

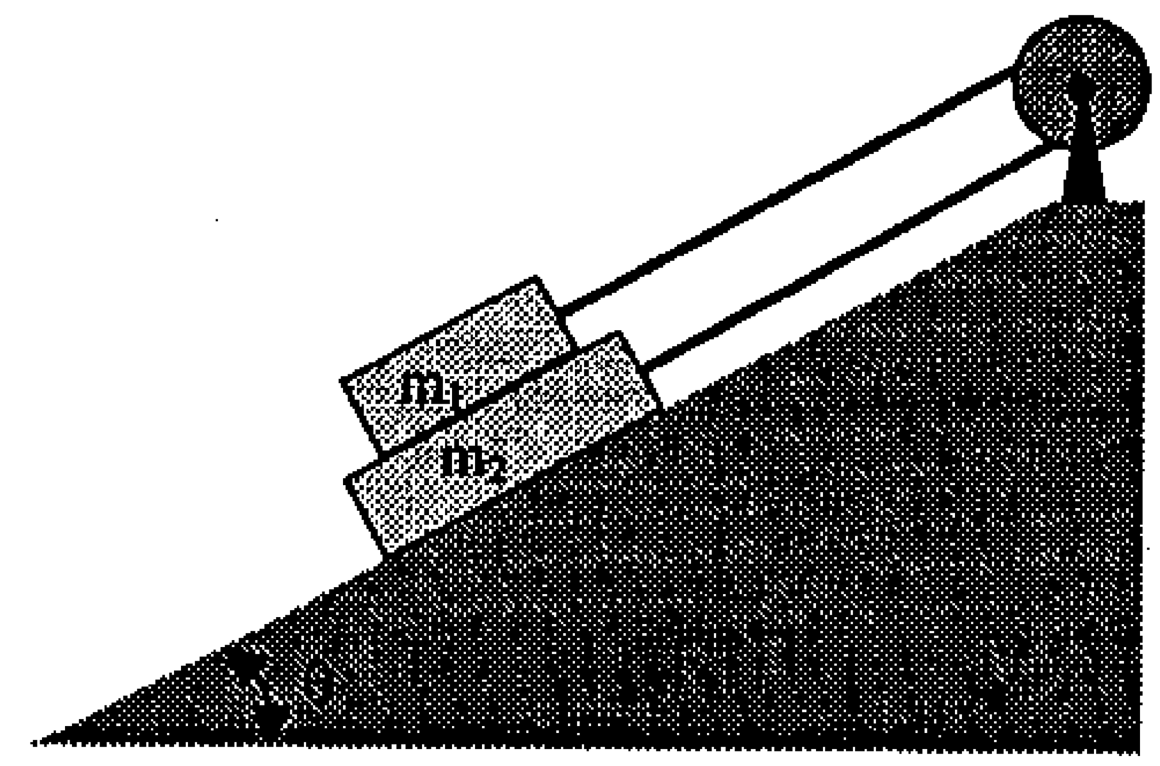
Sub: $T_1(\sin 75.0° + (0.286)\sin 25.0°) = 14.7\ N$

$T_1 = 13.5\ N \rightarrow T_2 = 3.87\ N$

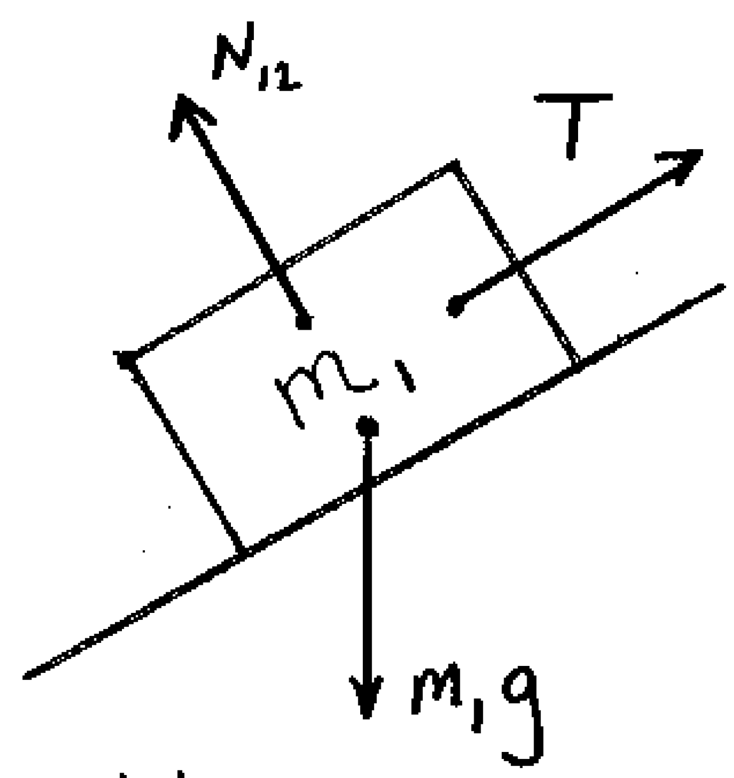
   (b) What is the reaction force to the weight of M? Explain fully. (3 points)

The "weight" of M is (downward) force of the entire earth on mass M. This force has magnitude 14.7 N. By Newton's 3rd law, M will exert an upward force of magnitude 14.7 N on the entire earth. This is the "reaction force" to the weight of M.

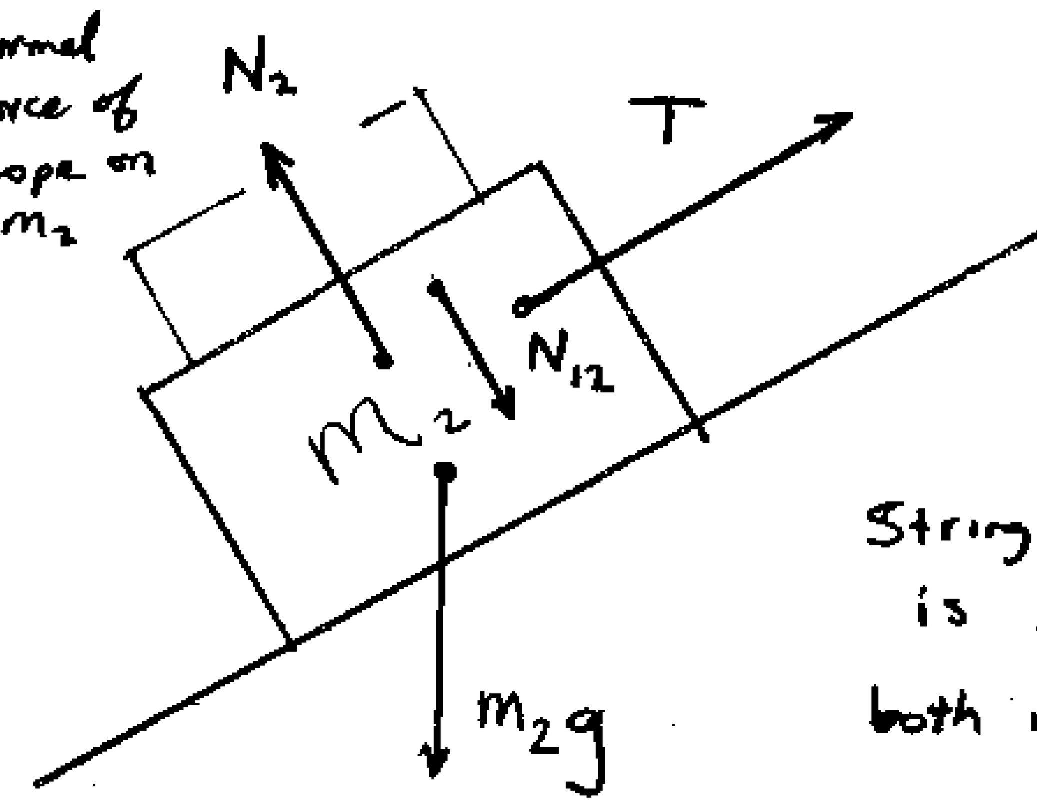
7. In the system shown, m_1=5.00 kg, m_2=15.0 kg, θ=25.0° with respect to the horizontal on Earth, the cord is inextensible, the pulley mass is negligible, and there is no friction.



(a) Draw neat, properly labelled free-body force diagrams for m_1 and m_2. Indicate which pairs of forces, if any, are equal in magnitude. (9 points)



Normal force of slope on m_2



N_{12} is force between surfaces of blocks 1 and 2. (Mag is same for each; direction is opposite)

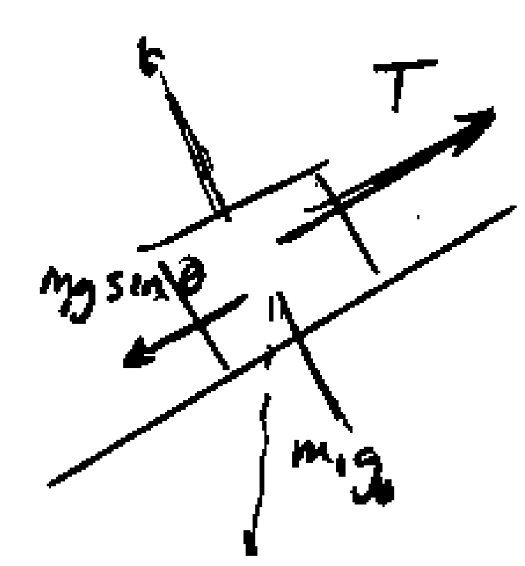
String tension T is same on both masses.

Note, no friction!

(b) Calculate the acceleration of mass m_1 and the magnitude of the tension in the cord. (10 points)

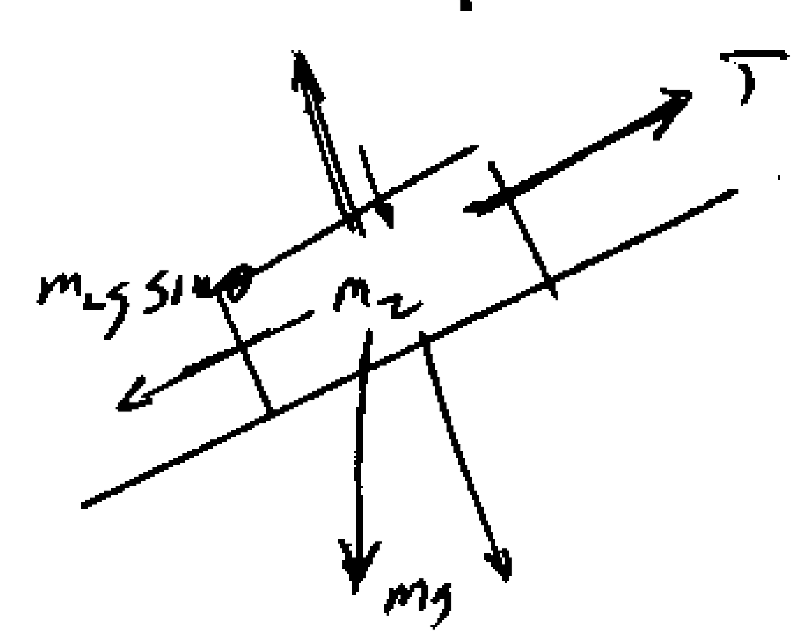
m_2 is larger in this case. We guess that m_2 will slide down the slope with some positive accel. a and then m_1 slides up the slope with accel a (same magnitude due to string!)

Add up-the-slope forces on m_1; result is $m_1 a$:



m_1: $$T - m_1 g \sin\theta = m_1 a \qquad (1)$$

Add the down-the-slope forces on m_2; result is $m_2 a$:



m_2: $$m_2 g \sin\theta - T = m_2 a \qquad (2)$$

Add eqn (1) and (2). Get:

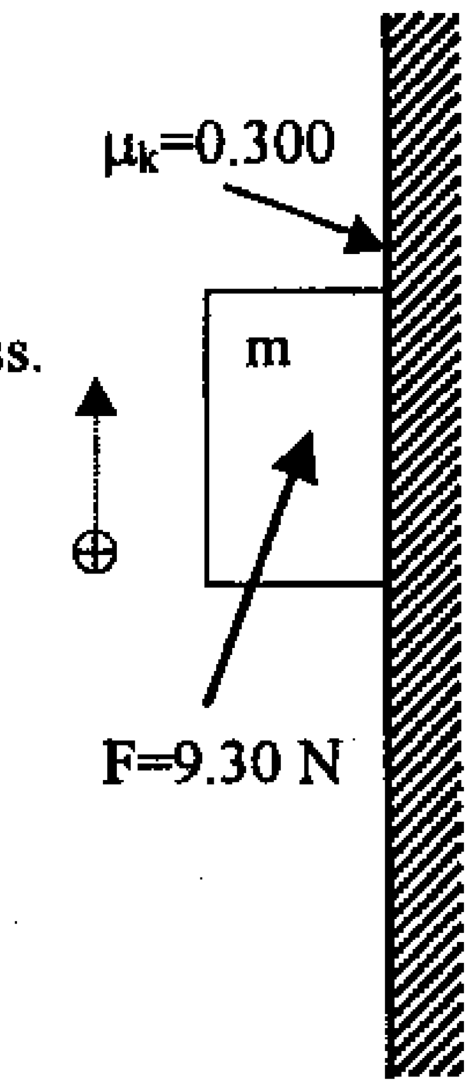
$$(m_2 - m_1) g \sin\theta = (m_2 + m_1) a$$

$$a = \frac{(m_2 - m_1) g \sin\theta}{(m_2 + m_1)} = \frac{(10.0\ \text{kg})(9.80\ \frac{m}{s^2}) \sin 25.0^\circ}{(20.0\ \text{kg})} = 2.07\ \frac{m}{s^2}$$

From (1),

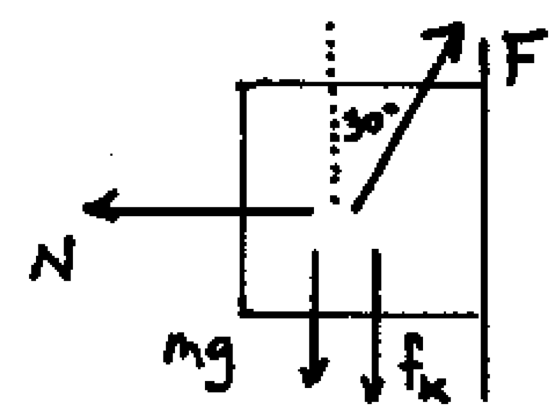
$$T = m_1 a + m_1 g \sin\theta = m_1 (a + g\sin\theta) = (5.00\ \text{kg})\left(2.07\ \frac{m}{s^2} + 9.80\ \frac{m}{s^2} \sin 25.0^\circ\right)$$
$$= 31.1\ \text{N}$$

8. A 0.600 kg mass is pushed up a rough wall by a 9.30 N force which is exerted at 30.0° from the vertical. (See figure.) The wall exerts a frictional force on the mass which opposes its (upward) motion; the coefficient of kinetic friction is 0.300 .



a) Draw a free-body diagram for the mass, showing all the forces acting on the mass. (5 pts)

$\vec{F}$ = applied force
$\vec{N}$ = Normal force of wall
$\vec{f_k}$ = Force of kinetic friction (from wall)



& mg is weight of mass!

b) Find the magnitude of the wall's normal force on the mass. (3 pts)

Horizontal forces must sum to zero, so

$N - F \sin 30° = 0$ or $N = F \sin 30° = (9.30\ N)(\sin 30.0°)$

$= \boxed{4.65\ N}$

c) Find the magnitude of the friction force on the mass. (3 pts)

$f_k = \mu_k N$, so

$f_k = (0.300)(4.65\ N) = \boxed{1.40\ N}$

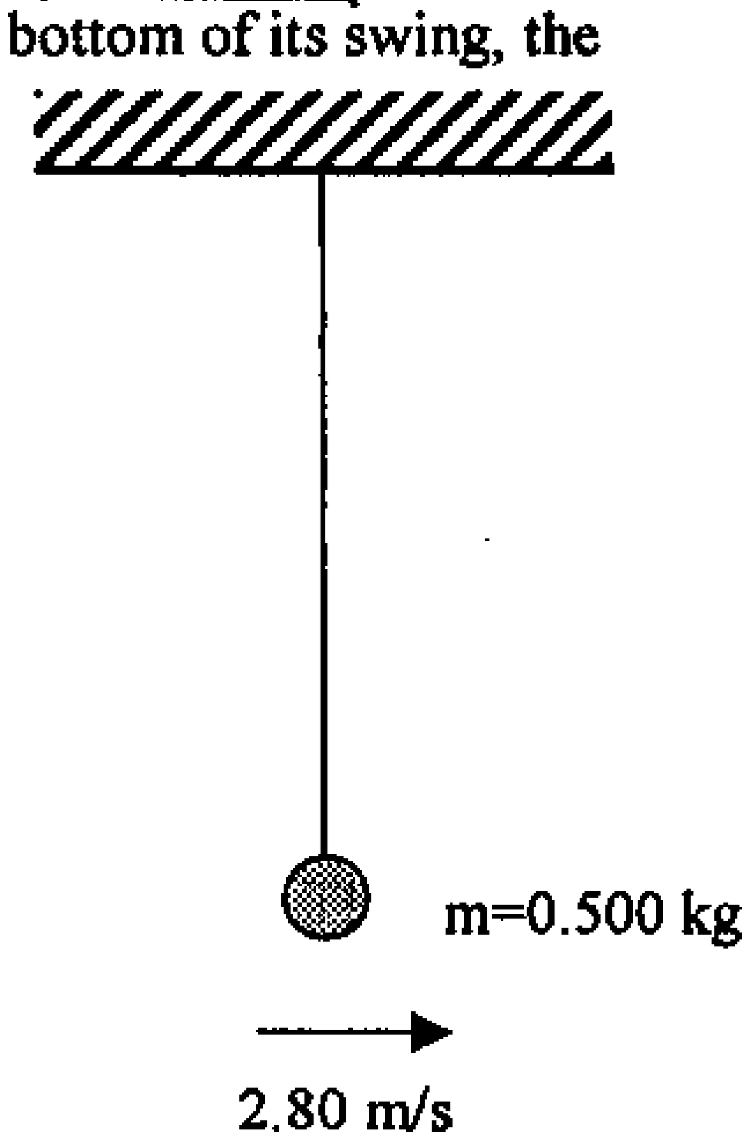
d) Find the acceleration of the mass. (3 pts)

Add the y-forces & get ma_y:

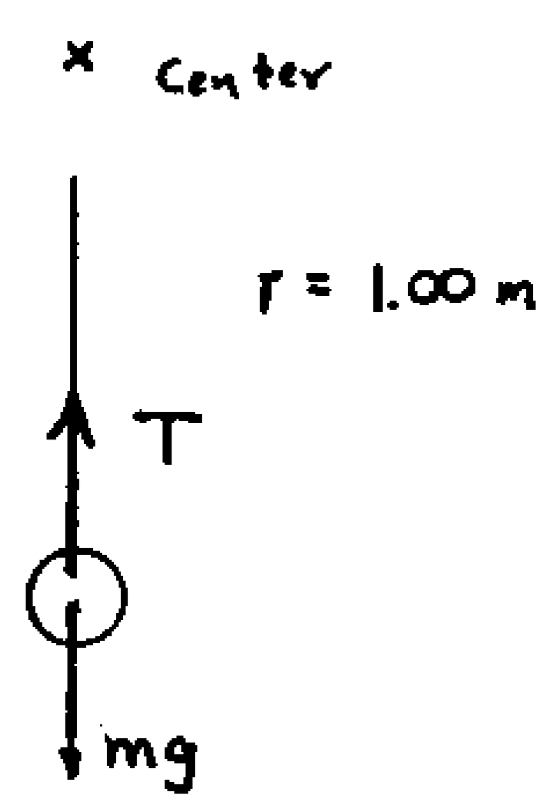
$\Sigma F_y = F \cos 30.0° - mg - f_k = (9.30\ N)(\cos 30.0°) - (0.600\ kg)(9.80\ \frac{m}{s^2}) - 1.40\ N$

$= 0.77\ N = ma_y$ Then $a_y = (0.77\ N)/m = \boxed{1.3\ m/s^2}$

9. A 0.500 kg mass swings on the end of a string of length 1.00 m. At the bottom of its swing, the speed of the mass is 2.80 m/s



Find the tension in the string. (6 pts)



Forces on mass at bottom of swing are as shown. Mass has (uniform) circ. motion at bottom of swing so that the radially inward forces sum to give $F_c = \frac{mv^2}{r}$, so:

$T - mg = \frac{mv^2}{r} = \frac{(0.500\ kg)(2.80\ \frac{m}{s})^2}{(1.00\ m)}$

$= 3.92\ N$

Then: $T = mg + 3.92\ N = (0.500\ kg)(9.80\ \frac{m}{s^2}) + 3.92\ N$

$= \boxed{8.82\ N}$