Name ______________________________ Seat Number ____________

PHYSICS 2110
Exam I – Fall 2008

INSTRUCTORS (Circle ONE):	CLASS MEETING TIME
Shriner	8:00 AM
Engelhardt	10:10 AM
Murdock	11:15 AM

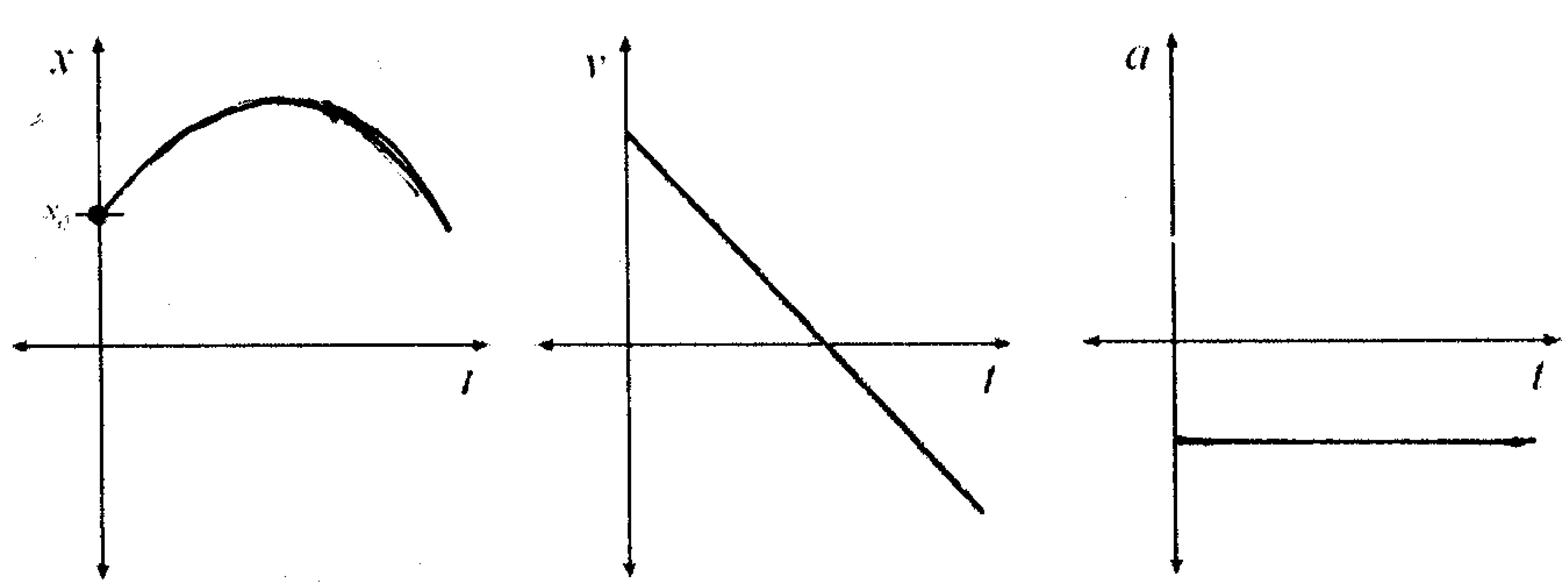
<u>YOU MUST SHOW YOUR WORK **AND** EXPLAIN YOUR REASONING TO RECEIVE CREDIT. ALL CELL PHONES AND OTHER COMMUNICATION DEVICES MUST BE TURNED OFF AND STORED OUT OF SIGHT. NO EXTRA PAPERS ARE ALLOWED OTHER THAN THE PROVIDED FORMULA SHEET.</u>

Free-body diagrams are ***required*** for problems involving forces.

PROBLEM	POINT VALUE	YOUR SCORE
1	4	
2	8	
3	6	
4	4	
5	16	
6	12	
7	9	
8	17	
9	12	
10	12	
TOTAL	100	

1. A particle moves along the x axis; the plot of v vs. t is given in (b) below.

In the spaces provided, make sketches of the curves for x vs t and a vs t. (You just need to give the *appearance* of these curves.) For the x vs. t curve, the initial value is indicated on the graph. (4 pts)



(a) (b) (c)

(Slope must start out positive, decrease to zero and then become more negative.)

(Slope of v(t) const & negative)

2. A car travels in a straight line; it is initially moving at 90. km/hr and decelerates uniformly such that it comes to rest after traveling 130. m.

(a) What is the magnitude of the car's acceleration? (4 pts)

$$V_0 = 90 \frac{km}{hr}\left(\frac{10^3 m}{1 km}\right)\left(\frac{1 hr}{3600 s}\right) = 25 \frac{m}{s}$$

Use

$v^2 = v_0^2 + 2a(x - x_0)$ w/ $v = 0$. Then

$$v^2 - v_0^2 = 2a(x - x_0) \qquad a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{0^2 - (25\frac{m}{s})^2}{2(130 m)} = -2.4 \frac{m}{s^2}$$

so $\boxed{|a| = 2.4 \frac{m}{s^2}}$

(b) How long does it take the car to stop? (4 pts)

Use $v = v_0 + at$

$$\rightarrow \quad t = \frac{v - v_0}{a} = \frac{0 - (25\frac{m}{s})}{(-2.4\frac{m}{s^2})} = \boxed{10.4 s}$$

3. A particle travels in a straight line. Its position is given by

$$x(t) = 4t + 3t^2 - 3t^3$$

where x is in meters when t is in seconds.

(a) What is the velocity of the particle at t = 1 s? (3 pts)

$v(t) = 4 + 6t - 9t^2$

$$\rightarrow \quad v(1s) = 4 + 6 - 9 = \boxed{1 \frac{m}{s}}$$

(b) At what time is its acceleration zero? (3 pts)

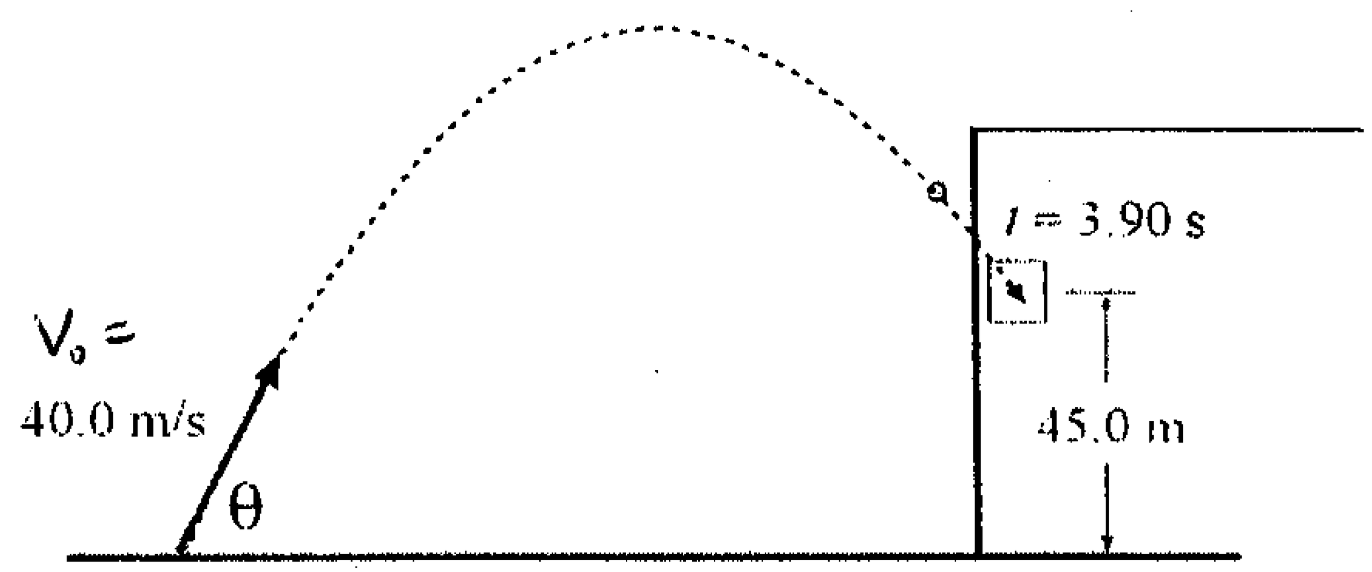
$a(t) = 6 - 18t$

$$a = 0 \quad \Rightarrow \quad 6 - 18t = 0 \quad \rightarrow \quad t = \frac{6}{18} = \boxed{0.33 s}$$

4. State Newton's 2nd Law (4 pts)

$$\vec{F}_{net} = m\vec{a}$$

5. A projectile is fired at a speed of 40.0 m/s (from ground level) toward a tall building. The projectile flies in through a window which is 45.0 m above the ground, 3.90 s after it was fired.



(a) At what angle θ above the horizontal was the projectile fired? (6 pts)

With $v_{y0} = V_o \sin\theta$, $a_y = -g$

and $t = 3.90$s, the $y(t)$ eqn gives

$$y = 45 = 0 + v_o \sin\theta\, t - \tfrac{1}{2} g t^2 = (40.0\tfrac{m}{s}) \sin\theta\, (3.90s) - \tfrac{1}{2}(9.80\tfrac{m}{s^2})(3.90s)^2$$

$$= (156m)\sin\theta - 74.5\,m$$

Solve for $\sin\theta$:

$$\sin\theta = \frac{45m + 74.5m}{156m} = 0.766 \longrightarrow \boxed{\theta = 50.0^\circ}$$

(b) What is the horizontal distance of the window from the point where the projectile was fired? (5 pts)

Then $V_{x_0} = V_o \cos\theta = (40.0\tfrac{m}{s}) \cos 50^\circ = 25.7\tfrac{m}{s}$

At $t = 3.90$ s, (and since $a_x = 0$),

$$x = x_o + V_{x_0} t = 0 + (25.7\tfrac{m}{s})(3.90s) = \boxed{100\,m}$$

(c) What was the speed of the projectile when it entered the window? (5 pts)

At $t = 3.9$ s,

$$V_x = V_{x_0} = 25.7\tfrac{m}{s}$$

$$V_y = V_{y_0} + a_y t = (40.0\tfrac{m}{s})\sin 50^\circ - (9.8\tfrac{m}{s^2})(3.9s) = -7.58\tfrac{m}{s}$$

and

$$V = \sqrt{V_x^2 + V_y^2} = \sqrt{(25.7\tfrac{m}{s})^2 + (-7.58\tfrac{m}{s})^2} = \boxed{26.8\tfrac{m}{s}}$$

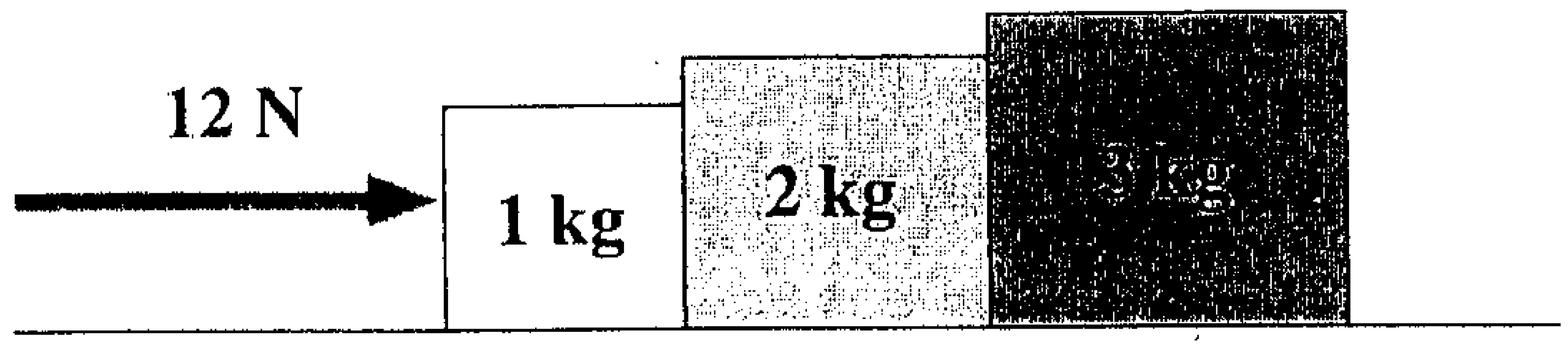
6. In each of the following situations, you are asked to compare two forces. You should identify which of the two forces has the largest magnitude or if the magnitudes are equal, and briefly explain your conclusion. (12 pts)

(a) If you travel north out of Cookeville on Washington Avenue (State Rt. 136, aka Hilham Highway), about 4 miles past Cookeville High School you will encounter a section of road where you go downhill, then uphill, then downhill, then uphill again over a fairly short distance. This section of road is sometimes referred to locally as "The Dips." Consider the forces on you, the driver, at the instant you pass through one of the low points at constant speed. Compare the magnitude of your weight and the magnitude of the normal force exerted upward on you by the seat.

Acceleration is upward $\Rightarrow \vec{F}_{net}$ is upward $\Rightarrow$

$n_{seat} > W$

(b) Three blocks are on a horizontal frictionless surface as shown. Compare the magnitude of the force that the 2 kg block exerts on the 1 kg block to the magnitude of the force that the 2 kg block exerts on the 3 kg block.

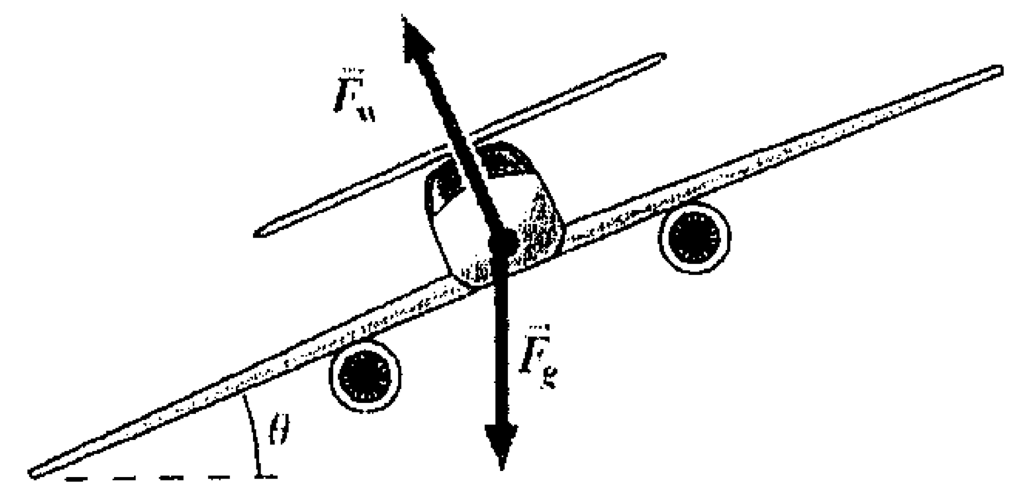


Net force on 2 kg block is to right (whole system accelerating)

$\Rightarrow F_{1kg \text{ on } 2kg} > F_{3kg \text{ on } 1kg}$. By Newton III, $F_{1kg \text{ on } 2kg} = F_{2kg \text{ on } 1kg}$ and

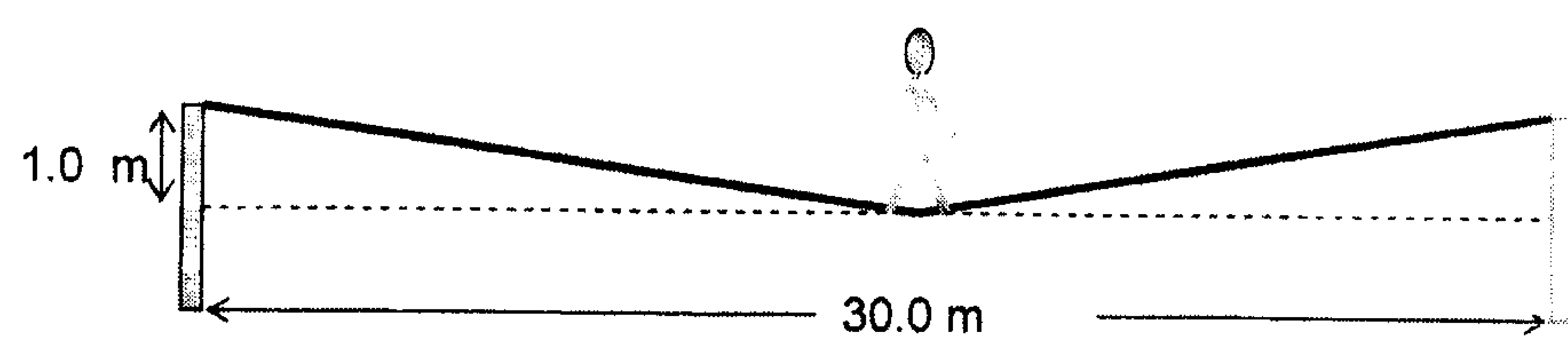
$F_{3kg \text{ on } F_{1kg}} = F_{1kg \text{ on } 3kg} \Rightarrow F_{2kg \text{ on } 1kg} > F_{2kg \text{ on } 3kg}$

(c) Consider an airplane banking in a horizontal circular turn at constant speed. There is a lift force $\vec{F_w}$ on the plane which points in a direction that is perpendicular to the body of the plane as illustrated here. Compare the magnitudes of the weight of the plane and the lift force.

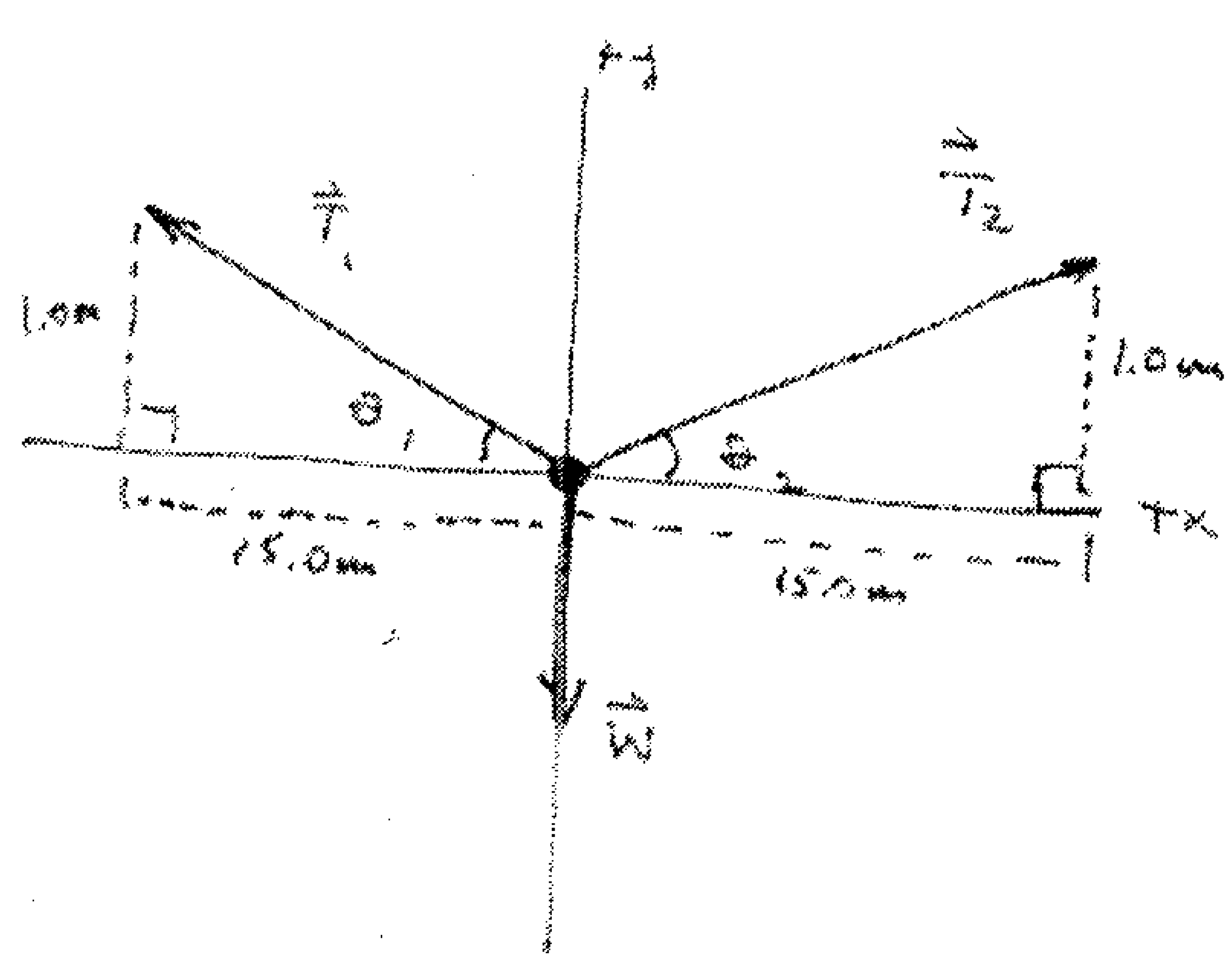


Uniform circular motion $\Rightarrow \vec{F}_{net}$ toward center of circle $\Rightarrow \Sigma F_{vert} = 0 \Rightarrow F_w > F_g$

7. A tightrope walker walks across a 30.0-m wire tied between two poles. The center of the wire is displaced vertically downward by 1.0-m when he is halfway across. If the tension in each half of the wire at this point is 6134 N what is the mass of the tightrope walker? Neglect the mass of the wire. (9 pts)



FBD: WIRE MIDPOINT



From geometry, θ_1 must $= \theta_2$ $(= \theta)$

Given, $T_1 = T_2 = 6134 N$, so:

$|\vec{T}_{1x}| = |\vec{T}_{2x}| = T\cos\theta$ ③

$|\vec{T}_{1y}| = |\vec{T}_{2y}| = T\sin\theta$ ④

$\tan\theta = \frac{1.0 \text{ m}}{15.0 \text{ m}}$

$\theta = \tan^{-1}\left(\frac{1.0 \text{ m}}{15.0 \text{ m}}\right)$

$\theta = 3.81°$

From Newton's 2nd law

$\Sigma F_x = ma_x$ and $\Sigma F_y = ma_y$

x: $T_{2x} - T_{1x} = 0$

$T_{2x} = T_{1x}$ ①

y: $T_{1y} + T_{2y} - W = 0$

$T_{1y} + T_{2y} = W$ ②

① Doesn't help us here. Substituting ④ → ② we find

$T\sin\theta + T\sin\theta = W$ where $W = mg$

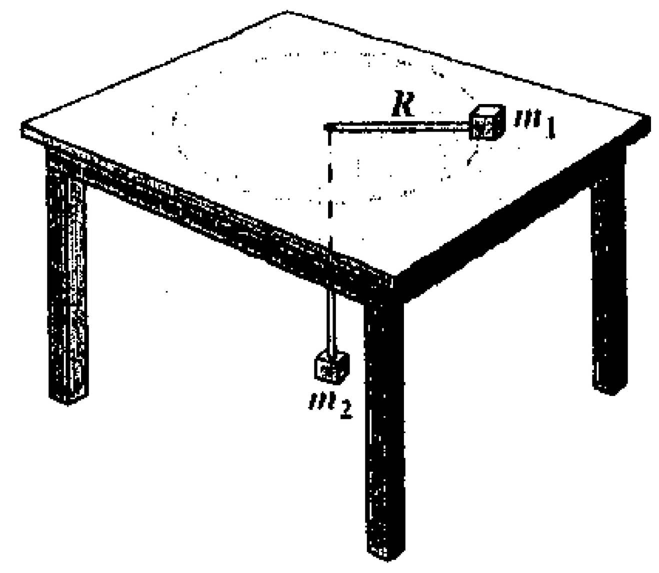
Solving for m

$m = \frac{2T\sin\theta}{g}$

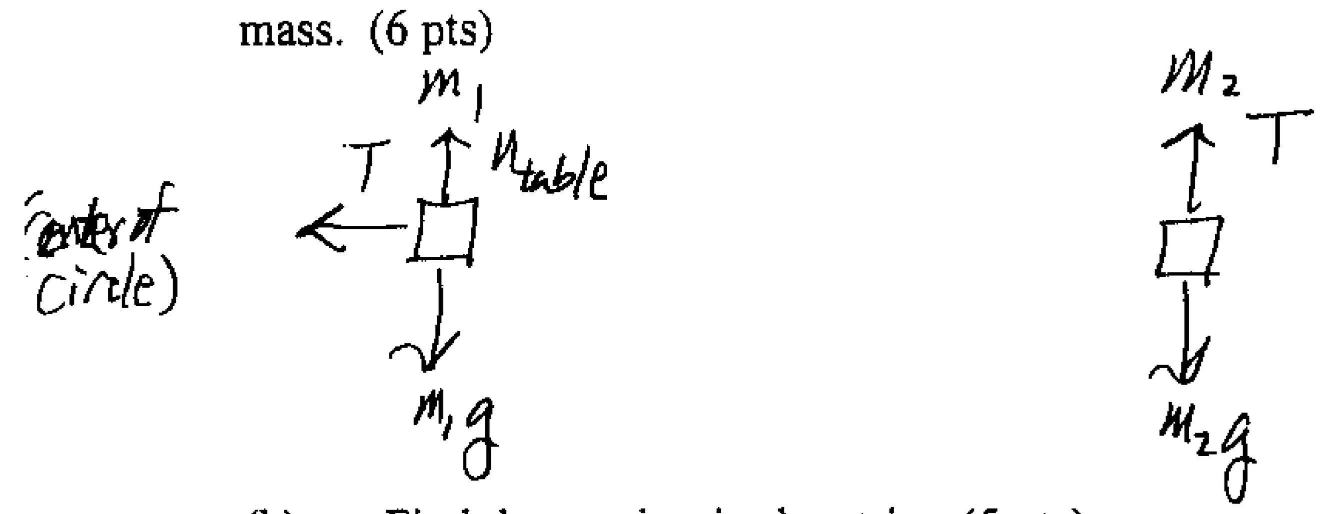
$m = \frac{2(6134 N)\sin 3.81°}{9.80 \text{ m/s}^2}$

$m = 83.$ kg (since θ is really only good to 2 sig. fig.)

8. A mass m_1 undergoes circular motion of radius R on a horizontal frictionless table. This mass is held in the circular path by a massless string attached to a second mass m_2 through a hole in the center of the table as shown in the picture. The hanging mass m_2 remains stationary while m_1 is moving.



(a) Draw clearly labeled free-body diagrams for each mass. (6 pts)



(b) Find the tension in the string (5 pts)

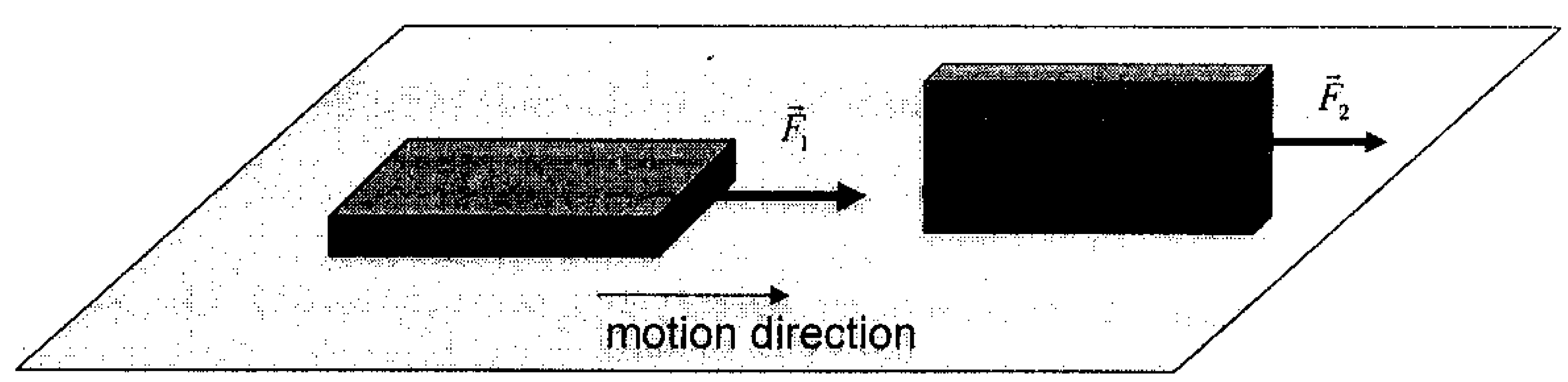
m_2 is at rest $\Rightarrow \vec{F}_{net, m_2} = 0 \Rightarrow T = m_2 g$

(c) Find the period of the circular motion (i.e., the time it takes m_2 to travel completely around the circle once). (6 pts)

For m_1, $\Sigma F_{radial} = T = \frac{mv^2}{R} \Rightarrow m_2 g = \frac{m_1 v^2}{R} \Rightarrow v = \sqrt{\frac{m_2 g R}{m_1}}$

Time to go thru circle $= \frac{2\pi R}{v} = 2\pi \sqrt{\frac{m_1 R}{m_2 g}}$

9. (a) A brick initially has its largest area face in contact with a rough surface, as shown on the left in the figure. A force $\vec{F_1}$ is required to pull the brick along the surface at constant speed. The brick is now flipped so that a face of smaller area is in contact, as on the right in the figure. The material of the brick is uniform on all faces. What force, $\vec{F_2}$, is now required to pull the brick along at constant speed as before? (6 pts)

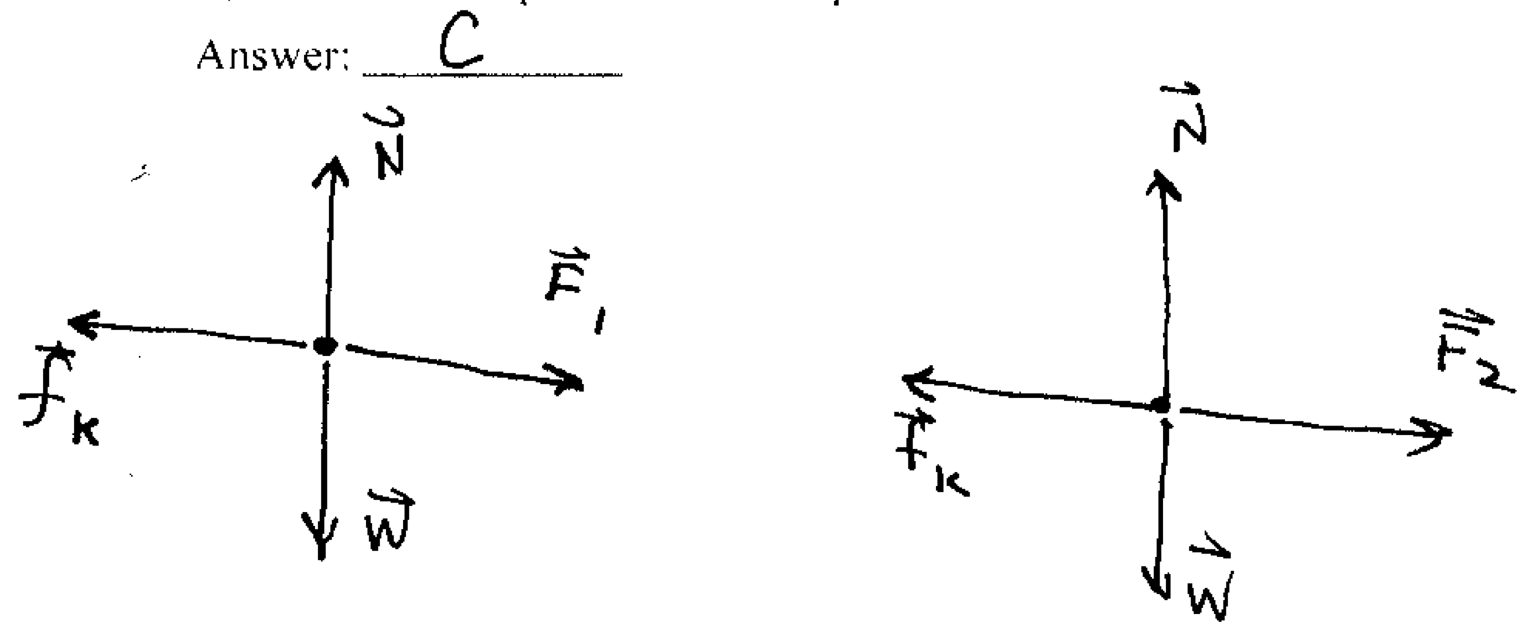


A) $F_2 > F_1$ B) $F_2 < F_1$ C) $F_2 = F_1$

D) One cannot say without knowing the coefficient of friction.

E) No force is required since the speed is constant.

Answer: C



where $f_k = \mu_k N$ and here $N = mg$ since $W = mg$

since $a = 0$ (constant speed), and $f_k = \mu_k mg$ in either case,

$F_1 - \mu_k mg = 0$

$F_2 - \mu_k mg = 0$

and since $\mu_k \neq 0$, $m \neq 0$, $g \neq 0$, $F_1 = F_2$

(b) If you jumped out of a plane, you would begin speeding up as you fall downward. Eventually, due to wind resistance, your velocity would become constant with time. After this occurs, the magnitude of the force of wind resistance is (6 pts)

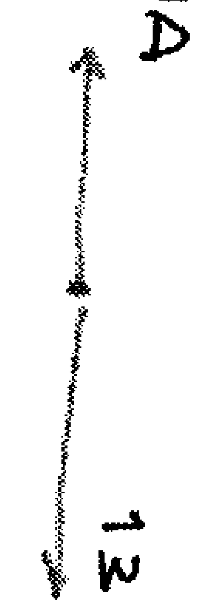
A) greater than the magnitude of the force of gravity acting on you.

B) slightly smaller than the magnitude of the force of gravity acting on you.

C) equal to the magnitude of the force of gravity acting on you.

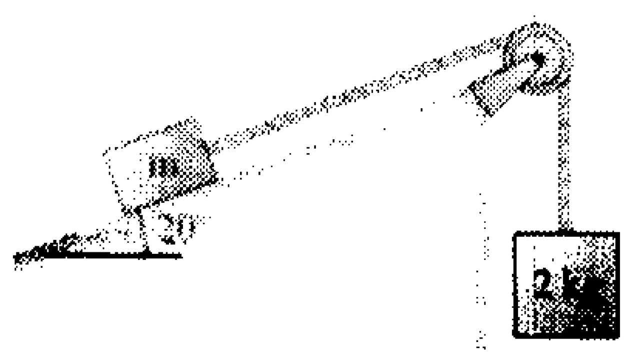
D) much smaller than the magnitude of the force of gravity acting on you.

Answer: C

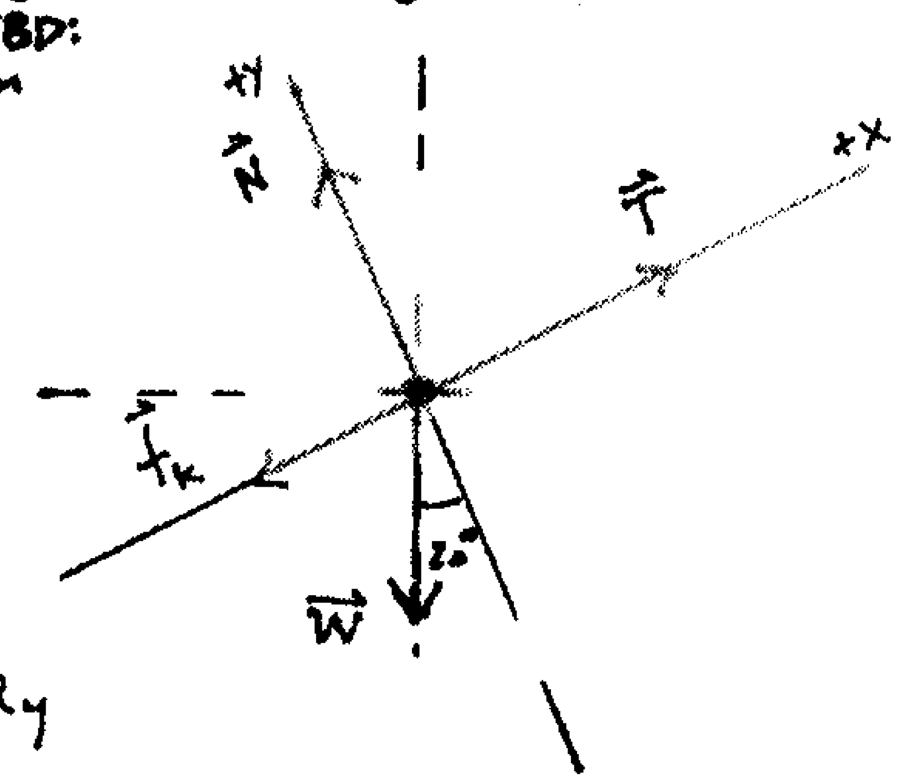


$a = 0$ Since v = constant So, $\Sigma F_{net} = 0$ Thus $(W=)mg = D$

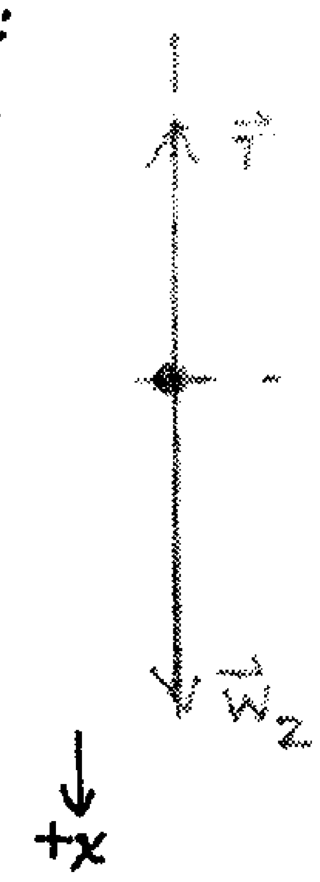
10. The figure shows a block of mass m resting on a 20.0° slope. The block has coefficients of friction $\mu_s = 0.55$ and $\mu_k = 0.45$ with the surface. It is connected via a massless string over a massless, frictionless pulley to a hanging block of mass 2.0 kg. Determine the minimum mass m that will stick and not slip? (12 pts)



FBD: m



FBD: 2kg



NEWTON'S 2nd LAW: $\Sigma F_x = ma_x \quad \Sigma F_y = ma_y$

m:

$x: \; T - W\sin 20° - f_s = ma_x$ ①

$y: \; N - W\cos 20° = ma_y$ ②

Block 2kg

$W_2 - T = (2\,kg)\,a_x$ ③

CONSTRAINTS:

The tension in the cable is the same on either side of the massless, frictionless pulley.

$a_y = 0$ for block m,

Block m & 2kg are constrained to share the same acceleration, a_x.

Block m:

$x: \; T - mg\sin 20° - f_k = ma_x$

where $f_s \le \mu_s N$ or $f_s^{max} = \mu_s N$

~~Solving for~~

① $T - mg\sin 20° - \mu_s N = ma_x$

$y: \; N - W\cos 20° = 0$

$N = mg\cos 20°$

substituting ~~for~~ N in ①

② $T - mg\sin 20° - \mu_s(mg\cos 20°) = ma_x$

From Block 2kg, x:

③ $T = m_2 g - (m_2)a_x$

Here we recognize that to find the minimum mass, m, for the block m to stick and not slip, $a_x = 0$. ② and ③ Become,

②' $T - mg\sin 20° - \mu_s(mg\cos 20°) = 0$

③' $T = m_2 g$

Substituting for T and solving for m,

$m_2 g - mg\sin 20° - \mu_s(mg\cos 20°) = 0$

$m_2 = m(\sin 20° + \mu_s\cos 20°)$

$$m = \frac{m_2}{(\sin 20° + \mu_s\cos 20°)}$$

$$m = \frac{2.0\,kg}{(\sin 20° + 0.55\cos 20°)}$$

$m = \underline{2.33\ kg}$