Ch5 Using Newton's Equations

- Static equilibrium ✓
- Multiple Objects ✓
- Frictional forces ✓
- Circular motion ✓

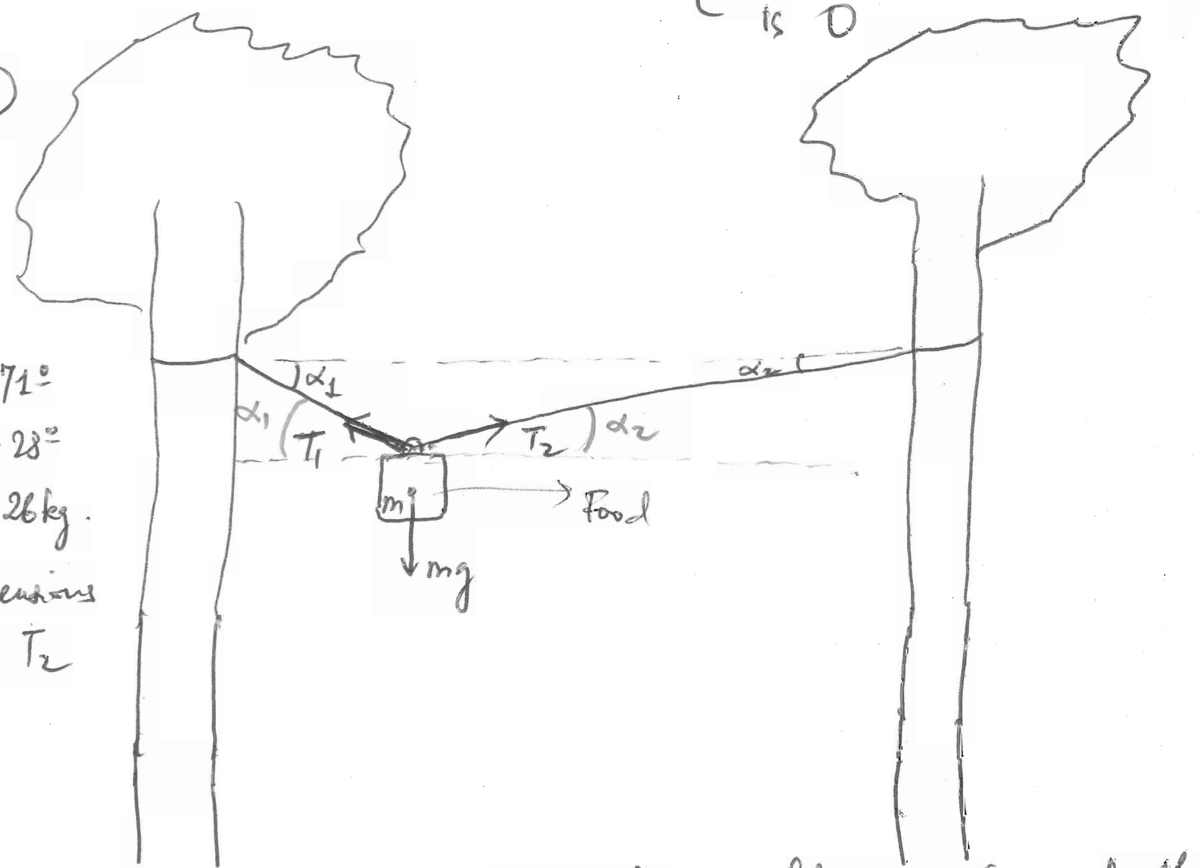
Common strategies for solutions:

1) Understand the problem making a sketch (making sense of the question)
2) Select a <u>convenient</u> coordinate system (to simplify the analysis)
   ↳ In general: { -most force pointing along axes of the coord. system; -motion of interest is along an axis of the coord. system.
3) Make a free-body diagram of forces acting on each object → so to facilitate the calculation of the net force on each object. Draw the x & y components for those forces that are not already aligned along the axes.
4) Write 2nd Newton's Law ($\vec{F}_{net} = m\vec{a}$) for each object, for each component (x or y) as needed (in each direction we can combine components arithmetically)
5) Solve for the requested information, obtaining numeric solutions with correct units. Check if your numbers make sense.

- Static equilibrium:

  $\hookrightarrow \vec{a} = 0 \longrightarrow \vec{F}_{net} = 0$ $\left\{ \begin{array}{l} \text{Net force on each object} \\ \text{in each direction } (x \,\&\, y) \\ \text{is } 0 \end{array} \right.$

5-36



$\alpha_1 = 71°$

$\alpha_2 = 28°$

$m = 26\,kg$.

Find tensions T_1 & T_2

1) ✓

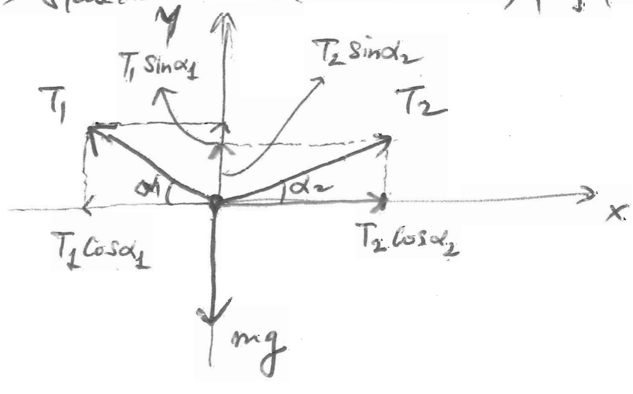
Tensions along the ropes allow static equilibrium (against the weight of the back pack)

2) Most convenient coordinate system: standard xy : $y \uparrow \underline{\quad} \rightarrow x$

since angles b/w forces $\vec{T}_1$, $\vec{T}_2$, $m\vec{g}$ are not $90°$ → best we can do is to align one force along an axis → pick $m\vec{g}$

→ standard x (horizontal), y (vertical)

3)



FBD helps us derive the net force on the pack in each direction.

→ 1) components of tensions along x-axis point in opposite directions

2) components of tensions along y-axis point in the same direction

4) Write 2nd Newton's Law for each component (x & y) for the pack: ($\vec{F}_{net} = m\vec{a} = 0$) ← static equilibrium.

FBD →
$$\begin{cases} \text{x-direction:} & \underbrace{T_2 \cos\alpha_2 - T_1 \cos\alpha_1}_{\text{Net force in x-direction}} = 0 \\ \text{y-direction:} & \underbrace{T_2 \sin\alpha_2 + T_1 \sin\alpha_1 - mg}_{\text{Net force in y-direction}} = 0 \end{cases}$$

$$\begin{cases} T_2 \cos 28^\circ - T_1 \cos 71^\circ = 0 & (a) \\ T_2 \sin 28^\circ + T_1 \sin 71^\circ = 26 \cdot 9.81 & (b) \end{cases}$$

5) Requested information: T_1 & T_2 : yes, we have 2 equations & 2 unknowns.

(a) $T_1 = T_2 \dfrac{\cos 28^\circ}{\cos 71^\circ}$ → (b) $T_2 \sin 28^\circ + T_2 \dfrac{\cos 28^\circ}{\cos 71^\circ} \sin 71^\circ = 26 \cdot 9.81$

$$\rightarrow T_2 = \frac{26 \cdot 9.81}{\sin 28^\circ + \cos 28^\circ \cdot \tan 71^\circ} = 84\ N$$

(a) $T_1 = 84 \dfrac{\cos 28^\circ}{\cos 71^\circ} = 228\,N$.

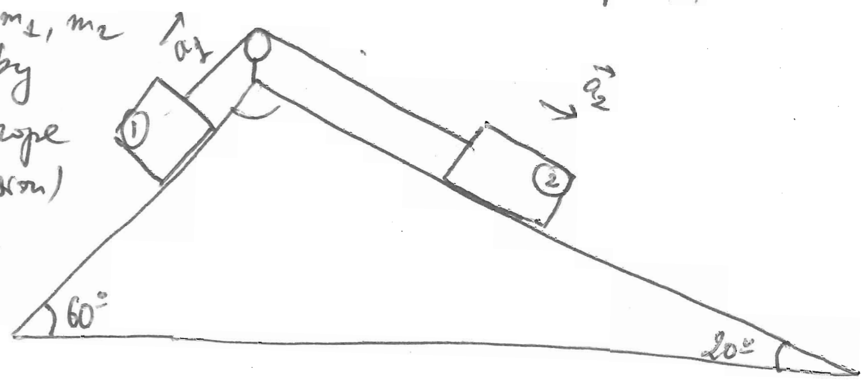
<u>Check:</u> it makes sense $T_1 > T_2$ ($\alpha_1 = 71^\circ > \alpha_2 = 28^\circ$)

Multiple Objects:
- Same five steps, account for each object.
- If objects are connected, they will have the same acceleration although it could be in different directions (when a pulley is involved)

- Two boxes m_1, m_2 connected by a massless rope (same tension)

$a_1 = a_2 = a$

- No friction b/w boxes & slopes.



Question: acceleration of system a?

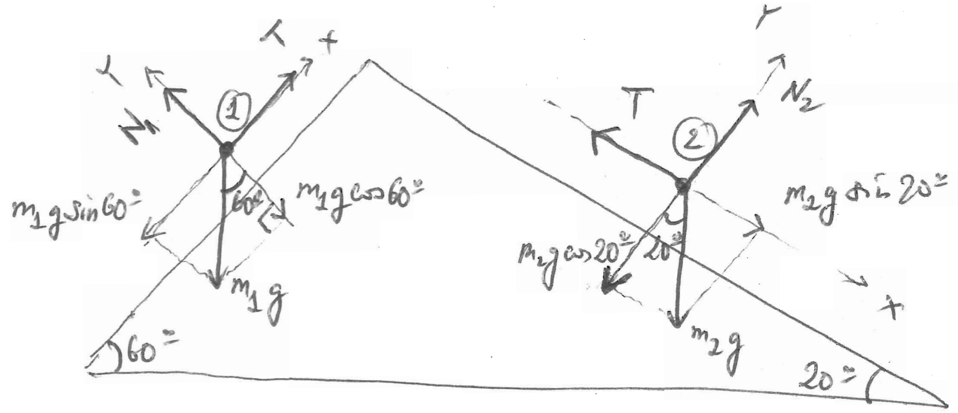
1) ✓ Depending on masses m_1, m_2 motion could be opposite to what we have put in the sketch: the equation will tell with the sign of a. (there will be a minus in the final equation for a! Otherwise it can't describe the situation when m_1 is sufficiently heavy to pull the system in the counterclockwise direction)

2) Convenient coordinate system(s):
Motions of interest are along slopes: normally x.

1) 

2) 

3) FBD's



<u>Note</u>: a) our coordinate systems allow 2 out of 3 forces aligned along the axes.

b) For each object: components along y-direction will cancel (no motion in that direction). Net force in the x-direction will dictate the acceleration: if m_1 is sufficiently small so $m_1 g \sin 60° < T \rightarrow m_1$ will accelerate up hill.

4) Write 2nd Newton's Law for each object and each direction: $\vec{F}_{net} = m \cdot \vec{a}$

<u>Object ①</u>

$$\text{FBD} \rightarrow \begin{cases} \text{x-direction}: & T - m_1 g \sin 60° = m_1 \cdot a \quad (\text{I}) \\ \text{y-direction}: & N_1 - m_1 g \cos 60° = 0 \end{cases}$$

<u>Object ②</u>

$$\text{FBD} \rightarrow \begin{cases} \text{x-direction}: & m_2 g \sin 20° - T = m_2 a \quad (\text{II}) \\ \text{y-direction}: & N_2 - m_2 g \cos 20° = 0 \end{cases}$$

5) Solve for a: (I), (II) } Provided m_1 & m_2 are given: there are 2 unknowns: T, a

→ Eliminate T.

(I) Solve for T → $T = m_1 g \sin 60° + m_1 \cdot a$

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

Note your prediction!

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

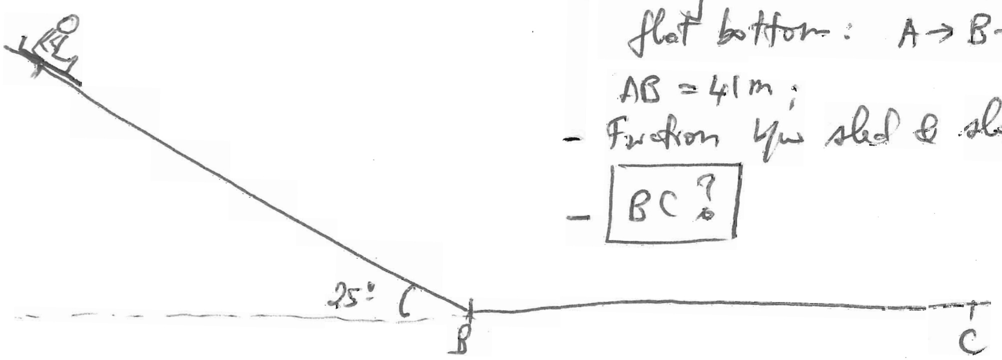
Different scenarios (you could do on your own when studying)

$$\begin{cases} a = 0 \text{ (static equilibrium)}: & m_2 \cancel{g} \sin 20^\circ = m_1 \cancel{g} \sin 60^\circ \rightarrow \dfrac{m_2}{m_1} = \dfrac{\sin 60^\circ}{\sin 20^\circ} \\ a > 0 \text{ (clockwise motion for system: as assumed)}: & \dfrac{m_2}{m_1} > \dfrac{\sin 60^\circ}{\sin 20^\circ} \\ a < 0 \text{ (counterclockwise motion)}: & \dfrac{m_2}{m_1} < \dfrac{\sin 60^\circ}{\sin 20^\circ} \end{cases}$$

} Static equilibrium is possible but not stable!

$\boxed{\text{Frictional Forces:}}$

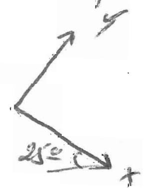
5.49



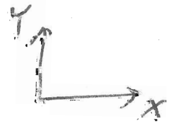
- Sliding downhill and then along flat bottom: A → B → C (stops @ C)
  AB = 41 m;
- Friction b/w sled & slope $\mu_k = 0.12$
- $\boxed{BC\,?}$

1) ✓ Note: { sled stops @ C: b/c of friction.
AB: constant acceleration b/c gravity (assuming it overcomes friction)
BC: constant deceleration b/c friction.

2) Convenient coord. systems: AB

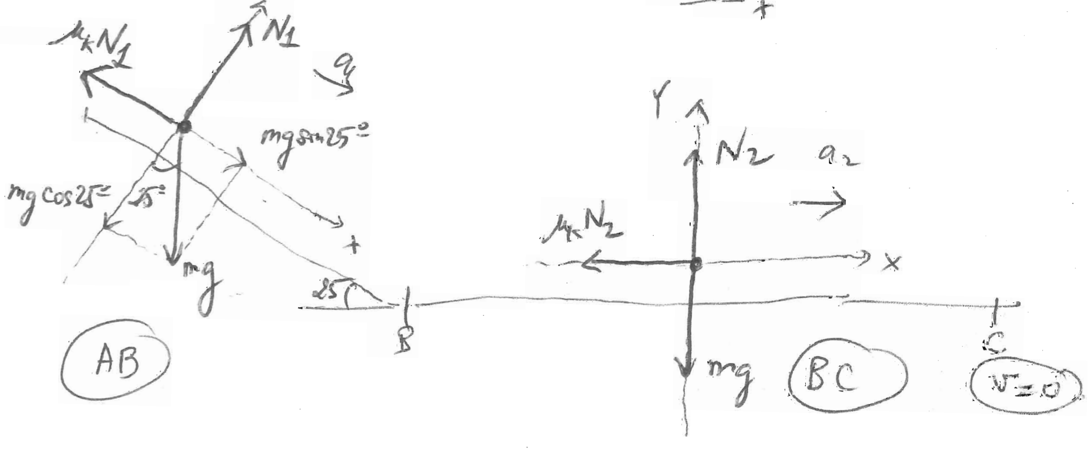


BC



3) FBD:

• Friction is always against motion.



4) Write 2nd Newton's Law $\vec{F}_{net} = m\cdot\vec{a}$

AB : FBD →
$$\begin{cases} \text{x-direction: } & mg\sin 25^\circ - \mu_K N_1 = ma_1 \\ \text{y-direction: } & -mg\cos 25^\circ + N_1 = 0 \end{cases}$$

BC FBD →
$$\begin{cases} \text{x-direction: } & -\mu_K \cdot N_2 = ma_2 \\ \text{y-direction: } & N_2 - mg = 0 \end{cases}$$

5) Solve for distance BC. First find a_2; then find v_B → use kinematic of #3: $\dfrac{\cancel{v_C^2}^{\,0} - v_B^2}{2x_{BC}} = a_2$ (*)

a) $a_2 = -\mu_K g$

b) Find v_B: is the final velocity for a constant deceleration downhill where initial velocity $v_A = 0$; given $x_{AB} = 41\,m$.

Kin. eq #3: $\dfrac{v_B^2 - \cancel{v_A^2}^{\,0}}{2x_{AB}} = a_1$

$a_1 = g(\sin 25^\circ - \mu_K \cos 25^\circ)$

$\rightarrow v_B = \sqrt{2\cdot 41\cdot 9.81(\sin 25^\circ - 0.12\cos 25^\circ)} = 15.9\ m/s$

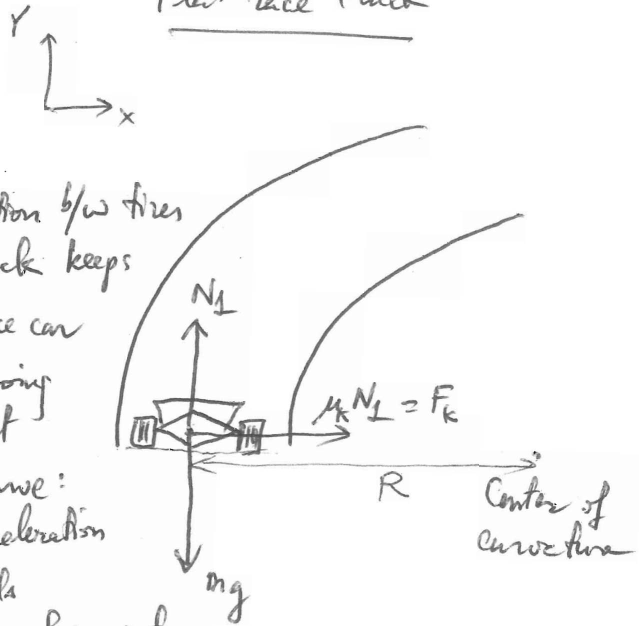
$$x_{BC} = \frac{-v_B^2}{2a_2} = -\frac{v_B^2}{-2\mu_K g} = \frac{15.9^2}{2\cdot 0.12\cdot 9.81} = \boxed{107\ m}$$

Uniform Circular Motion:

Application of 2^{nd} Newton's Law on a race car taking a circular turn in UCM with constant speed v, radius of curvature R

Race car track:

Flat race track



• Friction b/w tires & track keeps the race car from going off at the curve: ~ acceleration towards center of curvature in any UCM

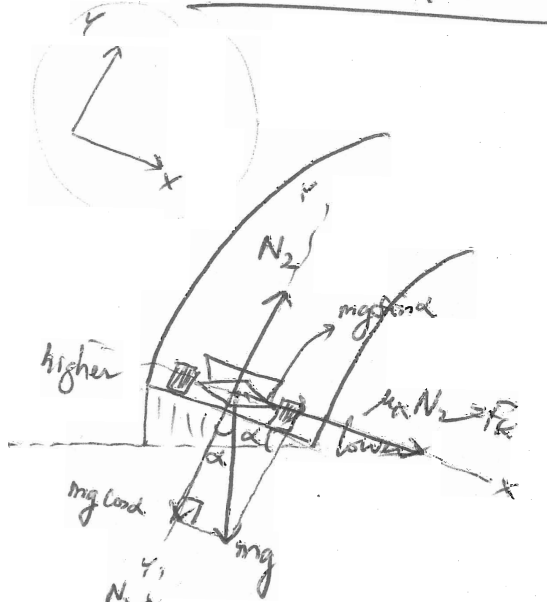
$$\vec{F}_{net} = m\vec{a}$$

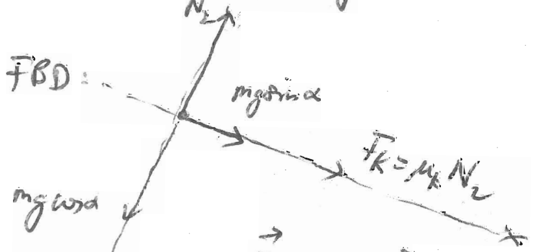
$$FBD \rightarrow \begin{cases} x\text{-direction}: & \mu_k N_1 = m \cdot \frac{v^2}{R} \\ y\text{-direction}: & N_1 - mg = m.0 = 0 \end{cases}$$

$$N_1 = mg \rightarrow \mu_k g = \frac{v^2}{R} \rightarrow$$

$$\rightarrow v_{Flat} = \sqrt{\mu_k g R}$$

Slanted race track





$$\vec{F}_{net} = m\vec{a}$$

$$FBD \rightarrow \begin{cases} x\text{-direction}: & mg\sin\alpha + \mu_k N_2 = m \cdot \frac{v^2}{R} \\ y\text{-direction}: & N_2 - mg\cos\alpha = 0 \end{cases}$$

$$N_2 = mg\cos\alpha \rightarrow g\sin\alpha + g\cos\alpha\,\mu_k = \frac{v^2}{R}$$

$$\rightarrow v_{Slanted} = \sqrt{gR(\sin\alpha + \mu_k\cos\alpha)}$$

$$\frac{v_{slanted}}{v_{flat}} = \sqrt{\frac{\sin\alpha + \mu_k\cos\alpha}{\mu_k}}$$

$v_S > v_F$ if $\sin\alpha + \mu_k\cos\alpha > \mu_k$

$$\frac{\sin\alpha}{1-\cos\alpha} > \mu_k$$

$\alpha = 20°$, $\mu_k = 0.2 \rightarrow \frac{\sin 20°}{1-\cos 20°} = 5.67 > 0.2$

$\boxed{\frac{v_S}{v_F} = 1.62}$

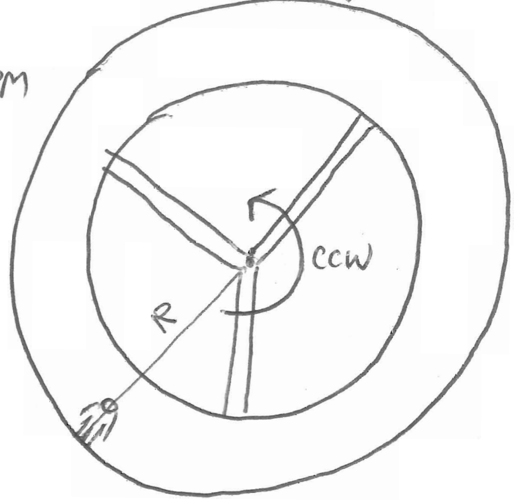
UCM: any object under UCM will travel at constant speed v but its velocity vector will change direction to stay in circular trajectory. This requires an acceleration towards center of curvature $a = \frac{v^2}{R}$.

Flat track: a provided by $F_k = \mu_k N_1$

Slanted track: a provided by $mg\sin\alpha + \mu_k N_2$

5.56 Hollow ring space station of $R = \frac{D}{2} = 225\,m$.

How many RPM to simulate gravity?



Rotates CCW to simulate gravity:

How? Astronaut standing on outer edge will be rotating in UCM, { speed = constant; velocity: changing → accel. towards center of curvature.

↓

provided by outer edge on the astronaut: N

$N = m\frac{v^2}{R}$

1) Outer space: no weight. (no actual mg)

2) Astronaut sitting or standing on outer edge so rotating with space station

3) To simulate gravity N = his weight on Earth = mg

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

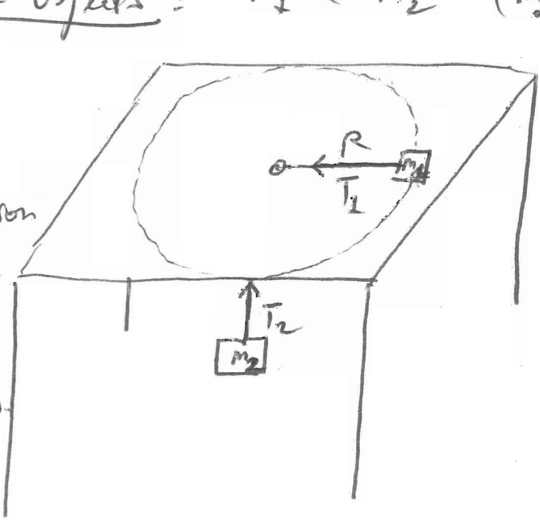
4) Convert $\frac{m}{s} \rightarrow \frac{rev}{min}$: $46.9\frac{\cancel{m}}{\cancel{s}} \cdot \frac{1\,rev}{2\pi \cdot 225\,\cancel{m}} \cdot \frac{60\,\cancel{s}}{1\,min} = 1.99\,rpm$

5.37 Multiple Objects: m_1 & m_2 (m_2: stationary : $a_2 = 0$) m_1 : UCM ← $\boxed{\text{No friction}}$

↳ $a_1 = \frac{v^2}{R}$

1)

Same analysis result for any position of m_1 on its circular trajectory → let's pick the one shown.

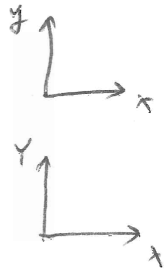


- Massless string: → same tension in the string.
- $T_1 = T_2 = T$

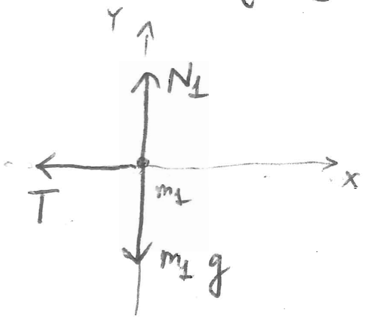
Tension { T_2 = to hold m_2 stationary; T_1 = keep m_1 on UCM

$\boxed{\begin{array}{l} T? \\ \text{Period } T\,? \end{array}}$ (Don't get confused!)

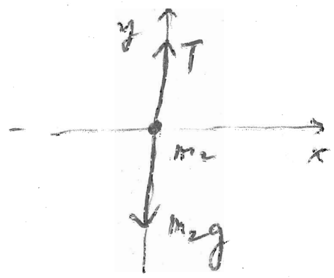
2) Convenient coord. systems $\begin{cases} m_1 \text{ (on table)} \\ m_2 \text{ (hanging)} \end{cases}$



3) $\underbrace{\text{FBD}}_{\text{of forces}}$ m_1 :



FBD m_2 :



4) 2nd Newton's Law for each object: $\vec{F}_{net} = m\vec{a}$

m_1 : $\begin{cases} \text{x-direction: } & -T = m_1 \cdot a_1 = m_1\left(-\frac{v^2}{R}\right) \rightarrow T = m_1 \frac{v^2}{R} \\ \text{y-direction: } & N_1 - m_1 g = 0 \end{cases}$

m_2 : $\begin{cases} \text{y-direction: } & T - m_2 g = 0 \rightarrow T = m_2 g \\ \text{x-direction: none} \end{cases}$

5) Solve for $\boxed{T = m_2 g = m_1 \frac{v^2}{R}}$

Period of circular motion of m_1 : T = time to complete one circumference

period!

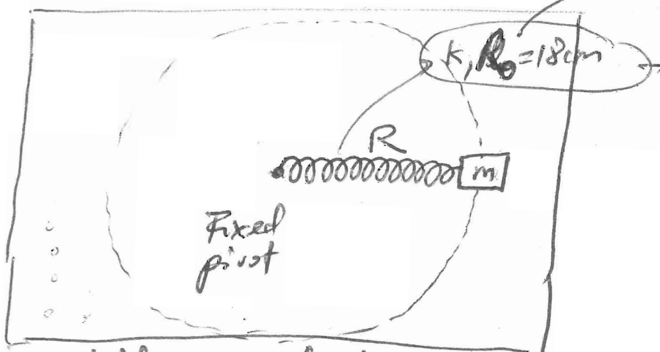
$$v = \sqrt{\frac{m_2}{m_1} g R} \longrightarrow = \frac{2\pi R}{v} = \frac{2\pi R}{\sqrt{\frac{m_2}{m_1} g R}}$$

$$\text{Period } T = 2\pi \sqrt{\frac{m_1}{m_2} \cdot \frac{R}{g}}$$

Sc62 Easiest view to analyze: from above:

when m is not rotating.

1)



→ spring parameters k=150 $\frac{N}{m}$

m = 2.1kg.

R?

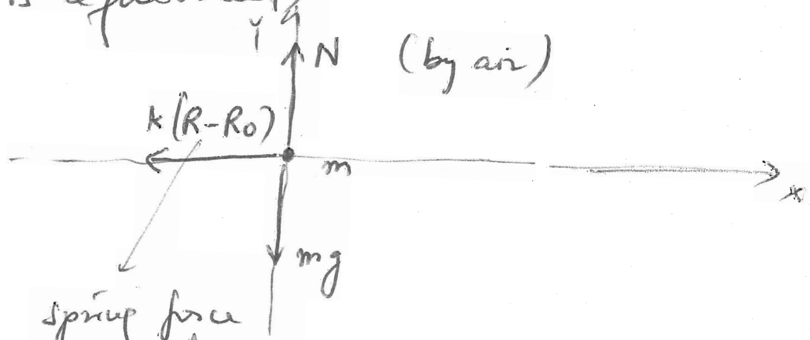
air table → no friction

m undergoes UCM (constant speed $v = 1.4\,\frac{m}{s}$): accel. towards center of curvature or fixed pivot → will be provided by the spring: which will be stretched (otherwise it would push m away from center of curvature!) → $R > R_0$.

2) Convenient coord. system

The position of m shown simplifies our analysis (any position on circular trajectory is equivalent)

3) FBD of forces:



spring force is given by stretched length from the natural length! (Hooke's law)

4) 2^{nd} Newton's law: $\vec{F}_{net} = m\vec{a}$

FBD → x-direction: $-k(R-R_0) = m\cdot\left(-\frac{v^2}{R}\right)$

y-direction: $N - mg = 0$

5) Solve for R: $kR^2 - kR_0R = mv^2 \rightarrow kR^2 - kR_0R - mv^2 = 0$

$k \rightarrow 150$ $\quad kR_0 \rightarrow 150\cdot 0.18 = 27$ $\quad mv^2 \rightarrow 2.1\cdot 1.4^2 = 4.12$

$$150R^2 - 27R - 4.12 = 0 \rightarrow R = \frac{27 \pm \sqrt{27^2 + 4 \cdot 150 \cdot 4.12}}{2 \cdot 150}$$

$$= \begin{cases} + & \boxed{R = 0.279\,m} \\ - & \text{Not relevant.} \end{cases}$$

$\Delta x = x_2 - x_1$

SI unit: $N \cdot m = J$ (Joule)

in x: $F\cos\theta \cdot \Delta x$

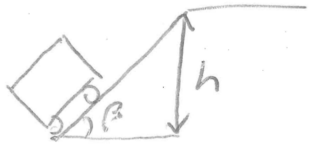
in y: $F\sin\theta \cdot 0 = 0$

Ch. 6 Work, Energy, Power

Description of motion (Ch. 2 & 3)
Force (Ch. 4 & 5)

Force & Work → pushing a piano up a ramp: force is important but for us it is equally important to know about the work performed or the energy spent:

long ramp (less steep)



short ramp (steeper)
$\beta > \alpha$

More work: 1) long ramp ✓ (2)

2) short ramp. (20)

More force: 1) long ramp (0)

2) short ramp. ✓ (22)

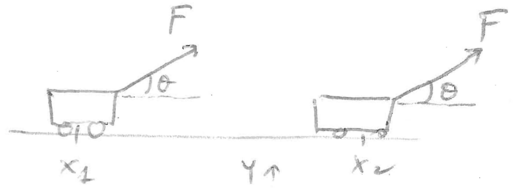
Work: → $\vec{F} \odot \Delta \vec{r}$ → displacement → Product b/w 2 vectors that gives a number: scalar product.

Work done — force applied

Work done $F . \Delta x$

$\Delta x = x_2 - x_1$

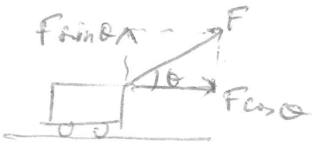
SI unit $N.m = J$ (Joule)



Work done:

in x: $F\cos\theta . \Delta x$
in y: $F\sin\theta . 0 = 0$

* Only forces in the direction of displacement will perform



Work & Energy:

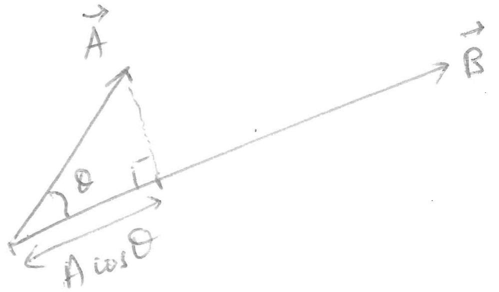
- By pulling suitcase at angle θ : $\begin{cases}\text{No work done in y-direction} \\ \text{Still energy is spent.}\end{cases}$

- Pushing the wall : $\begin{cases}\Delta x = 0 \to \text{No work} \\ \text{Energy is still spent}\end{cases}$

$\boxed{\text{Scalar product}}$: a math operation.

It's a product of two vectors that is a ~~number~~ or a scalar:

Two vectors $\vec{A}$ & $\vec{B}$ forming an angle θ :

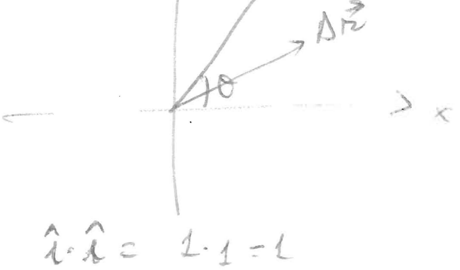


$$\vec{A}\cdot\vec{B} = A \cdot B\cos\theta$$
$$= \underbrace{A\cos\theta}_{\text{Projection of } \vec{A} \text{ onto direction of } \vec{B}} \cdot B$$

$$\text{Work} = \underbrace{\vec{F}}_{\text{Force}} \cdot \underbrace{\Delta\vec{r}}_{\text{displacement vector}} = \underbrace{F\cos\theta}_{\text{Projection of } \vec{F} \text{ onto direction of displacement vector}} \cdot \Delta r$$

→ Only the component of force applied in the direction of the displacement will perform work.

In general:



$$\Delta\vec{r} = \Delta x\,\hat{i} + \Delta y\,\hat{j}$$
$$\vec{F} = F\cos\theta\,\hat{i} + F\sin\theta\,\hat{j}$$

$\boxed{\text{Work done:}}$ $\vec{F}\cdot\Delta\vec{r} = (F\cos\theta\,\hat{i} + F\sin\theta\,\hat{j})\cdot(\Delta x\,\hat{i} + \Delta y\,\hat{j})$

$$= F\cos\theta\,\Delta x\,\underbrace{\hat{i}\cdot\hat{i}}_{1} + F\cos\theta\,\Delta y\,\underbrace{\hat{i}\cdot\hat{j}}_{0} + F\sin\theta\,\Delta x\,\underbrace{\hat{j}\cdot\hat{i}}_{0} + F\sin\theta\,\Delta y\,\underbrace{\hat{j}\cdot\hat{j}}_{1}$$

$\hat{i}\cdot\hat{i} = 1\cdot 1 = 1$

$\hat{i}\cdot\hat{j} = 0$ (they're perpendicular!)

$$= \boxed{F\cos\theta\,\Delta x + F\sin\theta\,\Delta y}$$

If force applied changes with position : (e.g. spring force) :
we need to integrate over infinitesimal displacement :

$$\text{Work} = \int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \odot d\vec{r}$$

infinitesimal displacement vector.

scalar product.

Work done by a spring: $F = -k\underset{\text{displacement}}{x}$ (ref. point is the natural length)

$$\text{Work} = \int_0^x -kx \cdot dx = -k \underbrace{\int_0^x x\,dx} = \ominus \frac{1}{2} k x^2$$

natural length.

When we pull spring from natural length ($x=0$) to certain displacement x : spring receives work rather than doing work → work done by spring is −.

Energy: motion → kinetic energy K.E.

↳ Same dimension as work :

Motion is changed when a force is applied on an object.

Work done by force: $\int_{\vec{r}_1}^{\vec{r}_2} \vec{F}_{net} \odot d\vec{r} = m \int_{\vec{r}_1}^{\vec{r}_2} \frac{d\vec{v}}{dt} \cdot d\vec{r}$

scalar product

2nd Newton $\vec{m} \cdot \vec{a} = \vec{m} \cdot \frac{d\vec{v}}{dt}$

$$= m \int_{\vec{r}_1}^{\vec{r}_2} d\vec{v} \cdot \vec{v} = m \underbrace{\int_1^2 v\,dv} = \frac{1}{2} m v^2 \Big]_1^2 = \frac{1}{2} m v_2^2 - \frac{1}{2} m v_1^2$$

Work applied → change of K.E. !

Power & Work :

Going from $0 \frac{mi}{h} \to 60 \frac{mi}{h}$: this change of K.E. requires certain amount of work.

Honda :

Porsche : more power (takes shorter to spend the same amount of energy).

Average power : $\overline{P} = \dfrac{\Delta Work}{\Delta t}$

Instantaneous power $P = \dfrac{d\,Work}{dt}$

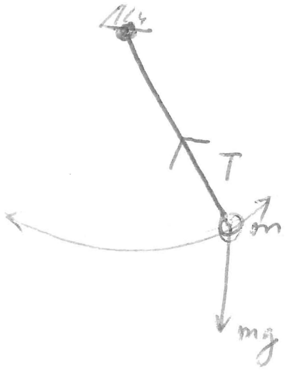
Power & velocity : $P = \dfrac{d\,Work}{dt} = \dfrac{d(\vec{F} \cdot \Delta\vec{r})}{dt}$

$$= \vec{F} \cdot \frac{d\vec{r}}{dt} = \vec{F} \cdot \vec{v}$$

$\vec{F}$ constant

scalar product.

For thought #8



Does T do any work?

No: Tension is perpendicular to direction of displacement. (along a circular path) Tension is along the radius of that circular path.

6.20) $\vec{F} = 1.8\hat{i} + 2.2\hat{j}$ (N)

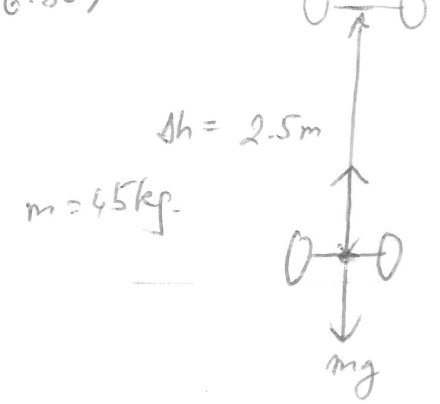
$0 \longrightarrow \vec{r} = 56\hat{i} + 31\hat{j}$ (m) $\rightarrow \Delta\vec{r} = \vec{r} - 0 = \vec{r}$.

Work done $= \vec{F}\cdot\Delta\vec{r} = 1.8\cdot 56 + 2.2\cdot 31 = 169\,J$.

$\hat{i}\cdot\hat{j} = 0$

$\hat{i}\cdot\hat{i} = \hat{j}\cdot\hat{j} = 1$

6.80)



- Work done per lift: $F\cdot\Delta h = mg\cdot\Delta h$

$= 45\cdot 9.81\cdot 2.5$

$= 1100\,J$

- Energy content of chocolate bar: $230\,Cal\cdot\frac{4186\,J}{1\,Cal}$

$= 963\,000\,J$

$\rightarrow$ # of lifts $= \frac{963}{1.1} = 873$ lifts

6.81) egg dropping question (PP # 1)
- ↳ Free fall
- ↳ Crash.

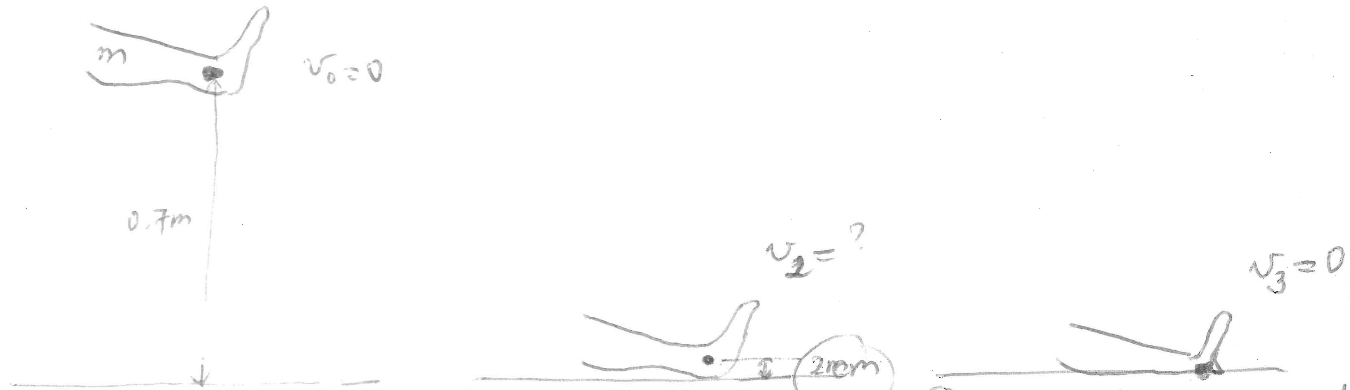
↳ leg falling off stretcher

↓ $m = 8\,kg$.

↓ $v_0 = 0$

1) Free fall : constant acceleration of value g until a little bit before touching the ground.

2) Crash : until it complete stopped constant deceleration (in the egg problem this deceleration was 10 times larger) → where damage occurs.



① Falling off the stretcher

② About to hit the ground. CM is still above the ground.

③ CM on the ground leg is completely stopped

Free fall or constant g.

constant deceleration stopping distance was 0.02 m

$KE_1 = 0$ → $KE_2 = \frac{1}{2} m v_2^2$ → $KE_3 = 0$

KE_2 is gone in a short period of time (stopping distance is only 0.02 m)

↓

leg & bones, ...

↳ $\boxed{\text{damage}}$

$\boxed{\text{Stopping Force ?}}$

Method #1 Work & Energy (Ch. 6)

① → ② Energy acquired before hitting the floor: same as energy spent to lift it from ground to $h = 0.7$ m.

$$mg \cdot \Delta h = 8 \cdot 9.81 \cdot 0.7 \text{ J}$$

② → ③ This same energy is absorbed by leg (displacement of hard floor is negligible, unlike if it was hitting a mattress!) in a stopping distance of 0.02 m.

$$8 \cdot 9.81 \cdot 0.7 \text{ J} = F_{stopping} \cdot 0.02\text{m}$$

$$F_{stopping} = \frac{8 \cdot 9.81 \cdot 0.7}{0.02} = 2744 \text{ N}$$

Method #2 Kinematic equations & Newton's law (Ch 2–4)

$$F_{stopping} = m \cdot a_{23}$$

① → ② Find v_2 : $\frac{v_2^2 - 0^2}{h} = 2g \rightarrow v_2 = \sqrt{2gh} = \sqrt{2 \cdot 9.81 \cdot 0.7} = 3.7 \frac{m}{s}$

② → ③ $\frac{0^2 - v_2^2}{0.02\text{m}} = 2 \cdot a_{23} \rightarrow a_{23} = -\frac{3.7^2}{0.04} = -343.35 \frac{m}{s^2}$

(large deceleration!)

$\rightarrow F_{stopping} = 8 \cdot 343.35 = 2774 \text{ N}$!

6.38) 75 kg long jumper $\quad v_0 = 0 \rightarrow v = 10\,\frac{m}{s}$, $\Delta t = 3.1\,s$ $\Big\}$ Power output?

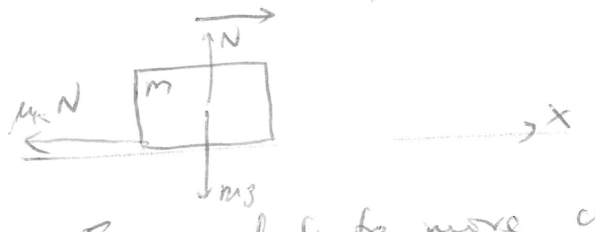
$$\bar{P} = \frac{\text{Work}}{\Delta t} = \frac{\Delta KE}{\Delta t} = \frac{\frac{1}{2} m v^2}{\Delta t} = \frac{\frac{1}{2}\, 75 \cdot 10^2}{3.1} = 1210\,W$$

6.67)

$m = 95\,kg$

$\mu_K = 0.78$

a) $v = 0.62\,m/s$



Power needed? $= F \cdot v$

Force applied to move chest: ? is that of friction $\mu_K N$ in opposite direction $\rightarrow \mu_K mg$

Power $= \mu_K mg \cdot v = 0.78 \cdot 95 \cdot 9.81 \cdot 0.62 = 450\,W$

b) Work done to go 11 m.

$\hookrightarrow \mu_K mg \cdot d = 0.78 \cdot 95 \cdot 9.81 \cdot 11 = 8000\,J.$