Ch5 Applications of Newton's Equations

1) Static equilibrium
2) Multiple objects
3) Frictional forces
4) Circular motion

Solution strategies: expanded three-step solution (2a 2b 2c)

1) Understand the problem, putting information onto diagrams

2a) Select a convenient coordinate system
→ That would $\boxed{\text{simplify}}$ the analysis
- → Most forces to point along the axes (no need to project components onto axes)
- → Motion of interest to point along an axis

2b) Free-body diagram for forces acting on each object
- To find easily $\boxed{\text{net force}}$ on that object.
- If there is some force not pointing along axes (of the selected coord. system), project its components along axes.

2c) Write Newton's 2nd Law for each object along each direction of the selected coordinate system
→ In 2D: $\vec{F}_{net} = m \cdot \vec{a} \longrightarrow \begin{cases} F_{net,x} = m \cdot a_x \\ F_{net,y} = m \cdot a_y \end{cases}$
(m is a scalar)

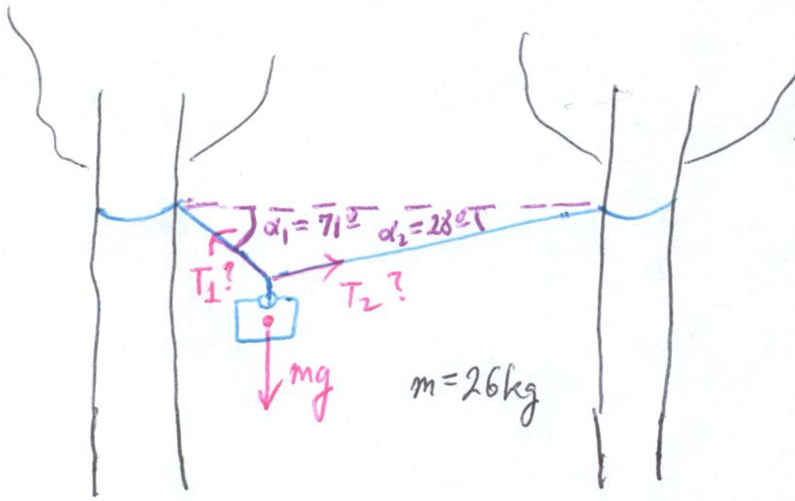
3) Solve for unknown(s) by plugging numeric values in the correct units. Check to make sure your numbers make sense.

Example 1 : Static Equilibrium:

$\to \vec{a}=0 \leftrightarrow \vec{F}_{net}=0 \leftrightarrow$ 2D $\begin{cases} F_{net,x}=0 \\ F_{net,y}=0 \end{cases}$

5.36

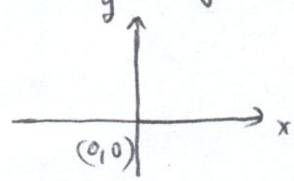
Step 1:



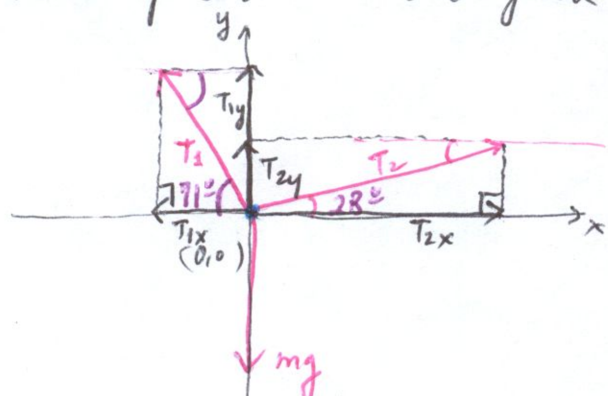
→ Find T_1 & T_2 for backpack to stay in static equilibrium

$\hookrightarrow \vec{F}_{net}=0$

Step 2a: Most convenient coord. system, standard Cartesian coord. syst. Since we can align at most one of three forces along an axis mg points along $-y$



Step 2b: A dot represent our back pack:



Free-body diagrams of forces acting on back pack

Components:

$\vec{T}_1 = T_{1x}\hat{\imath} + T_{1y}\hat{\jmath}$
$= T_1\cos 71°\,\hat{\imath} + T_1 \sin 71°\,\hat{\jmath}$

$\vec{T}_2 = T_{2x}\hat{\imath} + T_{2y}\hat{\jmath}$
$= T_2\cos 28°\,\hat{\imath} + T_2 \sin 28°\,\hat{\jmath}$

$\hookrightarrow$ Determine net forces in each direction:

$$\vec{F}_{net}: \begin{cases} F_{net_x} = T_{2x} - T_{1x} = T_2\cos 28° - T_1\cos 71° \\ F_{net_y} = T_{1y} + T_{2y} - mg = T_1\sin 71° + T_2\sin 28° - mg \end{cases}$$

Step 2c: Write 2nd Newton's Law in each direction:

$$F_{net,x} = m \cdot a_x = 0 \quad \text{or} \quad T_2 \cos 28 - T_1 \cos 71^\circ = 0 \quad (1)$$

$$F_{net,y} = m \cdot a_y = 0 \quad \text{or} \quad T_1 \sin 71^\circ + T_2 \sin 28^\circ - mg = 0 \quad (2)$$

Step 3: solve system of 2 equations (1) & (2) for 2 unknowns T_1 & T_2:

(1) solve for T_1: $\quad T_1 = \frac{\cos 28^\circ}{\cos 71^\circ} T_2$

(2) $\quad \frac{\cos 28^\circ \sin 71^\circ}{\cos 71^\circ} T_2 + \sin 28^\circ T_2 = 26 \cdot 9.81$

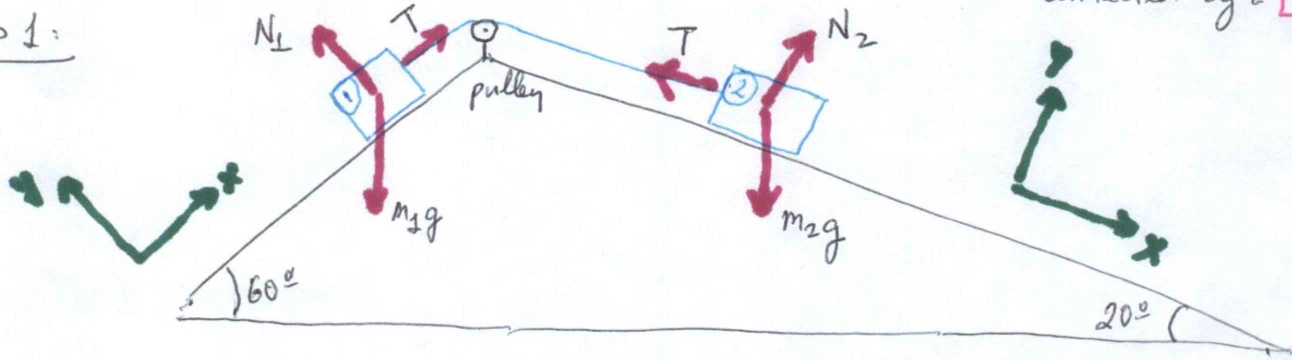
$$T_2 = \frac{26 \cdot 9.81}{\cos 28^\circ \cdot \tan 71^\circ + \sin 28^\circ}$$

$$T_2 = 84 N$$

(1) $\quad T_1 = \frac{\cos 28^\circ}{\cos 71^\circ} 84\ N = 228\ N$ much larger than tension in rope 2 → makes sense!

Example 2: Multiple Objects: two boxes of masses m_1 & m_2 on slopes of angles 60° & 20°, respectively, connected by a $\boxed{\text{massless}}$ rope

Step 1:



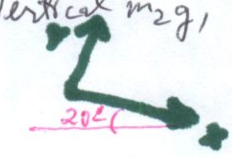
Motion of these two objects:
a) going together: $a_1 = a_2 = a$
b) frictions b/w boxes & slopes are negligible for this application
c) direction of motion:
(i) rope going CW @ pulley (① up ② downhill)
(ii) rope going CCW @ pulley (① down ② up)
(iii) static equilibrium ($a=0$)

we will start our analysis assuming (i). Sign & value of a will tell what is the actual direction of motion ($a>0 \rightarrow$ (i); $a<0 \rightarrow$ (ii); $a=0 \rightarrow$ (iii))

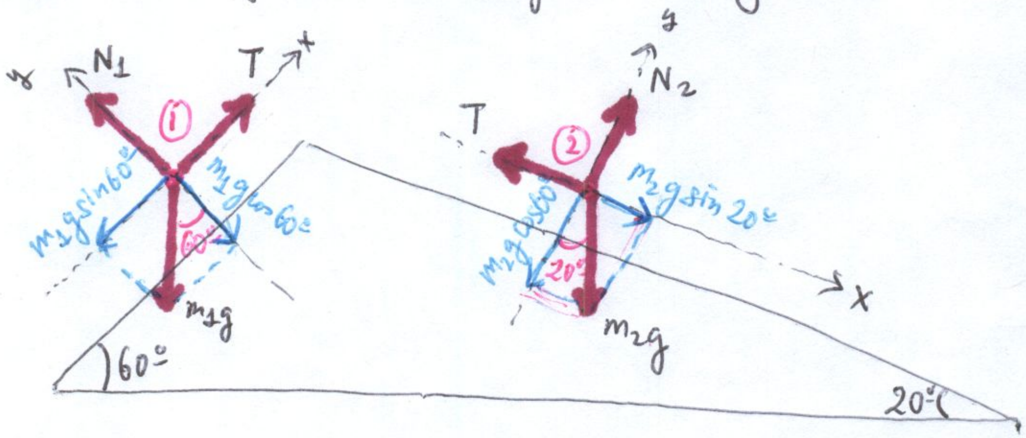
Step 2a Select most convenient coordinate system:
↳ forces & direction of motion along axes

Box ①: Motion on slope of 60° above horizontal
Forces: vertical m_1g, tension T (along x), normal N_1 (along y)

Box ②: Motion on slope of 20° above horizontal
Forces: vertical m_2g, tension T (along −x), normal N_2 (along y)



Step 2b: Free-body diagrams for each object with components for those forces not aligned along axes



Net force on ①

$$\begin{cases} F_{net,1,x} = T - m_1 g \sin 60° \\ F_{net,1,y} = N_1 - m_1 g \cos 60° \end{cases}$$

Net force on ②

$$\begin{cases} F_{net,2,x} = m_2 g \sin 20° - T \\ F_{net,2,y} = N_2 - m_2 g \cos 20° \end{cases}$$

Step 2c: Write 2nd Newton's Law for each object in each direction

$$\boxed{\begin{array}{ll} \text{Box ①} & \begin{cases} T - m_1 g \sin 60° = m_1 \cdot a & (1) \\ N_1 - m_1 g \cos 60° = 0 & (2) \end{cases} \\ \\ \text{Box ②} & \begin{cases} m_2 g \sin 20° - T = m_2 \cdot a & (3) \\ N_2 - m_2 g \cos 20° = 0 & (4) \end{cases} \end{array}}$$

soh cah toa

70% problem solved.

Step 3: Solve for unknowns.

Example: assume masses are given m_1 & m_2, find acceleration of system a

↳ solvable? $\begin{cases} \text{4 equations} \\ \text{unknowns: } T, N_1, N_2, a \end{cases}$ Yes!

Solution: 1st eliminate T: from (1) solve for T:

(1) $T = m_1 a + m_1 g \sin 60°$

→ (3) $m_2 g \sin 20° - m_1 a - m_1 g \sin 60° = m_2 a$

$$\boxed{a = \frac{m_2 g \sin 20° - m_1 g \sin 60°}{m_1 + m_2}}$$

Note: given the selected coord. systems this $-$ allows option (ii) for direction of motion of the two boxes (say $m_2 \gg m_1$). Signs are very important in physics equations!

With $-$ we have 3 options for a (depending on the actual ratio of the masses $\frac{m_2}{m_1}$)

(i) if $m_2 \sin 20° > m_1 \sin 60°$ or $\frac{m_2}{m_1} > \frac{\sin 60°}{\sin 20°} = 2.53$

$\Rightarrow a > 0$ or rope CW @ pulley or $m_1 \uparrow$ $m_2 \downarrow$

(ii) if $m_2 \sin 20° < m_1 \sin 60°$ or $\frac{m_2}{m_1} < \frac{\sin 60°}{\sin 20°} = 2.53$

$\Rightarrow a < 0$ or rope CCW @ pulley or $m_1 \downarrow$ $m_2 \uparrow$

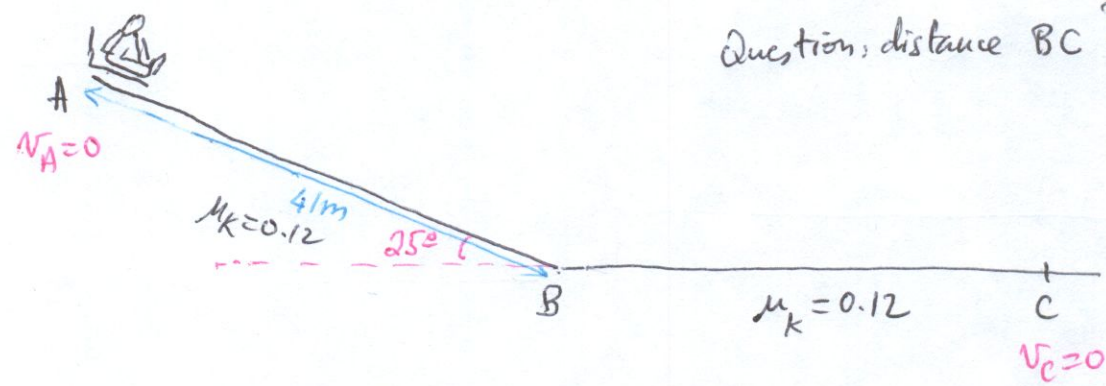
(iii) if $\frac{m_2}{m_1} = 2.53$ $\Rightarrow a = 0$ or static equilibrium

Example 3: Frictional Forces : real life application of Newton's 2^{nd} F^s BC

Child sledding down hill of 41m length (AB), then on flat bottom, with $\mu_K = 0.12$, till it stops.

Step 1:

Question: distance BC?



Motion of child & sled:

a) Why do they stop @ C? → Because of friction

b) Between A & B : constant acceleration motion

c) Between B & C : $F_k = \mu_k N = \mu_k mg$ (constant)

→ constant acceleration motion

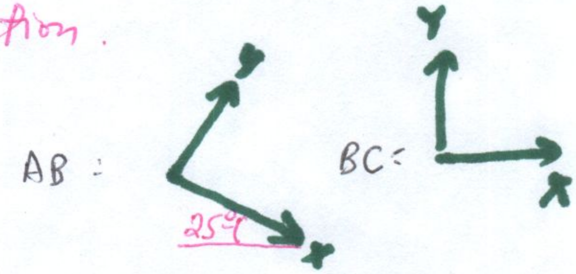
↳ We can describe with physics learned so far:

→ Constant - acceleration motion

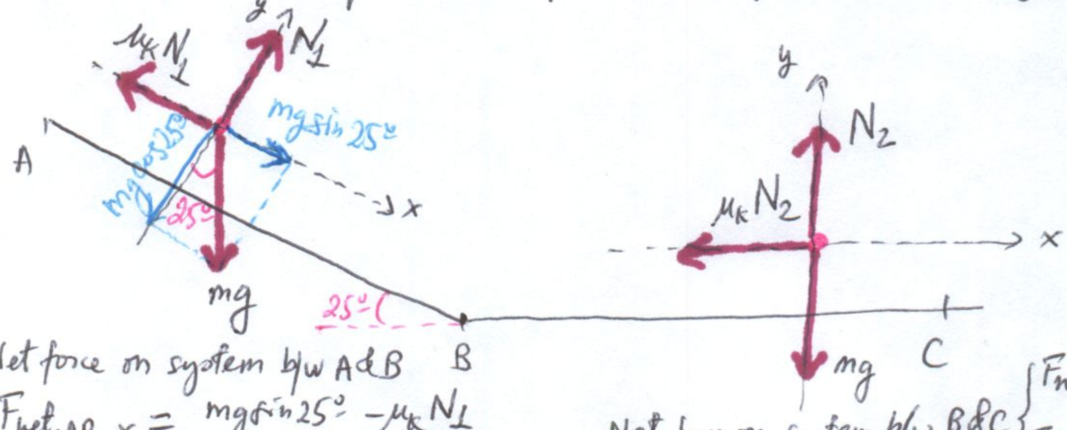
→ Newton's equation.

Step 2a: Select convenient coord. systems

↳ Direction of motion along x-axis



Step 2b: FBD's with components for those forces not aligned along axes



Net force on system b/w A & B

$F_{net,AB,x} = mg \sin 25° - \mu_K N_1$

$F_{net,AB,y} = N_1 - mg \cos 25°$

Net force on system b/w B & C

$$\begin{cases} F_{net,BC,x} = -\mu_K N_2 \\ F_{net,BC,y} = N_2 - mg \end{cases}$$

Step 2c: Write 2^{nd} Newton's Law for system in each part of its trajectory:

$$\boxed{\begin{array}{ll} A \text{ to } B: & \begin{cases} mg\sin 25° - \mu_K N_1 = m \cdot a_1 & (1) \\ N_1 - mg\cos 25° = 0 & (2) \end{cases} \\ B \text{ to } C: & \begin{cases} -\mu_K N_2 = m \cdot a_2 & (3) \\ N_2 - mg = 0 & (4) \end{cases} \end{array}}$$

70% of solution.

Step 3: Find $\underbrace{\text{distance } BC}_{(x-x_0)_{BC}}$ → need $\begin{cases} 1) \; a_2 \\ 2) \; v_B \end{cases}$ ⇒ $\frac{v_C^2 - v_B^2}{2a_2} = (x-x_0)_{BC}$

a_2: (3) $a_2 = -\frac{\mu_K N_2}{m} \underset{(4)}{=} -\frac{\mu_K \cancel{m} g}{\cancel{m}} = -\mu_K g$

v_B: velocity of child & sled @ bottom of hill.

(2) $N_1 = mg\cos 25°$ ⇒ (1) $a_1 = g\sin 25° - \mu_K g\cos 25°$

$a_1 = g(\sin 25° - \mu_K \cos 25°)$

We know $\begin{Bmatrix} a_1 \\ (x-x_0)_{AB} = 41m \\ v_A = 0 \end{Bmatrix}$ ⇒ Use kinematic eq #3 to find v_B:

$$\frac{v_B^2 - 0}{(x-x_0)_{AB}} = 2 \cdot a_1$$

$$\Rightarrow v_B = \sqrt{2a_1(x-x_0)_{AB}} = \sqrt{2 \cdot \underset{\uparrow 9.81\frac{m}{s^2}}{g}(\sin 25° - \underset{\uparrow 0.12}{\mu_K}\cos 25°) \cdot 41}$$

$$\boxed{v_B = 15.9\ \frac{m}{s}}$$

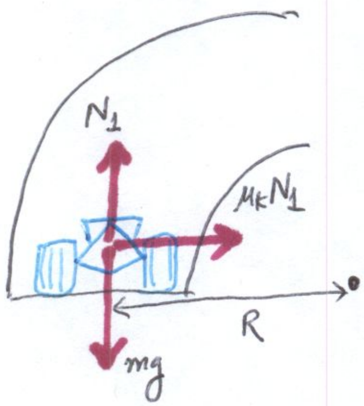
⇒ Kin eq. #3 b/w B & C: $\boxed{(x-x_0)_{BC} = \frac{0 - 15.9^2}{-2 \cdot 0.12 \cdot 9.81} = 107m}$

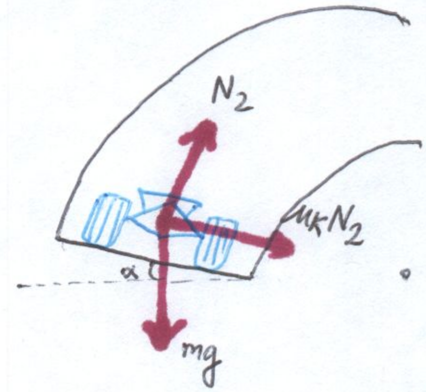
Example 4: Circular Motion : Race car tracks

Step 1:

Flat race car tracks (turns)

Slanted race car tracks (turns)



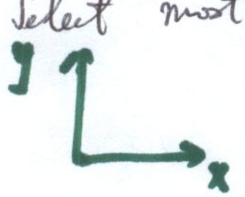


Motion of race car at turns:

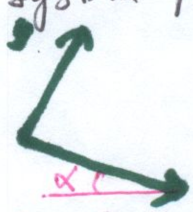
a) Race cars take turns in UCM (if you go at already max speed at turns, if you accelerate, you will go off curve). They have to change direction of velocity to follow the turn → need an acceleration (not along the turn, but towards center of curvature) $a = \frac{v^2}{R}$

b) What keep race cars on track? or what agent provides $a = \frac{v^2}{R}$? → Friction provides the acceleration toward center of curvature → wide tires = more friction → can go faster @ turn and sharper

Step 2a Select most convenient coord system for each situation

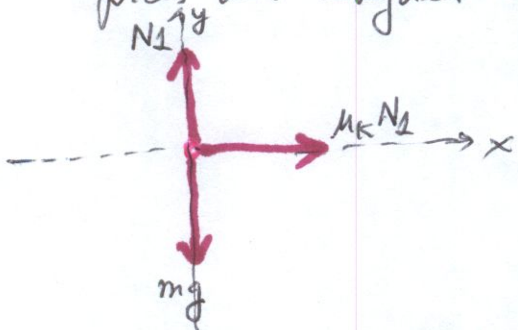


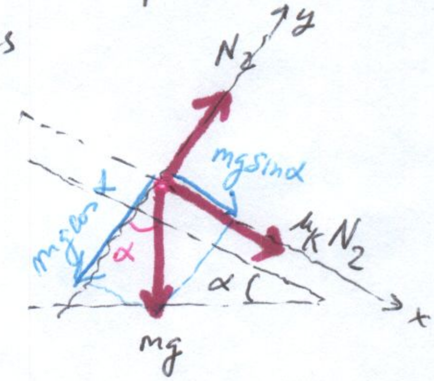
Flat track



Slanted track

Step 2b: FBD's for each situation, with components for those forces not aligned along axes





Net force on race car, flat track

$$F_{net,F,x} = \mu_K N_1$$
$$F_{net,F,y} = N_1 - mg$$

Net force on race car, slanted track

$$F_{net,s,x} = \mu_K N_2 \boxed{+ mg\sin\alpha}$$
$$F_{net,s,y} = N_2 - mg\cos\alpha$$

Step 2c: write 2nd Newton's Law for each situation:

Flat track $\begin{cases} \mu_K N_1 = m \cdot \dfrac{v^2}{R} \\ N_1 - mg = 0 \end{cases}$ $\rightarrow v_{Flat} = \sqrt{\mu_K g R}$

Slanted track $\begin{cases} \mu_K N_2 + mg\sin\alpha = m \cdot \dfrac{v^2}{R} \\ N_2 - mg\cos\alpha = 0 \end{cases}$ $\rightarrow v_{slanted} = \sqrt{gR(\sin\alpha + \mu_K \cos\alpha)}$

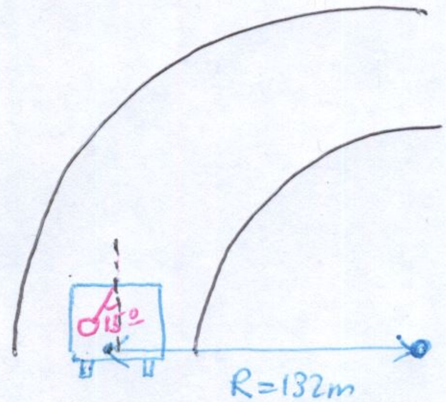
Step 3: for example: $\begin{cases} \alpha = 20^\circ \\ \mu_K = 0.2 \end{cases} \rightarrow \dfrac{v_{slanted}}{v_{flat}} = \dfrac{\sqrt{\sin\alpha + \mu_K\cos\alpha}}{\sqrt{\mu_K}} = 1.63$

$\rightarrow$ Slanted track allows higher speed @ turns!

5.25

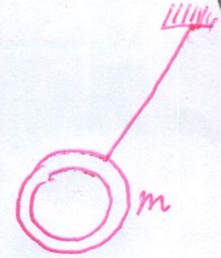
Step 1: Train in UCM turning on a flat track (unbanked)

$\left\{ \begin{array}{l} R = 132\,m \\ v\,?\ > 45\,\frac{km}{h} \text{ (limit)} \\ \boxed{\text{Strap @ } 15^\circ \text{ to vertical}} \end{array} \right.$



(Back view of train)

strap:



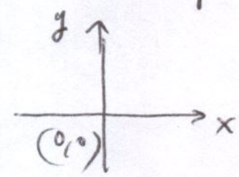
Consideration of motion of strap, to calculate train's speed

a) Strap in UCM $\longleftrightarrow$ $a = \frac{\boxed{v}^2}{R}$ acceleration towards center of curvature

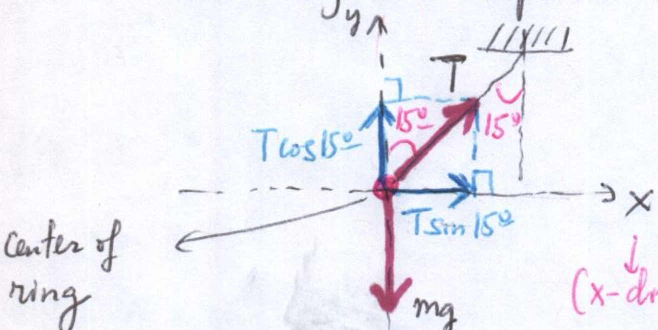
b) We need a for strap. $\rightarrow$ we need $\vec{F}_{net,\,strap}$ for a

Step 2a: convenient coord. system: (forces on strap)

$\hookrightarrow$ mg & T $\Rightarrow$



Step 2b: FBD for strap: most weight of strap is in the ring $\rightarrow$ this is our object $\rightarrow$ replace it by a dot:



$F_{net,\,strap,\,x} = T \sin 15^\circ$

$F_{net,\,strap,\,y} = T \cos 15^\circ - mg$

(x-direction = direction toward center of curvature)

Step 2c: Write 2nd Newton's equations for strap (ring)

$$\left\{ \begin{array}{l} T \sin 15^\circ = m \cdot a \\ T \cos 15^\circ - mg = 0 \rightarrow T = \frac{mg}{\cos 15^\circ} \end{array} \right.$$

Step 3: solve for T & v:

$$\left\{\begin{array}{l} T \sin 15^\circ = m \cdot \dfrac{v^2}{R} \\ T = \dfrac{mg}{\cos 15^\circ} \end{array}\right\} \quad \frac{\cancel{m}g}{\cos 15^\circ} \sin 15^\circ = \cancel{m} \cdot \frac{v^2}{R} \text{ or } \boxed{g \tan 15^\circ = \frac{v^2}{132}}$$

$$\rightarrow v = \sqrt{132 \cdot \tan 15^\circ \cdot 9.81} = 18.6 \frac{m}{s}$$

$$v_{limit} = 45 \frac{\cancel{km}}{\cancel{h}} \cdot \frac{1\cancel{h}}{3600s} \frac{1000m}{1\cancel{km}} = \frac{45}{3.6} \frac{m}{s} = 12.5 \frac{m}{s}$$

train went $6.1 \frac{m}{s}$ above speed limit

Ch6 Work, Energy, Power

Analysis of motion of an object:
- Kinematic equations (v, x, a, t) (Ch. 2 & 3)
- Newton's 2nd Law ($\boxed{F}$ Force, m, a) (Ch 4 & 5)
- $\boxed{\text{Work}}$ & energy (Kinetic & potential energy) (Ch 6 & 7)

Work and Force: pushing a piano up a ramp

Both charge same \$ per hr:

stronger guy	33	$F_s > F_w$	$W_s < W_w$
weaker guy	0	F_w	W_w

$\boxed{\text{Why?}}$

$$\boxed{\text{Work} \equiv \vec{F} \cdot \Delta\vec{r}}$$

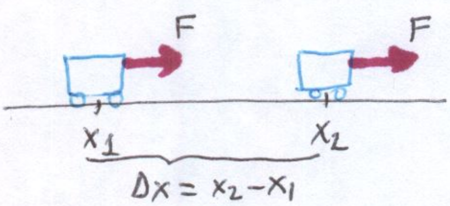
(Work equals $\boxed{\text{force applied}}$ "dot" $\boxed{\text{displacement}}$ vector)

"Dot": scalar (number) product of two vectors that produces a number

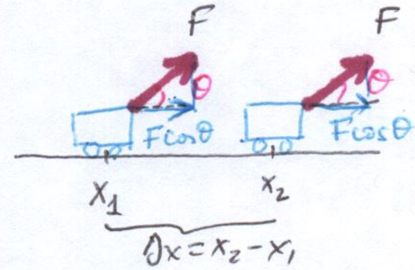
$\vec{A} \cdot \vec{B} \equiv AB\cos\theta$
- A is the magnitude or length of $\vec{A}$
- B " " " " " $\vec{B}$
- θ is the angle b/w vector $\vec{A}$ & vector $\vec{B}$

Work is a number, SI unit: $Nm \equiv J$ (Joules)

Work is affected by F, Δr, θ:



$$\text{Work} = F \cdot \Delta x \cdot \cos 0 = \boxed{F} \Delta x$$



$$\text{Work} = F \cdot \Delta x \cdot \cos\theta = \boxed{F\cos\theta} \cdot \Delta x$$

$F\cos\theta$ is the component of $\vec{F}$ in direction of displacement Δx

1) $F\sin\theta$ is the component of $\vec{F}$ in the direction that is perpendicular to the displacement

Any force perpendicular to direction of displacement performs no work (definition of scalar product & $\cos 90^\circ = 0$)

2) Only the component of $\vec{F}$ that is parallel to displacement will do work

3) $F\sin\theta$ does some work indirectly by reducing N → reducing friction force

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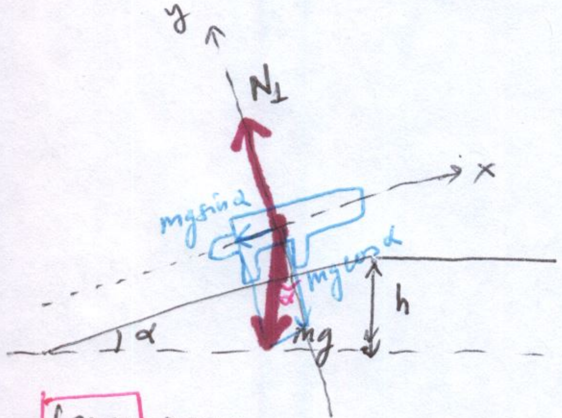
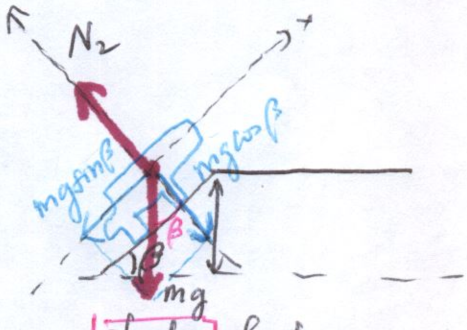
Piano mover:





$\boxed{\text{Longer}}$ ramp

To push : overcome $mg\sin\alpha$

↓

weak guy

$\boxed{\text{shorter}}$ & steeper ramp ($\beta > \alpha$)

overcome $mg\sin\beta$

larger force than $mg\sin\alpha$

↓

strong guy

↓

$W_s < W_w$

Work and Power :

Two cars with same mass ($m_1 = m_2 = m$) going from rest to $40 \frac{mi}{h}$

car#1 regular sedan ($P_1 =$ 150 H.P.) $\rightarrow W_1$

car#2 porsche ($P_2 =$ 300 HP) $\rightarrow W_2$

$\} W_1 = W_2$

work done to go from rest to $40 \frac{mi}{h}$

$W_1 > W_2$	$W_2 > W_1$	$W_1 = W_2$ ✓
10	5	0

(Work = Energy = $\frac{1}{2} m v^2$)

Average Power $= \bar{P} = \frac{\Delta W}{\Delta t}$

Same ΔW & double power $\Rightarrow$ half time
porsche gets to $40 \frac{mi}{h}$ in half the time it takes the regular sedan.

Instantaneous Power : $P = \frac{dW}{dt}$

Power & velocity : if force applied is constant (doesn't change with time)

$$\boxed{P = \frac{d(\vec{F} \cdot \Delta \vec{r})}{dt} = \vec{F} \cdot \underbrace{\frac{d\, \Delta \vec{r}}{dt}}_{\vec{v}} = \vec{F} \cdot \vec{v}}$$

SI unit: $\frac{Nm}{s} = \frac{J}{s} = W$ (Watts)

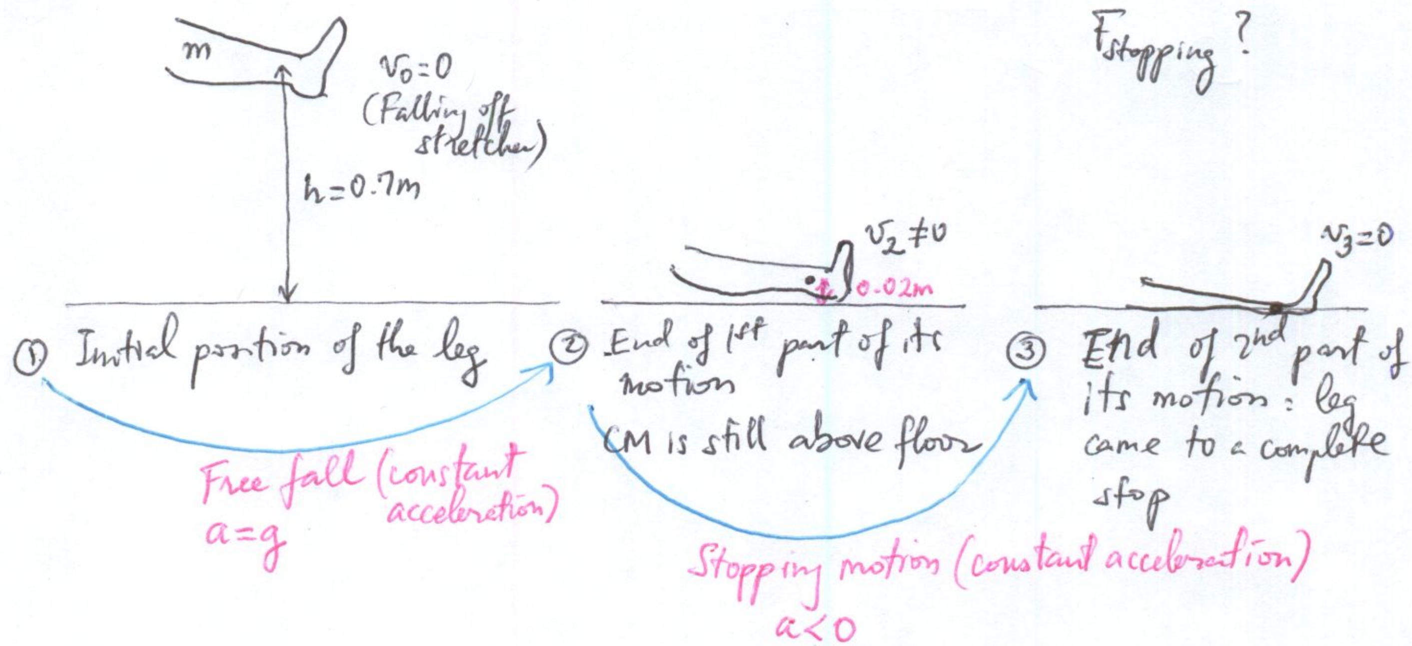
$1 H.P = 746 W$; $\frac{Btu}{h} = 0.293 W$

6.81 Leg falling off a stretcher ($\sim$ dropped egg question in PP1)

1st) Free fall during 0.7m until heel is about to touch the floor

2nd) Crashing against the floor to come to a complete stop

Step 1:



Step 2: Relevant equations:

Alternative #1: Work & Energy:

$$① \ KE_1 = 0J \xrightarrow{\text{Free fall}} ② \ KE_2 = \frac{1}{2} m v_2^2 \longrightarrow ③ \ KE_3 = 0J$$

energy absorbed by leg $\rightarrow$ damaged (more due to the short time interval this has to happen!)

(i) ΔKE_{12} = gravitational work = $mg \cdot h$

(ii) $\Delta KE_{23} = mgh = F_{stopping} \cdot \underbrace{\Delta y}_{0.02m} \Rightarrow F_{stopping} = \frac{mgh}{\Delta y} = \frac{8 \cdot 9.81 \cdot 0.7}{0.02} N$

$= 2744N$

Alternative #2 : Kinematic equations for constant acceleration & Newton's 2nd Law

1st part of motion { No time information → kin. eq #3 : $\frac{v_2^2 - v_0^2}{h} = 2g \Rightarrow v_2 = \sqrt{2gh}$

$$v_2 = \sqrt{2 \cdot 9.81 \cdot 0.7} = 3.7 \frac{m}{s}$$

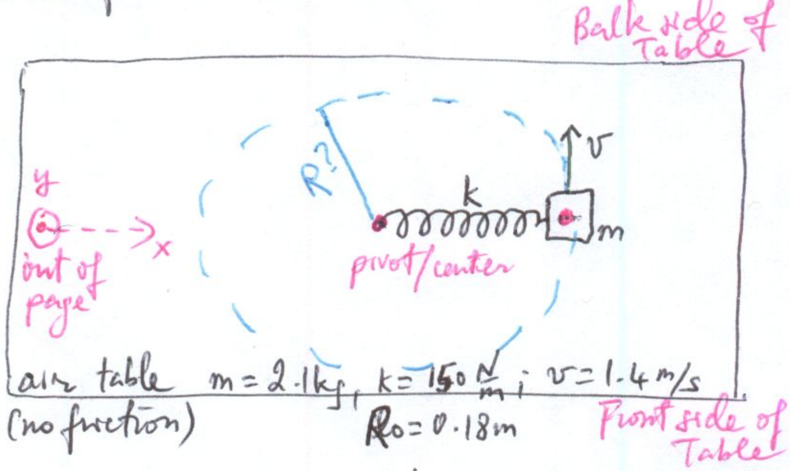
2nd part of motion { same → kin eq #3 : $\frac{v_3^2 - v_2^2}{\Delta y} = 2a \Rightarrow a_{stopping} = \frac{0 - 3.7^2}{0.02 \cdot 2}$

$$= -343.35 \frac{m}{s^2}$$

Stopping force : 2nd Newton's Law : $F_{stopping} = m \cdot a = 8 \cdot (-343.35) = -2774 N$

5.65 Mass attached to a spring, on air cushion → no friction
Circular motion at $v = 1.4\,\frac{m}{s}$ → UCM ↔ $a = \frac{v^2}{R}$; R?

Step 1: view from above 2D

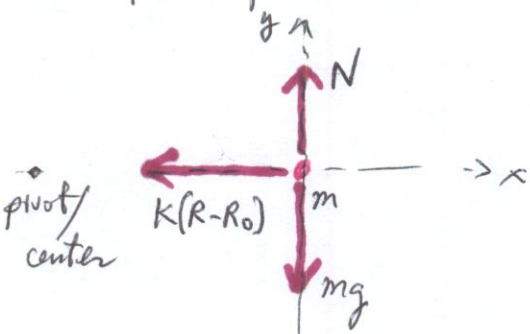


Focus on motion of the object: (i) Mass m in UCM @ $v = 1.4\,m/s$
→ Non-constant velocity → acceleration toward center of curvature $a = \frac{v^2}{R}$

(ii) Spring's force ($k\Delta x$ (Hooke's Law)) provides this a, to change direction of the velocity of m so it conforms to a circular trajectory.

Step 2a: select a convenient coord. system → standard (y, x) → view from above: y ⊙ - - -> x (out of page)

Step 2b: FBD for m
view from front side



$F_{net,m,x} = -k(R-R_0)$

$F_{net,m,y} = N - mg$.

Step 2c: Write 2nd Newton's Law for mass m: $\vec{F}_{net,m} = m\cdot\vec{a}$

In x-direction: $-k(R-R_0) = m\left(-\frac{v^2}{R}\right)$ (1) (accel. is negative, toward center of curvature)

In y-direction: $N - mg = 0$ (2)

Step 3: Solve for R

$(1) \times (-R)$ $\quad kR(R-R_0) = mv^2 \rightarrow \boxed{kR^2 - kR_0 R - mv^2 = 0}$

Quadratic eq. in R!

$$\boxed{\begin{array}{l} ax^2+bx+c=0 \\ x = \dfrac{-b \pm \sqrt{b^2-4ac}}{2a} \end{array}}$$

$$\hookrightarrow R = \frac{kR_0 \pm \sqrt{k^2R_0^2 + 4kmv^2}}{2k}$$

$$R = \frac{150 \cdot 0.18 \pm \sqrt{150^2 \cdot 0.18^2 + 4 \cdot 150 \cdot 2.1 \cdot 1.4^2}}{2 \cdot 150}$$

$$R = \begin{cases} 0.279\,m \\ \cancel{\text{negative}} \end{cases}$$

6.72 → Work or energy needed to apply a lift force of mg (to counter weight of barbell) over a displacement (vertical) of $\Delta h = 0.5\,m$ is

$$W = F \cdot \Delta h = mg\Delta h = 45 \cdot 9.81 \cdot 0.5 = 220\,J$$ → Energy burned per lift

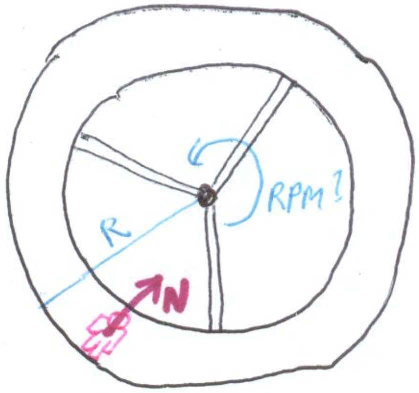
→ To compare, let's convert 230 kCal into J:

$$230 \times 10^3\,Cal \; \frac{4.186\,J}{1\,cal} = 963\,kJ$$ → Total energy to burn

$$\rightarrow \#\text{ lifts} = \frac{963 \times 10^3\,J}{220\,J} = 4377\text{ lifts.}$$

5.58) Hollow ring space station $R = \frac{D}{2} = 225\,m$, to rotate around its center to simulate Earth's gravity ($g = 9.81\,\frac{m}{s^2}$)

Step 1:



$R = 225\,m$

RPM = revolutions per minute

Motion of the astronaut: (i) Rotates with ring in UCM $\leftrightarrow a = \frac{v^2}{R}$ as it stands on outer edge of ring

(ii) What force will cause this a? Normal force N

No mg! (in outer space)

Step 2a: coord system: 1D $\uparrow y$

Step 2b: FBD for astronaut:

$N \uparrow \quad F_{net,y} = N$

Step 2c: 2nd Newton's Law for astronaut:

$$F_{net,y} = m \cdot a$$
$$N = m \cdot \frac{v^2}{R}$$

Step 3: To simulate Earth's gravity: $N_E = mg$.

$$\cancel{m}g = \cancel{m}\frac{v^2}{R}$$
$$v = \sqrt{gR}$$
$$= \sqrt{9.81 \cdot 225}$$
$$\boxed{v = 46.9\,\frac{m}{s}}$$

Convert this linear speed into angular speed (RPM)

$$46.9\,\frac{\cancel{m}}{\cancel{s}} \cdot \frac{60\,\cancel{s}}{1\,min} \cdot \frac{1\,Rev}{2\pi \cdot 225\,\cancel{m}} = \frac{46.9 \times 60}{2\pi \times 225}\,\frac{Rev}{min} = 1.99\,RPM$$

6.36] long jumper $m = 75\,kg$ $\quad$ rest $v_0 = 0 \xrightarrow[t=3.1s]{} v = 10\,\frac{m}{s}$ prejump speed

power output?

$$\bar{P} = \frac{\boxed{\text{Work}}}{\Delta t} = \frac{\Delta KE}{\Delta t} = \frac{\boxed{\frac{1}{2}mv^2 - 0}}{\Delta t} = \frac{\frac{1}{2}\cdot 75\cdot 10^2}{3.1} = \frac{3750}{3.1}\,W = 1210\,W$$

Note:

Constant $\vec{F}$: Work $= \vec{F}\cdot\Delta\vec{r}$ (Force applied vector dot displacement vector)

Non-constant $\vec{F}$: Work $= \int \vec{F}\cdot d\vec{r}$ ($d\vec{r}$: infinitessimal displacement vector)

$$= m\int \frac{d\vec{v}}{dt}\cdot d\vec{r} = m\int d\vec{v}\cdot\vec{v} \underset{1D}{=} m\int v\,dv = \frac{1}{2}mv^2$$

2nd Newton's Law

$$\vec{F} = \frac{d\vec{p}}{dt} = \frac{d(m\vec{v})}{dt} = m\frac{d\vec{v}}{dt}$$

For motion, work is kinetic energy!
