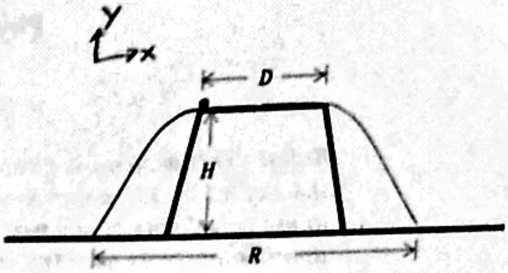
1. Thelma stands at the base of a plateau (see figure to the right) with a flat tip, and a height, $H = (2)(9.8)\ m$. She throws a rock upwards at an angle, θ, so that it just reaches to top of the plateau. The top of the plateau is covered with ice, and can be approximated as *frictionless*. The slides across width $D = (4)(9.8)\ m$ of the plateau in a time $T = 2.0\ s$.



5 PTS

a. What was the initial velocity, v_{0x}, of the rock in the x-direction when it left Thelma's hand?

SINCE THE ROCK "JUST REACHES" THE TOP OF THE PLATEAU, IT HAS NO VERTICAL COMPONENT OF VELOCITY. ALSO, BECAUSE THERE IS NO ACCELERATION IN THE X-DIRECTION, THE VELOCITY THE ROCK SLIDES ALONG THE PLATEAU WITH IS THE SAME AS THE X-COMPONENT OF ITS INITIAL VELOCITY.

$$\hookrightarrow V_{ox} = \frac{D}{T}$$

$$= \frac{(4)(9.8)}{2}$$

$$= \boxed{19.6\ m/s}$$

10 PTS

b. What is θ?

COORDINATE AXES

y, x

TO FIND θ, WE NEED $[V_{ox}\ \&\ V_{oy}]$ OR $[V_{ox}\ \&\ V_o]$

$\downarrow$

$\Delta y = H = (2)(9.8)$

$V_{oy} = ?$

$V_{fy} = 0$

$a_y = -9.8$

$t = ?$

$\downarrow$

$V_{fy}^2 = V_{oy}^2 + 2a\Delta y$

$0^2 = V_{oy}^2 - 2(9.8)(2)(9.8)$

$(2)^2(9.8)^2 = V_{oy}^2$

$(2)(9.8) = V_{oy}$

$V_{oy} = 19.6\ m/s$

$\downarrow$

$\tan\theta = \frac{V_{oy}}{V_{ox}} = 1$

$\longrightarrow \boxed{\theta = 45^\circ}$

$\downarrow$

$\Delta y = H = (2)(9.8)$

$V_{oy} = V_o \sin\theta\ ?$

$V_{fy} = 0$

$a_y = -9.8$

$t = ?$

$\downarrow$

$V_{fy}^2 = V_{oy}^2 + 2a\Delta y$

$0^2 = V_o^2 \sin^2\theta - 2(9.8)(2)(9.8)$

$(2)^2(9.8)^2 = V_o^2 \sin^2\theta$

$\frac{(2)(9.8)}{\sin\theta} = V_o$

$\downarrow$

$V_{ox} = V_o \cos\theta$

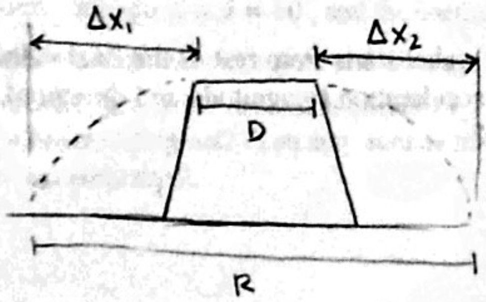
$V_{ox} = \frac{(19.6)\cos\theta}{\sin\theta}$

$1 = \cot\theta$

$\downarrow$

10 PTS

c. **The rock flies off the other side of the plateau, and eventually lands on the ground on the ground. What is the total horizontal distance, R, that it traveled?**



$\Delta x_1 = ?$
$V_{ox} = 2(9.8)$
$V_{fx} = 2(9.8)$
$a_x = 0$
$t_1 = ?$

$\Delta x = V_{ox} t + \frac{1}{2} a t^2$
$\Delta x_1 = (2)(9.8)(2) + 0$
$\Delta x_1 = (4)(9.8)$

$\Delta x_2 = ?$
$V_{ox} = 2(9.8)$
$V_{fx} = 2(9.8)$
$a_x = 0$
$t_2 = ?$

$\Delta x = V_{ox} t + \frac{1}{2} a t^2$
$\Delta x_2 = (2)(9.8)(2) + 0$
$\Delta x_2 = (4)(9.8)$

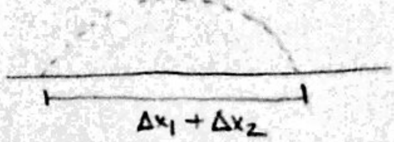
→ FOR BOTH KINEMATICS EQUATIONS WE NEED TIME TO SOLVE FOR Δx_1 & Δx_2

$\Delta y = H = 2(9.8)$
$V_{oy} = 2(9.8)$ ← [FROM PREVIOUS PART]
$V_{fy} = 0$
$a_y = -9.8$
$t_1 = ?$

$V_{fy} = V_{oy} + a_y t$
$0 = (2)(9.8) + (-9.8) t_1$
$t_1 = 2 \text{ s}$
& $t_1 = t_2$

$R = \Delta x_1 + D + \Delta x_2$
$R = (4)(9.8) + (4)(9.8) + (4)(9.8)$
$R = (12)(9.8)$
$\boxed{R = 117.6 \text{ m}}$

NOTE: $[\Delta x_1 + \Delta x_2]$ CAN ALSO BE FOUND BY WRITING THE KINEMATICS EQUATIONS FOR A PROJECTILE LIKE BELOW



2. Bill is in the middle of an empty field, and launches off a model rocket. The rocket has a mass of m Assume that the rocket travels in a straight line upwards.

5pts

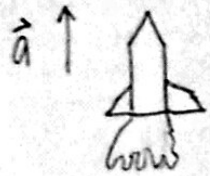
a. The engines fired for a time, T, and the rocket starts from rest. If the final velocity of the rocket is v, what is the average acceleration (magnitude and direction), a, of the rocket while its engine was firing?

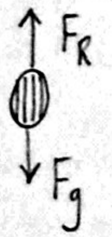
$$a_{ave} = \frac{\Delta V}{\Delta t} = \frac{V_f - V_i}{t_f - t_i} = \frac{v - 0}{T - 0}$$

$$\boxed{a_{ave} = \frac{v}{T}, \text{ upwards}}$$

20pts

b. Neglect any drag force (air resistance) on the rocket. What is the magnitude and direction of the force, $\vec{F}_R$, that the rocket engines exert on the rocket as it fires?





$\uparrow F_{net}$

$$\Sigma F_x = 0$$

$$\Sigma F_y = F_R - F_g = F_{net}$$

Solve for F_R:

$$F_R = F_{net} + F_g$$

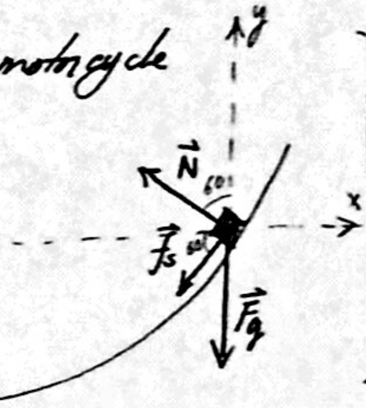
$$F_R = ma + mg \longrightarrow F_R = m(a+g)$$

Plug in our average acceleration from (a):

$$\boxed{F_R = m\left[\frac{v}{T} + g\right], \text{ upwards}}$$

There are 3 forces acting on the motorcycle

- Weight, $\vec{F}_g$, $F_g = mg$
- Normal, $\vec{N}$, perp. to surface
- Friction, $\vec{f}_s$, parallel to surface

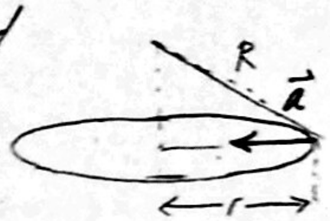


10 pts.

When the motorcycle is about to slide out, friction points inward

In uniform circular motion, $\vec{a}$ points to the center of the circular trajectory, and

$|\vec{a}| = v_m^2/r$



3 pts.

But $r = R\sin\theta$, so $a = v^2/R\sin\theta$ 2 pts.

- $\vec{F} = m\vec{a}$ in xy axes (with $\theta = 60°$) 8 pts

$$\begin{cases} -N\sin\theta - f_s\cos\theta = ma_x = -mv_m^2/R\sin\theta \\ N\cos\theta - f_s\sin\theta - mg = ma_y = 0 \end{cases}$$

$$\Rightarrow \begin{cases} N\sin\theta + \mu_s N\cos\theta = mv_m^2/R\sin\theta \\ N\cos\theta - \mu_s N\sin\theta = mg \end{cases}$$

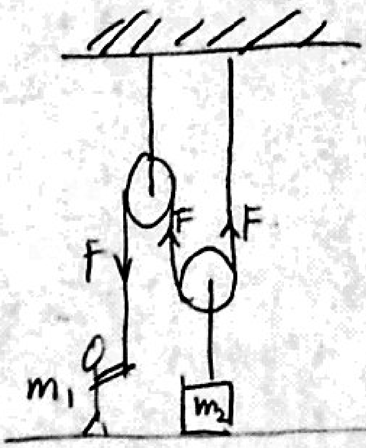
1 pt.

$$\underset{\text{divide}}{\Rightarrow} \frac{v_m^2}{gR\sin\theta} = \frac{\sin\theta + \mu_s\cos\theta}{\cos\theta - \mu_s\sin\theta}$$

$$\Rightarrow \frac{v_m^2}{g} = R\sin\theta\left(\frac{\sin\theta + \mu_s\cos\theta}{\cos\theta - \mu_s\sin\theta}\right) = \frac{35}{2}$$

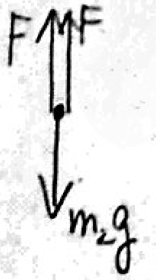
1 pt.

4. Solution:



(a) Free body diagram for m_2

12



m_2 just starts to leaves means that the normal force on m_2 is 0, and also, the acceleration is 0 for "just" to start. So net force along y-direction is 0.

FBD: 5.

Newton's 2nd: 3.

$$2F = m_2 g$$

Final answer: 4.

$$\boxed{F = \frac{1}{2} m_2 g.}$$

(b). Free body diagram for m_1

13.

M is the critical value for m_2. When $m_2 = M$, Tom will "just" cannot be able to lift m_2. that means Tom is "just" leaving the ground. So net force along y-direction is 0.

FBD: 5.

Newton's 2nd: 4.

$$m_1 g = F = \frac{1}{2} M g \quad (\text{where } M = m_2).$$

Final answer: 4.

$$\boxed{M = 2m_1}$$