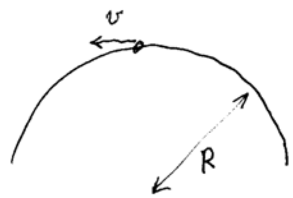
Week 4    5-38, 44, 46    Bonus 63 & ~~67~~
6-2, 4, 5

5-38 : loop de loop roller coaster




$R = 6.3\ m$    $m = 60\,kg$
$v = 9.7\ m/s$
forces of seat on person ?

sol : First calc the acceleration $= a = \frac{v^2}{R} = \frac{(9.7)^2}{6.3} = 14.9\,m/s^2$
this is downwards, and the magnitude is larger than $g = 9.8\,m/s^2$

So, the seat must press downwards on the passenger

second : quantitative

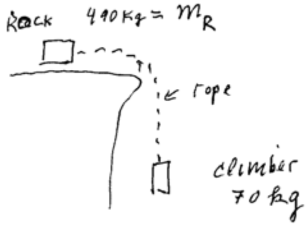
net force $F = m \cdot a = 60 \times 14.9 =$ ~~540N~~ 894N

$F =$ weight $+ f$ ; $f$ = force of seat (downwards) on passeng

$f = F - mg =$ ~~590~~ 894N $- \underbrace{60 \times 9.8}_{588} =$ **306 N** downward
↑ this is nearly half the weight.

conclusion :
The rider can safely unbuckle seat belt

**5-44**: Repeat example 5-4 assuming coeff. friction $\mu$ between rock & ice = $0.057 \equiv \mu$




a) force of friction on rock $\equiv f$

$f$ = normal force × $\mu$

$= 9.8 \times 490 \times 0.057 = 525\,N$

$T$ = Tension in rope

b) net force on rock


to the right is positive

$T - f = m_R \times a$

$T - 525 = 490 \times a$ (1)

c) net force on climber


$mg = 70 \times 9.8 = 686\,N$

$m_{cl}g - T = m_c \times a$

$686 - T = 70 \times a$ (2)

d) math: eliminate T from Eqs (1) & (2)

$T - 525 = 490 \times a$

$686 - T = 70 \times a$

add: $686 - 525 = 560 \times a$

$T - 525 + (686 - T) = (490 + 70)a$

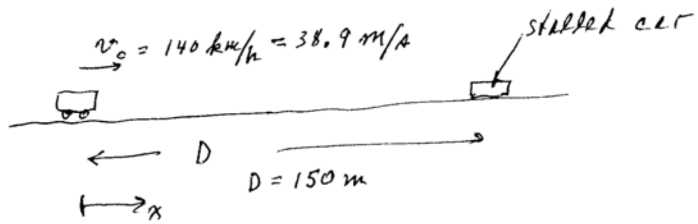
$a = \frac{161}{560} = \boxed{0.29\ m/s^2}$

e) Time for rock to slide off the edge (distance = 51 m)

$51\,m = \frac{1}{2} a t^2$ $\quad t^2 = \frac{51 \times 2}{0.29} = 355\ s^2$ $\quad \boxed{t = 18.8\ s}$

5-46 : Train, coeff. friction $\mu = 0.58$

$v_0 = 140\ \text{km/h} = 38.9\ \text{m/s}$




$D = 150\ \text{m}$

will the train stop in time ?

$x = v_0 t - \frac{1}{2} a t^2$ ← don't use

stopping force on train = friction force = $\mu \times Mg$ (M: mass of train)

accel. of train $= \dfrac{\text{friction force}}{\text{mass}} = \dfrac{\mu \times Mg}{M} = \mu g = 5.68\ \text{m/s}$
$0.58 \times 9.8$

stopping distance = $S$

$\frac{1}{2} v_f^2 - \frac{1}{2} v_0^2 = S \times a$

($v_f = 0$, $v_0^2 = (38.9)^2$)

$0 - \frac{1}{2} \times (38.9)^2 = S \times (-5.68)$

$S = \dfrac{(38.9)^2}{2 \times 5.68} = \boxed{133\ \text{m}}$

stopping distance $S$ is less than distance to stalled car

∴ **Train stops in time**

time to stop:

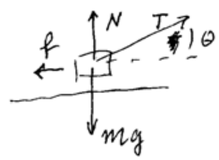
$v = v_0 + at$

$0 = 38.9 + (-5.68)\, t$

$t = \dfrac{38.9}{5.68} = 6.85\ \text{s}$

Bonus 63 : Example 5.11 dragging a trunk $\mu = 0.75$


plot tension as a function of rope angle




① $T\sin\theta + N = mg$ ← vertical directn

② $f = T\cos\theta$ (forces in horiz direction cancel since zero accel)

③ $f = N \times \mu$ ← law of friction

method : Eliminate the normal force N (it is less than mg)
Eliminate the friction force f

② + ③ $N \times \mu = T\cos\Theta$ $\therefore N = \dfrac{T\cos\theta}{\mu}$

① $T\sin\theta + N = mg$

$T\sin\theta + T\dfrac{\cos\theta}{\mu} = mg$

$$\boxed{T = \frac{mg}{\sin\theta + \frac{\cos\theta}{\mu}}}$$

To find the minimum of T, look for the maximum of the denominator $\sin\theta + \frac{1}{\mu}\cos\theta = den$

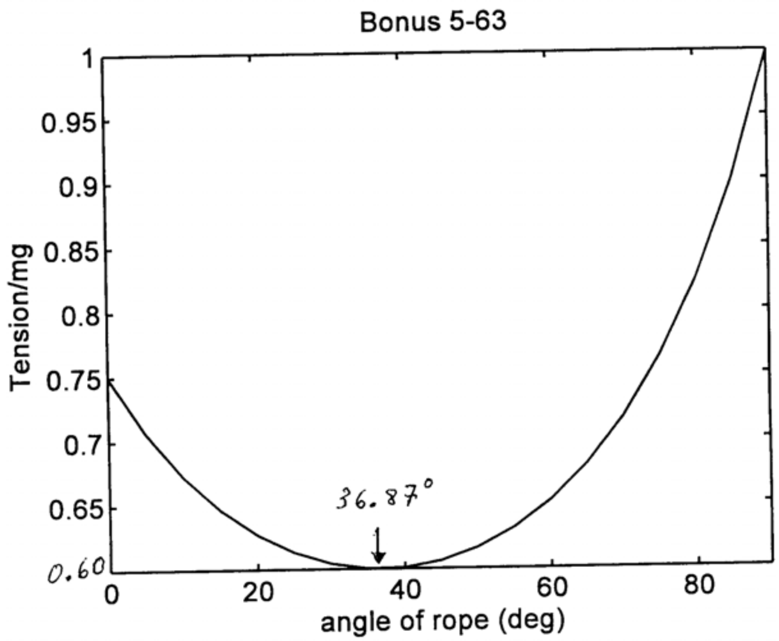
$\dfrac{d\,(den)}{d\theta} = 0 = \dfrac{d}{d\theta}\left[\sin\theta + \frac{1}{\mu}\cos\theta\right] = \cos\theta_m - \frac{1}{\mu}\sin\theta_m$

$\therefore \tan\Theta_m = \mu$ $\theta_m = 36.87^\circ$ $\sin\theta_m + \frac{1}{\mu}\cos\theta_m =$

$1.66 = 0.6 + \frac{1}{.75} \times 0.8$

$$\boxed{T/mg = \frac{1}{1.66} = 0.6 \qquad \theta_{min} = 36.87^\circ}$$

min



Bonus 5-63
Tension/mg
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.60
0
20
40
60
80
angle of rope (deg)
36.87°

6-2: If the scalar product between two non-zero vectors is zero, this means that the two vectors are perpendicular to each other

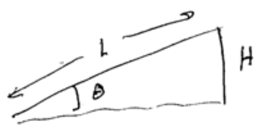
6-4 You pick up a suitcase, then (gently) put it down (again). What work do you do?

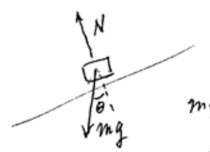
Answer: on the way up you do : weight of suitcase × height
on the way down you do : − the answer above
reason for − sign: the force your hand exerts is up (so as to prevent the suitcase from falling) but the direction of motion of your hand is down.

total work you do = 0

you pick up a suitcase, then drop it:
your work is weight of suitcase × height.

6-5: work to drag a piano up a ramp.




$mg\cos\theta$ = normal force N of ramp on piano

f friction $= \mu \times mg\cos\theta$

length of ramp $L = \frac{H}{\sin\theta}$

total force you exert = component of weight along ramp plus the force to overcome friction $= mg\sin\theta + \mu mg\cos\theta$

Your work $= L \times$ your force $= \frac{H}{\sin\theta} \times mg(\sin\theta + \mu\cos\theta)$

$= H \times mg\left(1 + \mu\frac{\cos\theta}{\sin\theta}\right)$

The steeper the angle the less work you do