Hills & Ramps

1. A car is parked on a steep hill in San Francisco. The base angle of the hill is 10°. If the parking brake were to suddenly fail, calculate:
   a. the acceleration of the car down the hill.

no brakes → frictionless ∴ $a = g\sin\theta = 10\sin 10$

$a = 1.74\ m/s^2$

   b. How long would it take the car to roll 30 meters down the hill?

$x = \frac{1}{2}at^2 + v_i t + x_i \qquad 30 = \frac{1}{2}(1.74)t^2$

$t^2 = 34.55$

$t = 5.88\ s$

   c. How fast would the car be going after rolling down 30 meters?

$v = at + v_i \qquad v = (1.74)(5.88) + 0$

$v = 10.2\ m/s$

2. Some physics students are rolling a ball (initial speed = 0) down a ramp with a base angle θ. The ball rolls a distance of 85 cm down the ramp, and then levels off. They determine that the ball is rolling with speed of 1.2 m/s when the ball gets to the bottom of the ramp.
   a. How many seconds did it take the ball to roll down the ramp?

$x = .85m$, $v_i = 0\ m/s$, $v_f = 1.2\ m/s$

$\bar{v} = \frac{v_i + v_f}{2} = \frac{0+1.2}{2}$

$\bar{v} = 0.6\ m/s$

$\bar{v} = \frac{\Delta x}{t} \qquad .6 = \frac{.85}{t}$

$t = 1.42\ s$

   b. What was the acceleration of the ball down the ramp?

$a = \frac{v_f - v_i}{t} = \frac{1.2 - 0}{1.42}$

$a = 0.847\ s$

   c. What was the base angle, θ?

$a = g\sin\theta \qquad 0.847 = (10)\sin\theta$

$\sin\theta = .0847$

$\theta = 4.86°$

3. A bicyclist, mass 90 kg is coasting along a road with a constant speed of 15 m/s. Suddenly, the road becomes a hill, with a base angle of 5°. The bicyclist does not try to pedal, and slows to a stop. Assuming the hill is of constant grade, and ignoring friction, calculate:
   a. the acceleration of the bicyclist.

$a = g\sin\theta = (10)\sin 5$

$a = 0.87\ m/s^2$

   b. the time needed to stop.

$a = \frac{v_f - v_i}{t} \qquad -0.87 = \frac{0-15}{t}$

$t = 17.2\ s$

   c. the distance coasted up the hill.

$x = \frac{1}{2}at^2 + v_i t = \frac{1}{2}(-.87)(17.2)^2 + (15)(17.2)$

$x = 129\ m$

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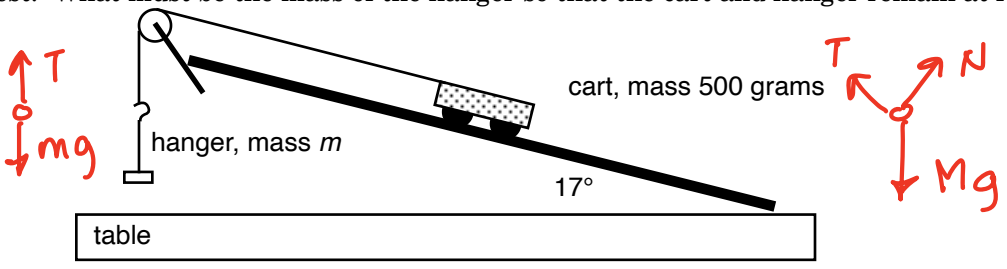
d. the net force on the bicyclist while coasting to a stop.

$\Sigma F = ma = (90)(.87) = 78.3\ N$

4. A physics teacher is doing a demonstration on components of gravity. There is a frictionless lab cart and track set up so that the track has a base angle of 17°. The cart has a mass of 500 grams. The teacher wants to put some mass on the hanger so that the cart and pulley are balanced and stay at rest. What must be the mass of the hanger so that the cart and hanger remain at rest?



$\Sigma F_{sys} = 0$

$mg - Mg\sin\theta = 0$

$m(10) = (.5)(10)\sin 17$

$m = 0.15\ kg$

5. After a real good snow fall, some little kids are tobogganing on a big hill. The base angle of the hill is 15°. The total mass of the kids and their toboggan is 120 kg. The kids start from rest at the very top of the hill, and coast 65 meters to the bottom of the hill in 8.6 seconds.

$m = 120\ kg$
$\theta = 15°$
$d = 65\ m$
$t = 8.6s$

a. What was the acceleration of the kids on the toboggan? (Hint: there is friction present, so you cannot just use $a = g\sin\theta$.)

$x = \frac{1}{2}at^2 + v_i t + x_i$

$65 = \frac{1}{2}a(8.6)^2$

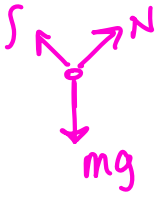
$a = 1.76\ m/s^2$

b. What was the net force acting on the kids?

$\Sigma F = ma = (120)(1.76)$

$\Sigma F = 211\ N$

c. What was the component of their weight pulling them down the hill?



$w_{\parallel} = mg\sin\theta = (120)(10)(\sin 15)$

$w_{\parallel} = 311\ N$

d. What was the force of friction acting on them while they were sliding down the hill?

$\Sigma F_{\parallel} = ma$

$mg\sin\theta - f = ma$

$311 - f = 211$

$f = 100\ N$

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6. You (mass 55 kg) are enjoying yourself one day at Water World on a giant water slide. You know that the base angle of the slide is a whopping 20°. The slide itself is 125 meters long. Starting from rest, you slide to the bottom in a time of 11 seconds.

$d = 125\text{m}$
$\theta = 20°$
$t = 11\text{ s}$
$v_i = 0$

a. What was your acceleration down the slide?

$x = \frac{1}{2}at^2 + v_i t + x_i$

$125 = \frac{1}{2}a(11)^2$

$a = 2.07\ \text{m/s}^2$

b. What was the force of friction acting on you while you were sliding?

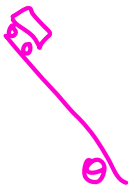
$\Sigma F_{\parallel} = ma$

$mg\sin\theta - f = ma$

$(55)(10)\sin 20 - f = (55)(2.07)$

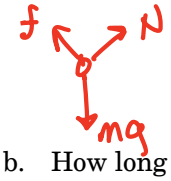
$f = 74.5\text{ N}$

7. A 900 kg roller coaster car is at rest at the top of the first big hill (base angle of 35°). The hill is 85 meters long. Assuming there is a constant frictional force of 1200 N acting on the car,



$\theta = 35°$
$m = 900$
$d = 85\text{m}$
$f = 1200\text{N}$

a. What is the net force on the roller coaster car?



$\Sigma F_{\parallel} = ma$ $\quad mg\sin\theta - f = ma$

$\Sigma F_{\parallel} = (900)(10)\sin 35 - 1200 = 5162 - 1200$

$\Sigma F = 3962\text{ N}$

b. How long would it take for the car to reach the bottom of the hill?

$\Sigma F = ma$

$3962 = 900\,a$

$a = 4.4\ \text{m/s}^2$

$x = \frac{1}{2}at^2 + v_i t + x_i$

$85 = \frac{1}{2}(4.4)t^2$

$t^2 = 38.62$

$t = 6.21\text{ s}$

c. How fast would the coaster be going at the bottom of the hill?

$v = at + v_i$

$v = (4.4)(6.21) + 0$

$v = 27.3\ \text{m/s}$