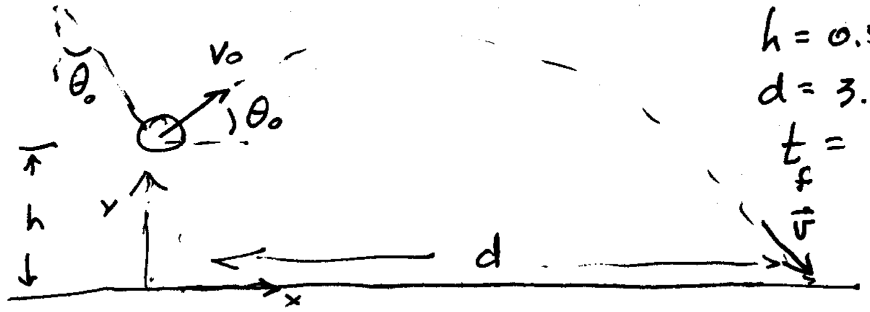
MIDTERM I Ph 1401 (1) 9/03

I.



$h = 0.5\ m$

$d = 3.0\ m$

$t_f = 1.7\ s$

$V_{ox} = V_0 \cos\theta_0$

$V_{oy} = V_0 \sin\theta_0$

1. $V_x = V_{ox}$ $\qquad x = 0 + V_{ox} t$

$V_y = V_{oy} - g t$ $\qquad y = h + V_{oy} t - \frac{1}{2} g t^2$

for the choice of coordinate axes shown above

We are given that $x = d$ at $t = t_f$

So $d = V_{ox} t_f$ $\qquad \boxed{V_{ox} = \frac{d}{t_f} = \frac{3.0\ m}{1.7\ s} = 1.76\ m/s}$

and $y = 0$ at $t = t_f$

So $0 = h + V_{oy}(t_f) - \frac{1}{2} g t_f^2$

$$\boxed{\begin{aligned} V_{oy} &= \tfrac{1}{2} g t_f - \frac{h}{t_f} \\ V_{oy} &= \tfrac{1}{2}(9.8\ \tfrac{m}{s^2})(1.7\ s) - \frac{0.5\ m}{1.7\ s} \\ V_{oy} &= 8.03\ m/s \end{aligned}}$$

2. When she hits

$V_x = V_{ox} = 1.76\ m/s$

$V_y = V_{oy} - g t_f = 8.03 - 9.8\,(1.7) = -8.62\ m/s$

3. The angle θ_0 (between rope + vertical at $t=0$) is the same as the angle between $\vec{V}_0$ and horizontal ... by geometry

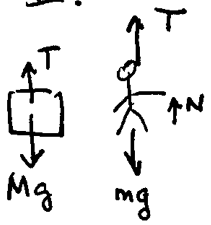
$\tan\theta_0 = \frac{V_{oy}}{V_{ox}} = \frac{8.03\ m/s}{1.76\ m/s} = 4.56 \Rightarrow \theta_0 = 77.6^\circ$

4. Max height when $v_y = 0$ at $t = t_1$ and $x_m = x_1$, $y_m = y_1 - h$ (location rel. to start)

$t_1 = \frac{V_{oy}}{g}$; $x_m = \frac{V_{ox} V_{oy}}{g}$; $y_m = \frac{1}{2}\frac{V_{oy}^2}{g}$

$x_m = \frac{(1.76)(8.03)}{9.8} = 1.44\ m$ $\qquad y_m = \frac{1}{2}\frac{(8.03)^2}{g} = 3.29\ m$ $\qquad$ (Ouch!)

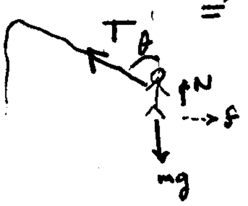
II.



1) The tension he exerts is just enough to lift the package, so

$$T = Mg = (60)(9.8) = 588\,N \Leftarrow$$

2) The tension in the rope is the same.
So he exerts again $T = 588\,N \Leftarrow$



3) The vertical and horizontal components of the ground force on him are shown in the figure.

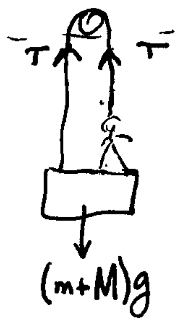
$$N + T\cos\theta = mg \quad \Rightarrow \quad N = mg - T\cos\theta$$
$$f = T\sin\theta \qquad N = (150)(9.8) - (588)\cos 45^\circ$$

$\Rightarrow$ $N = 1054$ Newtons

$\Rightarrow$ $f = (588)\sin 45^\circ = 418$ Newtons

4) $\mu_s \geq \dfrac{f}{N}$ to not slip

$$\mu_s \geq \frac{418}{1054} = 0.395 \Leftarrow$$



5) Considering the (package + Alex) to be the system, the forces on this system are shown at left

So $2T = (m+M)g$

$$T = \tfrac{1}{2}(m+M)g) = \tfrac{1}{2}(60+150)9.8$$

$T = 1029$ Newtons $\Leftarrow$

6) The forces on Alex are shown on the left, where N' = force of package on him

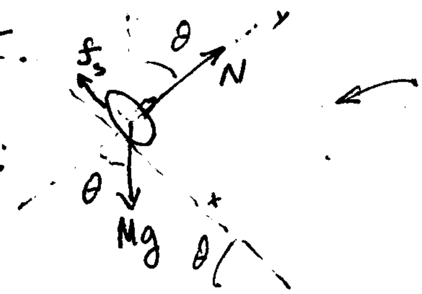
$$T + N' = mg$$
$$N' = mg - T = mg - \tfrac{1}{2}(mg + Mg)$$
$$N' = \tfrac{1}{2}(m-M)g = \tfrac{1}{2}[150-60](9.8)$$

$N' = 294$ Newtons $\Leftarrow$

in the up direction

III.

1\.



Here N = normal force, f_s = friction force

2\. Net force on her (+ sled) is obtained from Newton's 2nd Law

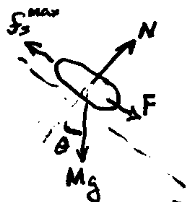
$$\Sigma F_x = 0 \qquad \Sigma F_y = 0$$

$$f_s = Mg\sin\theta \qquad N = Mg\cos\theta$$

$$f_s = (50)(9.8)\sin 25^\circ$$

$$f_s = 207 \text{ Newtons}$$

3\. As he exerts force (F), she will not move until $F_{Tot} > f_s^{max}$



where $f_s^{max} = \mu_s N = \mu_s Mg\cos\theta$

$$f_s^{max} = (0.80)(50)(9.8)\cos 25^\circ$$

$$f_s^{max} = 355 \text{ Newtons}$$

From diagram, $F_{min} + Mg\sin\theta = f_s^{max}$ so $F_{min} = f_s^{max} - Mg\sin\theta = 355\,N - 207\,N$

So Ari must push down the hill with $F_{min} \geq 148$ Newton to get her started. Gentle push means $F \geq 148$ Newtons

4\. Once she starts, kinetic friction exists + she accelerates (a)

$$\Sigma F_x = Mg\sin\theta - f_k = Mg\sin\theta - \mu_k Mg\cos\theta$$

$$\Sigma F_x = \cancel{M}g(\sin\theta - \mu_k\cos\theta) = \cancel{M}a$$

$$a = g[\sin\theta - \mu_k\cos\theta]$$

$$a = 9.8[\sin 25^\circ - (0.10)\cos 25^\circ]$$

$$a = 3.25 \text{ m/s}^2$$

Since a = constant

$$d = \tfrac{1}{2}at_h^2 \quad \text{where } t_h = \text{time she reaches bottom of hill}$$

$$t_h = \sqrt{\frac{2d}{a}} = \sqrt{\frac{2(100)}{3.25}} = 7.84 \text{ seconds}$$

with speed $\quad V_h = at_h = (3.25)(7.84) = 25.5 \text{ m/s}$

5\. On level ground, her acceleration comes only from kinetic friction

$$f_k = -\mu_k Mg = Ma' \quad \text{so} \quad a' = -\mu_k g = -(0.1)(9.8) = -.98 \text{ m/s}^2$$

$$V = V_h + a'(t - t_h) \quad \text{with } V = 0 \text{ when } t - t_h = \frac{-V_h}{a'} = \frac{-25.5 \text{ m/s}}{-.98 \text{ m/s}^2}$$

$$t = t_h + \frac{25.5}{.98} = 7.84 + 26.01 = 33.9 \text{ seconds}$$

Grading guide for first midterm Phys 1401(1) October 2003

Problem I – 30 points
1. 8 pts
2. 7 pts
3. 6 pts
4. 9 pts

Problem II – 35 points
1. 6 pts
2. 4 pts
3. 8 pts
4. 4 pts
5. 6 pts
6. 7 pts

Problem III – 35 points
1. 8 pts
2. 7 pts
3. 6 pts
4. 7 pts
5. 7 pts