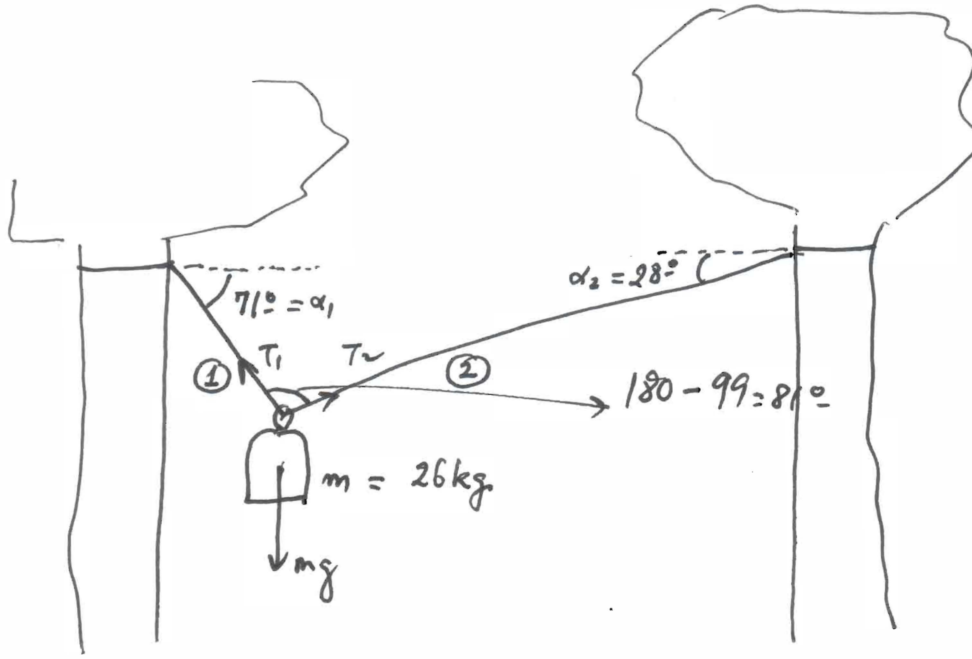
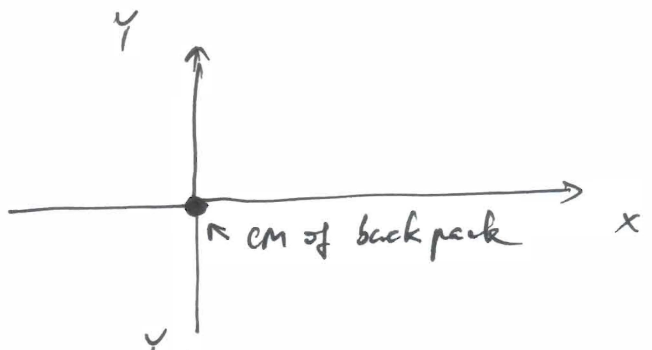
53

5.36

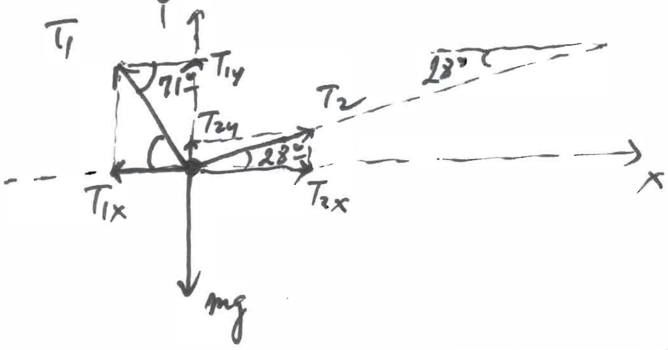


Tension in each rope? $T_1 \neq T_2$ (intuitively $T_1 > T_2$)

1) Sketch ✓
2) Focus is on backpack: 3 forces: mg, T_1, T_2 → pick standard XY cartesian coord. system.



3)



$T_{1x} = T_1 \cos 71°$ $\qquad T_{2x} = T_2 \cos 28°$

$T_{1y} = T_1 \sin 71°$ $\qquad T_{2y} = T_2 \sin 28°$

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

4) $\begin{cases} F_{net\,x} = m.0 = 0 = T_2 \cos 28^\circ - T_1 \cos 71^\circ & \text{(a)} \\ F_{net\,y} = m.0 = 0 = T_1 \sin 71^\circ + T_2 \sin 28^\circ - mg & \text{(b)} \end{cases}$

→ 2 equations w/ 2 unknowns : T_1 & T_2

5) Solve for T_1 & T_2 :

(a) → $T_1 = T_2 \dfrac{\cos 28^\circ}{\cos 71^\circ}$

(b) → $T_2 \cos 28^\circ \tan 71^\circ + T_2 \sin 28^\circ - 26 \times 9.81 = 0$

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

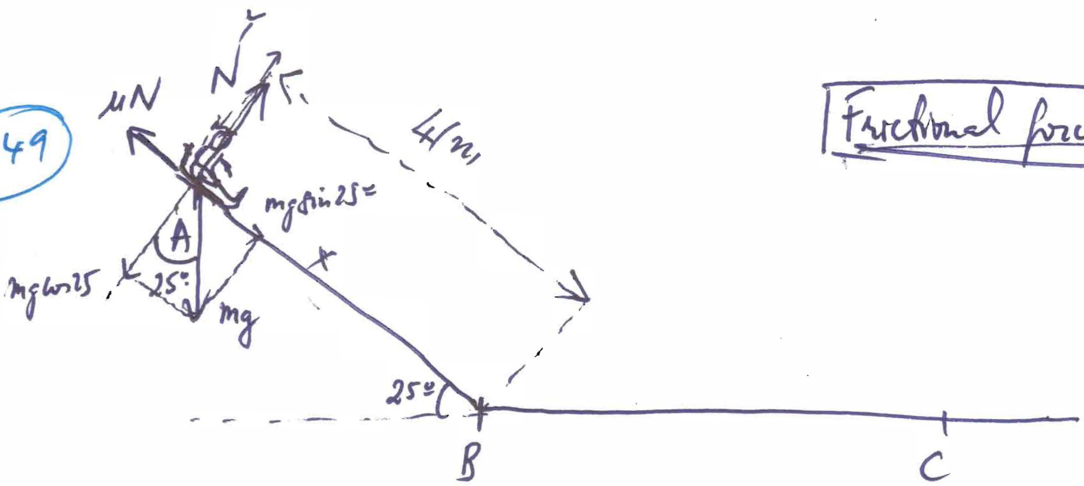
$$T_1 = 84 \frac{\cos 28^\circ}{\cos 71^\circ} = 228N$$

$T_1 > T_2$

55

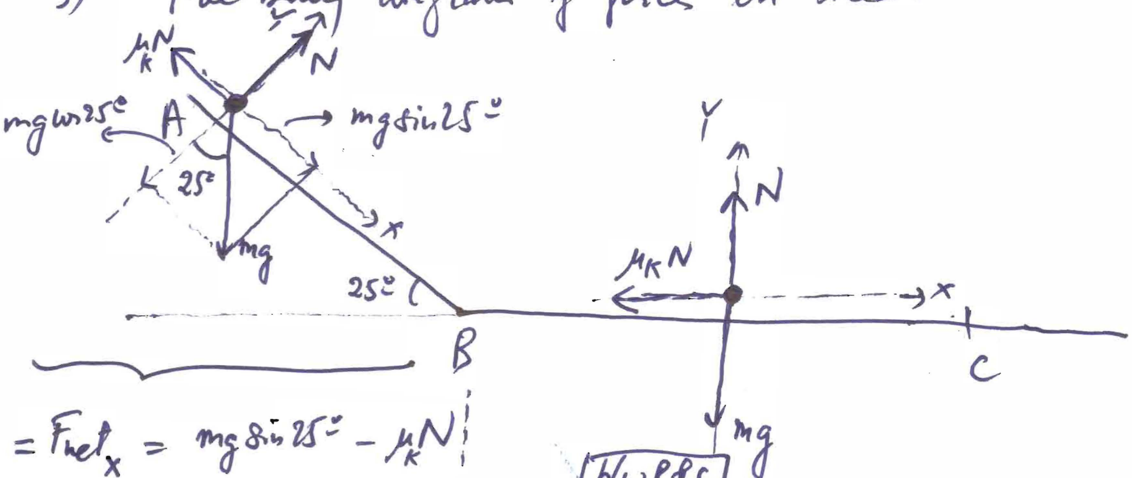
Frictional forces $\mu_K = 0.12$

5.49



Sled starts @ A from rest
@ B it has some velocity
B/w B & C sled is decelerated due to frictional force (kinetic)
What is the distance BC? → Follow our 5-step strategies:

1) Sketch ✓
2) Convenient coord. system. y, x b/w A & B; y, x b/w B & C
3) Free body diagram of force on sled.



b/w A&B

$$\begin{cases} m a_x = F_{net_x} = mg \sin 25° - \mu_K N \\ 0 = m.0 = F_{net_y} = N - mg \cos 25° \end{cases}$$

b/w B&C

$$m \tilde{a}_x = F_{net_x} = -\mu_K N$$

$$0 = m.0 = F_{net_y} = N - mg$$

4) ✓

5) Solve for requested information or distance BC.
a) Find initial velocity @ B v_{0B}
b) obtain $\tilde{a}_x$
c) $(x - x_0)_{BC} = \dfrac{v_c^2 - v_{0B}^2}{2 \tilde{a}_x}$ $(v_c = 0)$

a) Find velocity of child & sled system @ B: use informatio[n]
provided b/w A & B:
$$\begin{cases} (x - x_0)_{AB} = 41\,m \\ a_x \text{ from Newton's equation} \begin{cases} \cancel{m}a_x = \cancel{m}g\sin 25^\circ - \mu_k \cancel{m}g\cos 25^\circ \\ a_x = g(\sin 25^\circ - \mu_k \cos 25^\circ) \end{cases} \end{cases}$$

$$= 9.81(\sin 25^\circ - 0.12\cos 25^\circ)$$

$$\boxed{a_x = 3.08\ m/s^2}$$

3rd kinematic equation for constant acceleration:

$$\frac{v_B^2 - v_{0A}^2}{(x - x_0)_{AB}} = 2a_x \qquad (v_{0A} = 0 \text{ since system started motion @ A})$$

$$v_B = \sqrt{2a_x(x - x_0)_{AB}}$$

$$v_B = \sqrt{2 \times 3.08 \times 41} = 15.9\ m/s$$

This is the initial velocity for the next portion of trajectory BC

$$\boxed{v_{0B} = 15.9\ m/s}$$

b) B/w B&C: $\tilde{a}_x = -\mu_k \frac{N}{m} = -\mu_k \frac{\cancel{m}g}{\cancel{m}} = -\mu_k g = -0.12 \times 9.81 = -1.18\,\frac{m}{s^2}$

$\tilde{a}_x = -1.18\ m/s^2$

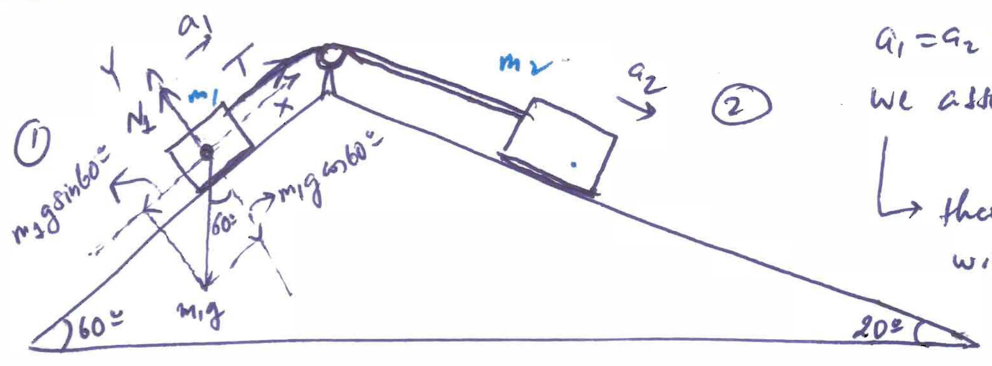
deceleration due to friction (this will bring the system to a complete stop @ C)
or $v_C = 0$

c) $$(x - x_0)_{BC} = \frac{0 - 15.9^2}{2(-1.18)} = \boxed{107\,m}$$

Multiple objects (Ch5. cont.)

- m_1 & m_2 connected via a massless rope (same tension through out the rope)
- no friction.

given



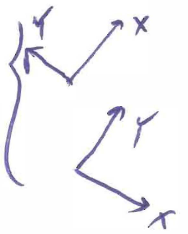
$a_1 = a_2 = a$

we assume a_1 is uphill & a_2 downhill → their numeric value with signs will indicate correct directions.

- Question: $a_1 = a_2 = a$, what is a or the acceleration of the system? → Use 5-step strategies to find the answer using 2nd Newton's Law.

1) Sketch & understanding question. ✓

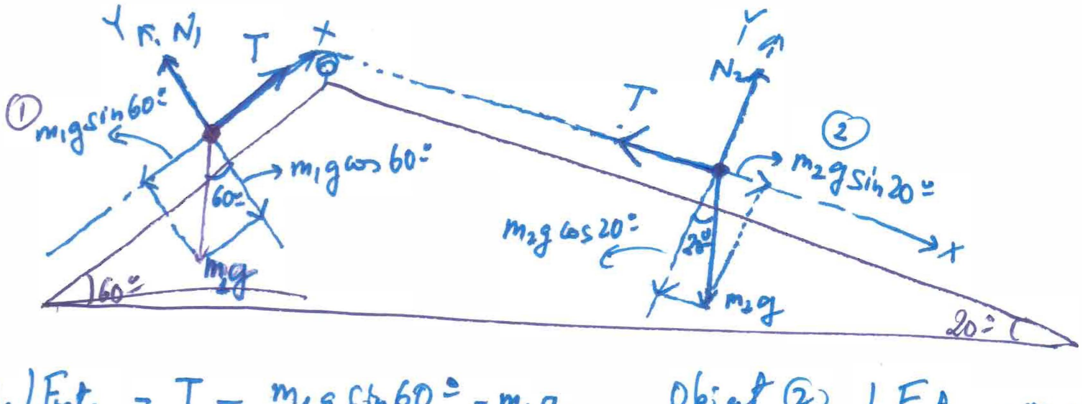
2) Convenient coord system



: Left slope or object ①

: Right slope or object ②

3)



Object ①: $\begin{cases} F_{net_{1x}} = T - m_1 g \sin 60° = m_1 a_x \\ F_{net_{1y}} = N_1 - m_1 g \cos 60° = 0 \end{cases}$

Object ②: $\begin{cases} F_{net_{2x}} = m_2 g \sin 20° - T = m_2 a_x \\ F_{net_{2y}} = N_2 - m_2 g \cos 20° = 0 \end{cases}$

4) ✓

5) Solve for a_x: we have 4 equations with unknowns: T, N_1, N_2, a_x (4)

Actually we just need the equations along x: 2 equations with 2 unknowns (T & a_x):

$$T - m_1 g \sin 60^\circ = m_1 a_x$$
$$m_2 g \sin 20^\circ - T = m_2 a_x$$

$$g\left(m_2 \sin 20^\circ - m_1 \sin 60^\circ\right) = (m_1 + m_2) a_x$$

$$\boxed{a_x = g\,\frac{m_2 \sin 20^\circ - m_1 \sin 60^\circ}{m_1 + m_2}}$$

Analysis: $a_x = \begin{cases} + & : \text{system moving clockwise } (① \uparrow \ \& \ ② \downarrow) \\ - & : \text{" " CCW } (① \downarrow \ \& \ ② \uparrow) \\ 0 & : \text{static equilibrium.} \end{cases}$

$$a_x = \begin{cases} >0 & m_2 \sin 20^\circ > m_1 \sin 60^\circ \Rightarrow \dfrac{m_2}{m_1} > \dfrac{\sin 60^\circ}{\sin 20^\circ} \\ <0 & \text{if } \dfrac{m_2}{m_1} < \dfrac{\sin 60^\circ}{\sin 20^\circ} \\ 0 & \dfrac{m_2}{m_1} = \dfrac{\sin 60^\circ}{\sin 20^\circ} \end{cases}$$

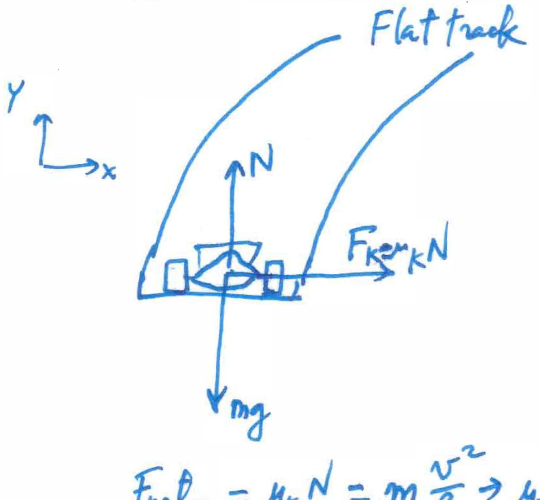
Circular Motion (Uniform)

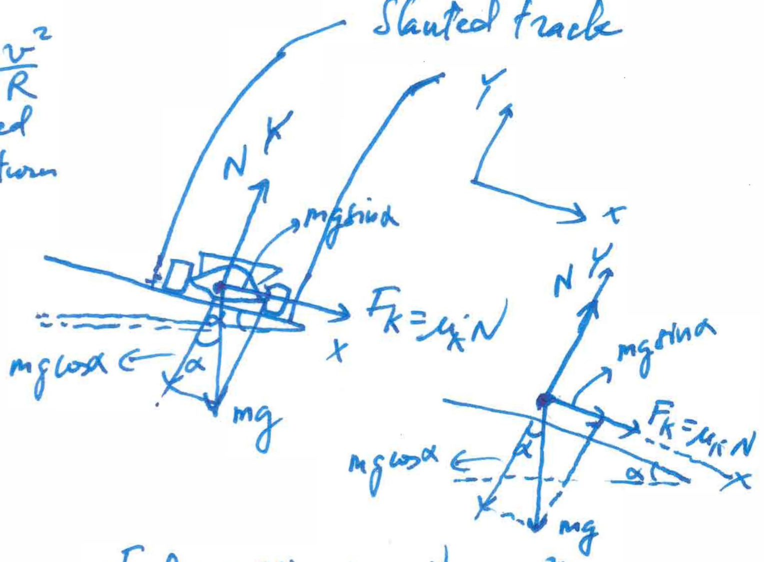
(Ch 5. cont.)

$a = \dfrac{v^2}{R}$

v: const. speed

R: radius of turn





$$F_{net_x} = \mu_K N = m\frac{v^2}{R} \rightarrow \mu_K \cancel{m} g = \cancel{m}\frac{v^2}{R}$$
$$F_{net_y} = N - mg = 0$$
$$v = \sqrt{\mu_K g R}$$

How fast it can turn on a flat track

$$F_{net_x} = mg\sin\alpha + \mu_K N = m\frac{v^2}{R}$$
$$F_{net_y} = N - mg\cos\alpha = 0$$
$$g(\sin\alpha + \mu_K \cos\alpha) = \frac{v^2}{R} \rightarrow v = \sqrt{gR(\sin\alpha + \mu_K \cos\alpha)}$$

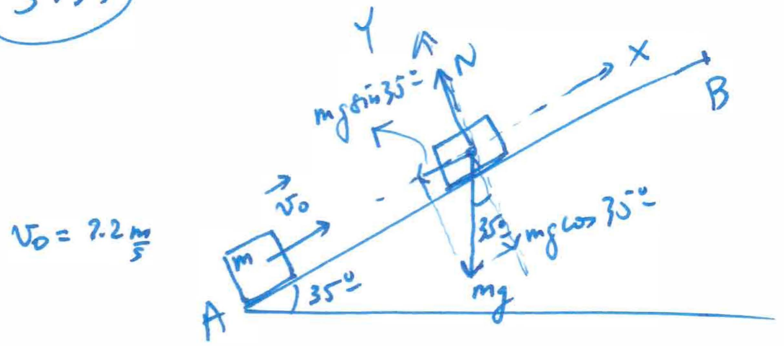
E.g: $\alpha = 20°$ $\rightarrow$ $(\sin 20° + \mu_K \cos 20°) = (0.34 + \mu_K 0.94)$

$\mu_K = 0.2$ $\quad$ $0.34 + \mu_K 0.94 = 0.53$

Flat track: $\quad$ Slanted track

$v = \sqrt{gR\mu_K}$ $<$ $v = \sqrt{gR\,(0.34 + \mu_K 0.94)}$

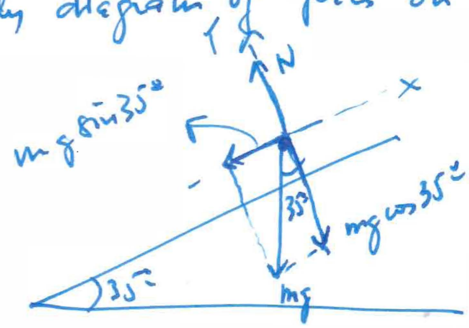
5.33 No friction



Block will come to a stop @ B b/c its downhill component of its weight applies a deceleration. What is the distance AB?

↳ 5-step strategies.

1) Sketch & interpretation ✓
2) Free-body diagram of forces on block:



3) $F_{net_x} = -mg\sin 35° = m a_x$

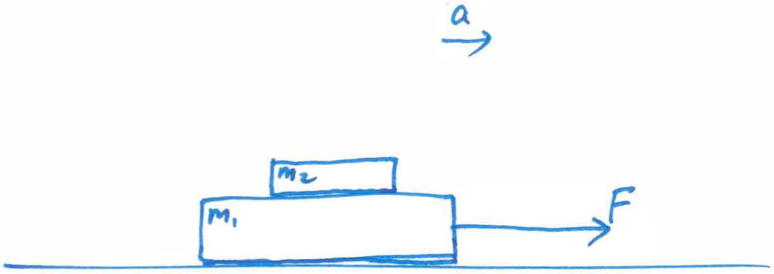
$F_{net_y} = N - mg\cos 35° = 0$

4)

5) $a_x = -g\sin 35°$

$$(x - x_0)_{AB} = \frac{V_B^2 - V_A^2}{2a_x} = \frac{0 - 2.2^2}{-2g\sin 35°} = 0.43\,m.$$

5.48



$m_1 = 1.2\,kg$

$m_2 = 0.31\,kg$

together: $v_0 = 0 \rightarrow v = 0.96\,\frac{m}{s}$ in $\Delta t = 0.42\,s$

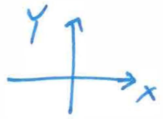
Const. acceleration $v = v_0 + at$ $\rightarrow$ $a = \frac{v - v_0}{\Delta t} = \frac{0.96}{0.42}$

$a = 2.28\,m/s^2$

5-step strategy:

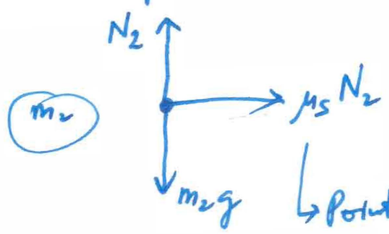
1) Sketch ✓

2) Convenient coord. system:

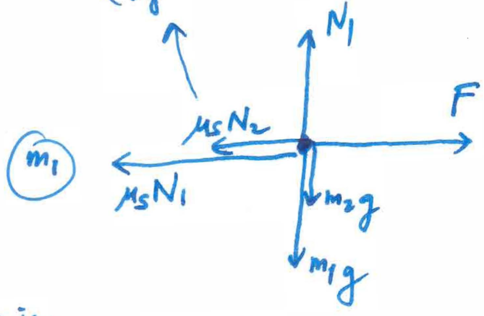


3) FBD of forces:

Focus on top book m_2:



(by action & reaction)



$\rightarrow$ Pointing $+x$

b/c 1) This force will give m_2 the acceleration forward.

2) When m_1 moves forward in $+x$, m_2 tends to slide backward in $-x$

$\rightarrow$ friction always oppose motion.

$$F_{net_x} = \mu_s N_2 = m_2 a$$

$$F_{net_y} = N_2 - m_2 g = 0$$

$\downarrow$

4) $$\mu_s \cancel{m_2} g = \cancel{m_2} a$$

5) $$\mu_s = \frac{a}{g}$$

For two books to move together

$$\mu_s \geq \frac{a}{g} = \frac{2.28}{} = 0.23$$

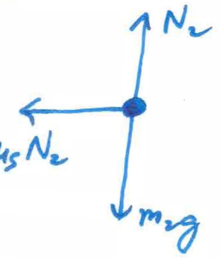
For upper bound for μ_s : the other info provided in the problem: the paperback book slides off when the textbook is brought to a stop in 0.33 s:

$$v_0' = v(t = 0.42\,s) = 0.96\,m/s \xrightarrow[\Delta t = 0.33\,s]{} v' = 0$$

Const. deceleration $\rightarrow$ $a' = \dfrac{v' - v_0'}{\Delta t} = \dfrac{0 - 0.96}{0.33}$

$$a' = -2.91\,m/s^2$$

Focus on top book:



1) Friction switches direction to provide the deceleration for top book.

or 2) When bottom book is slowing down, top book tends to slide forward $\rightarrow$ friction switches direction to oppose motion.

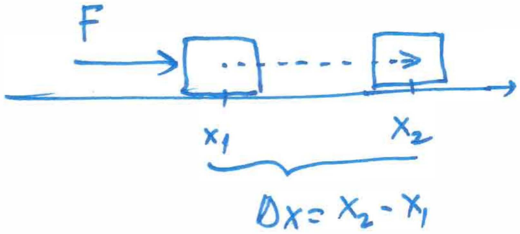
$$F_{net_x} = -\mu_s \cancel{m_2} g = \cancel{m_2} a' \rightarrow \mu_s = -\frac{a'}{g} = -\frac{(-2.91)}{9.81}$$

$$\mu_s = 0.3$$

(upper limit for our μ_s)

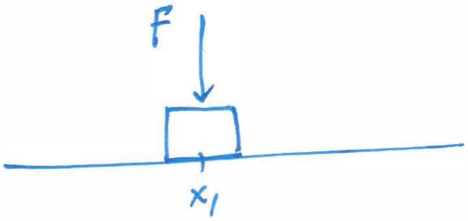
$\Rightarrow$ B/w textbook & paperback: $\boxed{0.23 \leq \mu_s \leq 0.3}$

Ch6: Work, Energy, Power

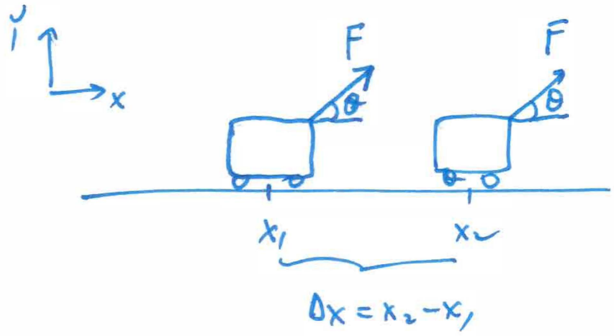


Work = $F . \Delta x$ (SI: N.m or J)

Force applied — displacement — Joule



Work = $F . 0 = 0$



Work = $\underbrace{F\cos\theta}$. Δx

only that component of the force in the direction of displacement is producing work.

(in y-direction: Work = $F\sin\theta \underbrace{\Delta y}_{0} = 0$)

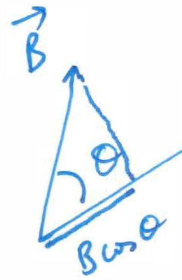
Work done = $\vec{F} \cdot \Delta\vec{r}$

Applied force (vector)

displacement (vector)

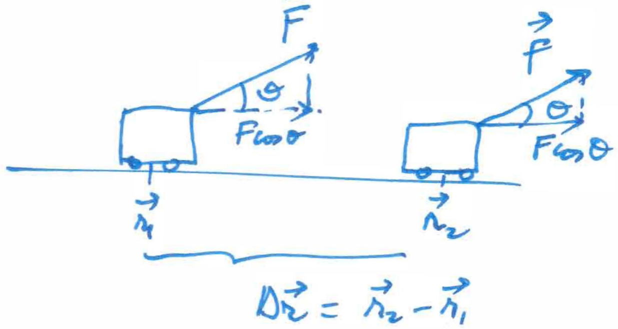
Scaler product b/w two vectors (produce a number) ↳ work

Scalar product b/w 2 vectors $\vec{A}$ & $\vec{B}$:



$\vec{A}\cdot\vec{B} = A \underbrace{B\cos\theta}$

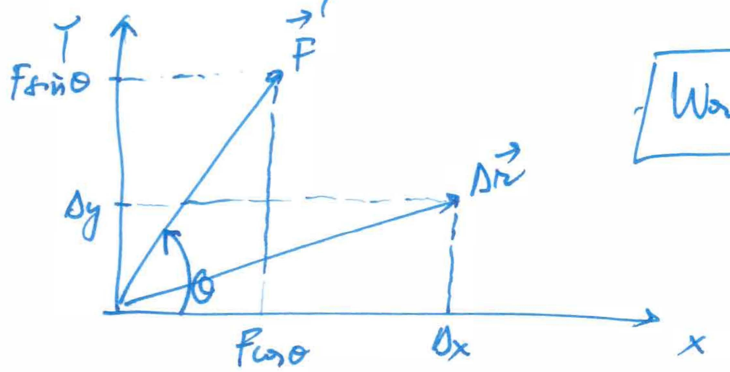
projection of $\vec{B}$ onto direction of $\vec{A}$



$\vec{F}\cdot\Delta\vec{r} = \underbrace{F\cos\theta}\ \Delta r$

projection of $\vec{F}$ onto direction of $\Delta\vec{r}$

Mathematically: use Cartesian coords:



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

$\hat{i}\cdot\hat{i} = 1$ (projection of $\hat{i}$ onto direction of $\hat{i}$ is 1)

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

$\hat{i}\cdot\hat{j} = 0$ (projection of $\hat{i}$ onto $\hat{j}$ is 0 since they are perpendicular to each other)

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

So far: $\vec{F}$ is constant during the displacement. If it is changing during the displacement:

$$\text{Work done} = \int_{\vec{r}_1}^{\vec{r}_2} \vec{F} \cdot \underbrace{d\vec{r}}_{\text{infinitesimal displacement vector}}$$

$\vec{F}$: Force applied.

E.g.: Work done in stretching a spring: (from 0 to x)

recovery by spring.

$\vec{F} = -k\Delta x$ or $-kx$ (ref. @ the natural length)

$$\int_0^x F \cdot dx = +\int_0^x kx\,dx = +k\frac{x^2}{2}\Big]_0^x = \frac{1}{2}kx^2$$

Work done by us is $+kx$

scalar product in 1D is just regular product

$$\boxed{\int_a^b x^n\,dx = \left[\frac{x^{n+1}}{n+1}\right]_a^b}$$

Calculus.

$\boxed{\text{Energy:}}$ as related to motion → kinetic energy or K.E.

2nd Newton's Law: $\vec{F}_{net} = \frac{d\vec{p}}{dt} = m\frac{d\vec{v}}{dt}$

m const.

$$\Delta K.E. = \int_{\vec{r}_1}^{\vec{r}_2} \vec{F}_{net} \cdot d\vec{r} = m\int_{\vec{r}_1}^{\vec{r}_2} \frac{d\vec{v}}{dt} \cdot d\vec{r} = m\int_{\vec{r}_1}^{\vec{r}_2} d\vec{v} \cdot \underbrace{\frac{d\vec{r}}{dt}}_{\vec{v}}$$

Work applied is equal to the change in K.E. of the system.

$\vec{v} \cdot d\vec{v}$

$$= m\int_{\vec{r}_1}^{\vec{r}_2} v\,dv = \frac{1}{2}mv^2\Big]_{\vec{r}_1}^{\vec{r}_2}$$

$$= \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = KE_2 - KE_1$$

→ $\boxed{KE = \frac{1}{2}mv^2}$ (linear motion $\vec{v} \parallel d\vec{v}$)

$\boxed{\text{Power:}}$ P : work or energy per unit time ($SI = \frac{J}{s} = W$ or Watt)

(How fast you can change K.E. of a car is related to the "HP" or horse power)

Average power: $\bar{P} = \frac{\Delta \text{work}}{\Delta t}$

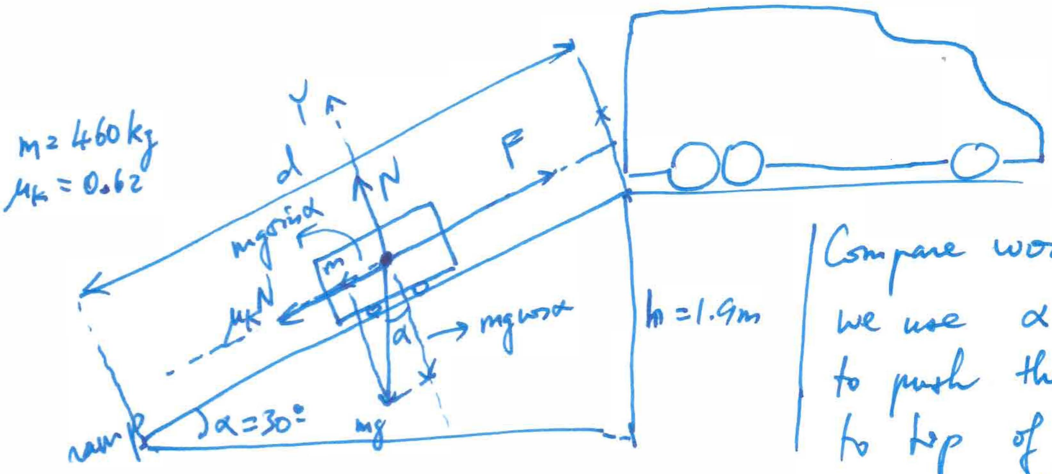
Instantaneous power: $P = \frac{d\,\text{Work}}{dt}$

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

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

$\vec{F}$ is constant

Example or Application



Compare work done if we use $\alpha = 30°$ or $\alpha = 15°$ to push the piano from bottom to top of ramp (h is fixed @ 1.9 m)

$F \cdot d = F \cdot \frac{h}{\sin\alpha}$

$d \sin\alpha = h$

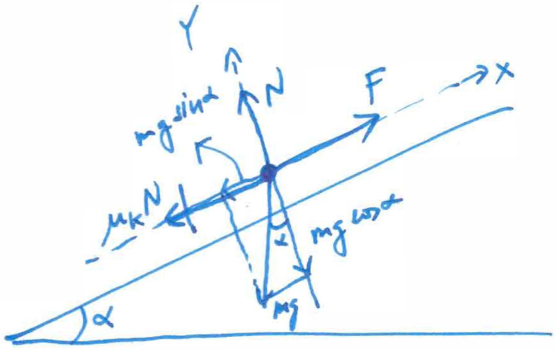
$h = 1.9\,m$

$\alpha = 30°$ or $15°$

→ Need to find F using 5-step strategy:

1) Sketch. 2) Convenient coord. system

3) FBD of forces on piano:



$$F_{net_x} = F - mg\sin\alpha - \mu_k N = 0$$

$$F_{net_y} = N - mg\cos\alpha = 0$$

heavy object: $a=0$
(minimum effort principle)

4) Write RHS for Newton's 2^{nd} law:

5) Solve for F:

$$F - mg\sin\alpha - \mu_k mg\cos\alpha = 0$$

$$\boxed{F = mg(\sin\alpha + \mu_k \cos\alpha)}$$

Work done: $F.d = F.\dfrac{h}{\sin\alpha} = mgh\dfrac{\sin\alpha + \mu_k\cos\alpha}{\sin\alpha}$

$$= mgh\left(1 + \frac{\mu_k}{\tan\alpha}\right)$$

$\alpha = 15° \rightarrow$ Work done $= 460 \times 9.81 \times 1.9\left(1 + \dfrac{0.62}{\tan 15°}\right) = 28.5\,kJ$

$\alpha = 30° \rightarrow$ Work done $= 460 \times 9.81 \times 1.9\left(1 + \dfrac{0.62}{\tan 30°}\right) = 17.8\,kJ$

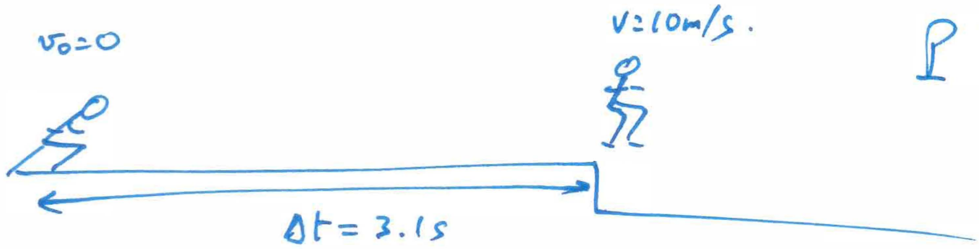
(Steeper ramp: less work done!)

Force applied:
- $\alpha = 15° \rightarrow F = 460 \times 9.81(\sin 15° + 0.62\cos 15°) = 3.88\,kN$
- $\alpha = 30° \rightarrow F = 4.68\,kN$

(Steeper ramp, require larger force applied!)

6.38

$m = 75\,kg$



P ?

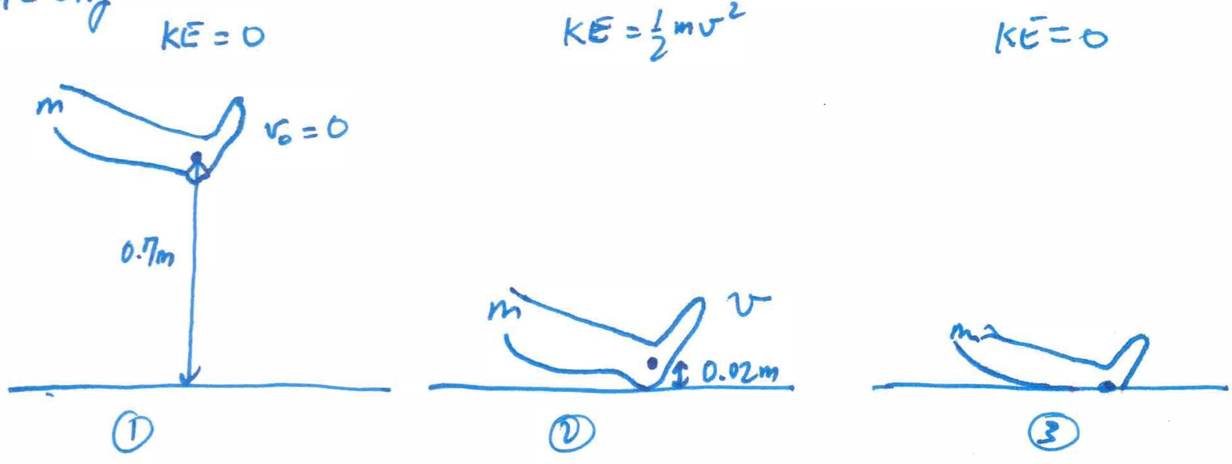
$$P = \frac{\Delta KE}{\Delta t} = \frac{KE - KE_0}{\Delta t} = \frac{\frac{1}{2}mv^2 - 0}{\Delta t} = \frac{\frac{1}{2}75 \times 10^2}{3.1}$$

$$= \frac{3750\,J}{3.1\,s} = 1.21\,kW$$

$1\,HP = 746\,W \longrightarrow \quad P = 1.21\,kW \dfrac{1\,HP}{0.746\,kW} = 1.6\,HP$

6.81 Stopping force on a falling leg ?

$m = 8\,kg$



Free fall velocity increasing from 0 to v

Stopping/decelerating ~~crash~~ motion bringing v to 0 by a stopping force (is it 80N?)

Alternative #1 : using work / energy :

① → ② : energy acquired by leg = $F \cdot h = mgh$
This also equals the ΔKE b/w ① & ② $= \frac{1}{2} mv^2$

② → ③ the energy acquired is lost but during a displacement of only $d = 0.02m$!

$$mgh = F_{stop} \cdot d \rightarrow \text{since } d \ll h$$
$$\Rightarrow F_{stop} \gg \underbrace{mg}_{\simeq 80N} !$$

$$F_{stop} = \frac{8 \times 9.81 \times 0.7}{0.02} = 2744 N$$

Alternative #2 : using kinematic equations & Newton's 2nd law

① → ② find v : $\frac{v^2 - 0^2}{h} = 2g \rightarrow v = \sqrt{2gh}$
$= \sqrt{2 \times 9.81 \times 0.7}$
$= 3.7 m/s$

② → ③ find acceleration a → $F_{stop} = ma$

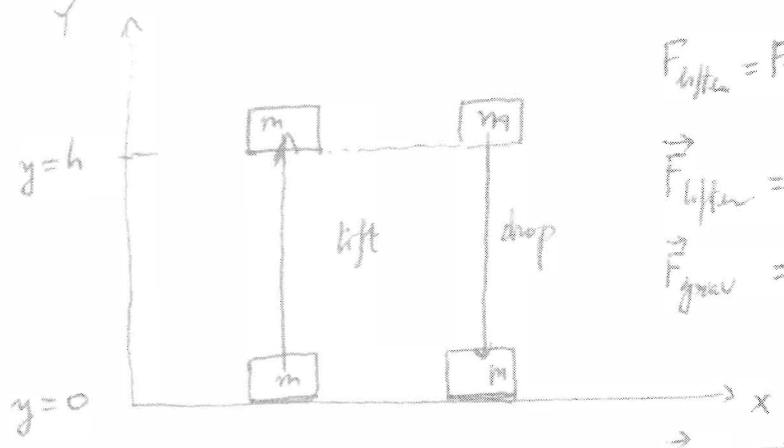
$$\frac{0 - v^2}{d} = 2a \rightarrow a = -\frac{v^2}{2d} = -\frac{3.7^2}{2 \times 0.02} =$$

$$\boxed{a = -343.35 \, m/s^2}$$

deceleration

$$F_{stop} = ma = -8 kg \cdot 343.35 \, m/s^2 = -\underline{2774 N}$$

Ch 7 Conservation of Energy



F_{lifter} = Force by lifter = mg (no upward acceleration)

$\vec{F}_{lifter} = mg\,\hat{j}$; $\vec{\Delta y} = h\,\hat{j}$

$\vec{F}_{grav} = -mg\,\hat{j}$; $\vec{\Delta y} = h\,\hat{j}$ $(0 \to h)$ $\vec{\Delta y} = h\hat{j}$

$\vec{\Delta y}_{drop} = -h\,\hat{j}$

Lifting: { Work done by lifter: $\vec{F}_{lifter} \cdot \vec{\Delta y} = +mgh$
Work done by gravity: $\vec{F}_{grav} \cdot \vec{\Delta y} = -mgh$ }

Dropping: { Work done by dropper: $\vec{F}_{dropper} \cdot \vec{\Delta y}_{drop} = 0 \cdot (-h\hat{j}) = 0$
Work done by gravity: $\vec{F}_{grav} \cdot \vec{\Delta y}_{drop} = +mgh$ }

→ Work done by gravity or gravitational potential energy is conserved;
or gravitation is a conservative force.

Kinetic friction: μ_K

Moving box at constant speed:

$0 \to l$ { $\vec{F}_{app} = \mu_K mg\,\hat{i}$
$\vec{F}_f = -\mu_K mg\,\hat{i}$
$\vec{\Delta x} = l\,\hat{i}$ }

$0 \to l$ { work done by pusher: $\vec{F}_{app} \cdot \vec{\Delta x} = \mu_K mgl$
work done by friction: $\vec{F}_f \cdot \vec{\Delta x} = -\mu_K mgl$ }

$\vec{F}_{app} = -\mu_K mg\,\hat{i}$
$\vec{F}_f = \mu_K mg\,\hat{i}$

$l \to 0$ { work done by pusher: $\vec{F}_{app} \cdot \vec{\Delta x} = \mu_K mg\,l$
work done by friction: $\vec{F}_f \cdot \vec{\Delta x} = -\mu_K mgl$ }

energy is not conserved → friction is not a conservative force.

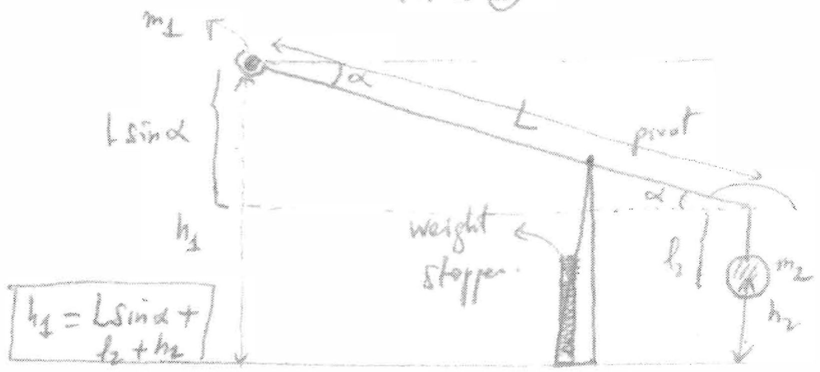
Conservation of Mechanical Energy.

Mechanical energy: sum of kinetic energy and gravitational potential energy $\frac{1}{2}mv^2 + mgh$

$$\boxed{\left(\frac{1}{2}mv_i^2 + mgh_i\right) = \left(\frac{1}{2}mv_f^2 + mgh_f\right)}$$

P.P.3 q.71: Trebuchet or catapult:

initial (i) time (i)



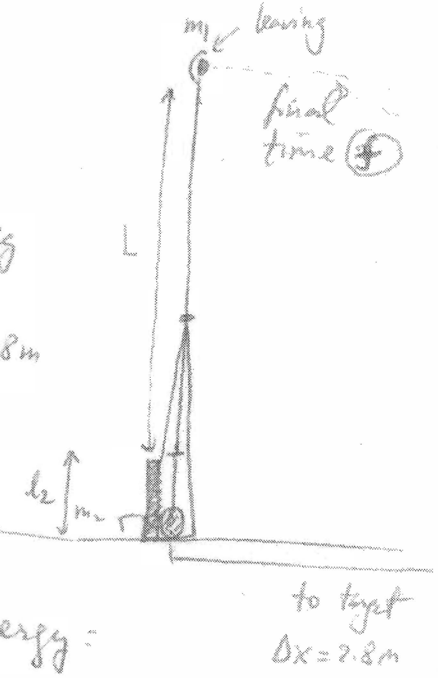
$L + l_2 = 1.1m$

$m_1 = 1kg$

$m_2 = 0.1kg$

$\boxed{h_2 ?}$ →

$\Delta x_{Range} = 2.8m$



→ System based on conservation of mechanical energy:

$$M.E_{(i)} \text{ of } m_1 \,\&\, m_2 = ME_{(f)} \text{ of } m_1 \,\&\, m_2$$

(S.I.)

$$\underbrace{\frac{1}{2}m_1\cancel{v_{1i}^2}_{0} + \frac{1}{2}m_2\cancel{v_{2i}^2}_{0}}_{\cancel{KE_i}\ 0} + \underbrace{m_1gh_1 + m_2gh_2}_{PE_i} = \underbrace{\frac{1}{2}m_1v_{1f}^2 + \frac{1}{2}m_2 v_{2f}^2}_{KE_f} + \underbrace{m_1 g\, 1.1 + m_2 g\, 0}_{PE_f}$$

v_{2f} → 0 due to weight stopper

$$m_2gh_2 = \frac{1}{2}m_1v_{1f}^2 + \underbrace{m_1g(1.1 - h_1)}_{m_1g(1.1 - L\sin\alpha - l_2 - h_2)}$$

$$(m_1 + m_2)gh_2 = \frac{1}{2}m_1v_{1f}^2 + \underbrace{m_1 g(1.1 - L\sin\alpha - l_2)}_{\text{estimate } \alpha = \ldots}$$

$$\boxed{h_2 = \frac{\frac{1}{2} m_1 v_{1f}^2}{(m_1 + m_2) g}}$$

Find v_{1f}: from projectile motion of m_1:

horizontal: uniform motion $\Delta x = v_{1f} \underset{\uparrow \text{need}}{\Delta t} \Rightarrow v_{1f} = \frac{\Delta x}{\Delta t} = \frac{2.8}{\sqrt{\frac{2.2}{9.81}}} = 5.9 \ \frac{m}{s}$

vertical: constant deceleration. $\Delta y = \frac{1}{2} g t^2 \rightarrow t = \sqrt{\frac{2 \Delta y}{g}} = \sqrt{\frac{2 \times 1.1}{9.81}}$

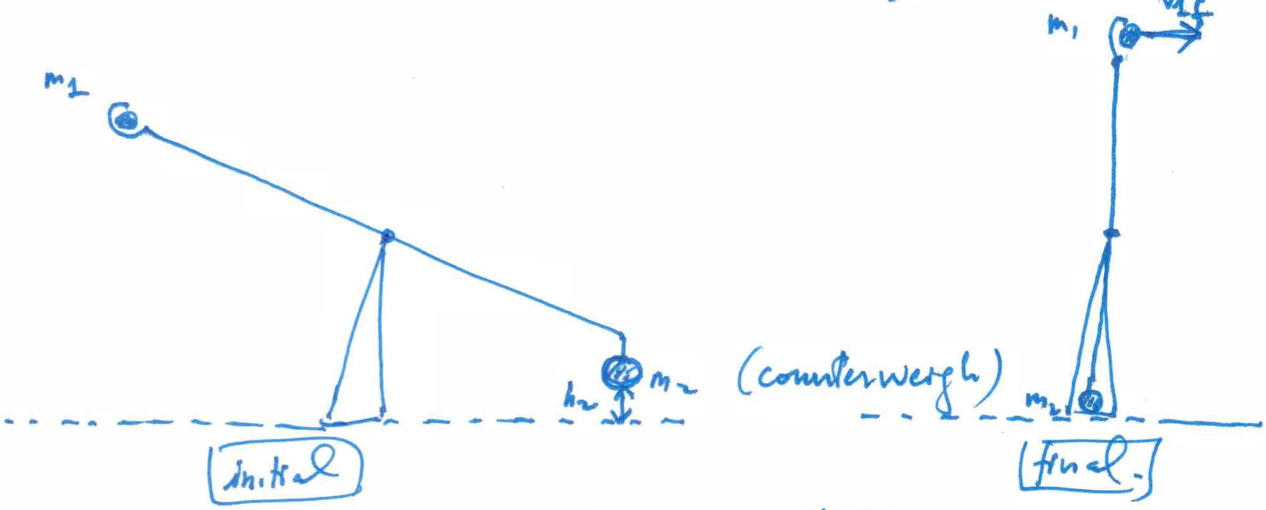
Conserv. M.E:

$$h_2 = \frac{\frac{1}{2} 0.1 \times 5.9^2}{(0.1 + 1) \times 9.81} = \quad m$$

Ch 8. Conservation of Energy

Mechanical energy is conserved: Kinetic energy + Grav. Potential Energy

$$\left(\frac{1}{2}mv^2 + mgh\right)_i = \left(\frac{1}{2}mv^2 + mgh\right)_f$$



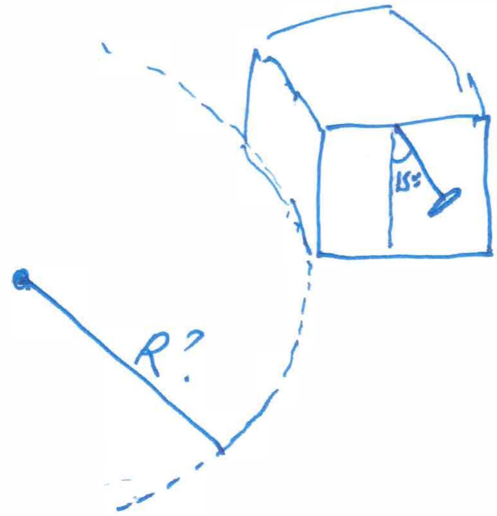
Conserv. Mech. Energy: h_2 → v_{1f}

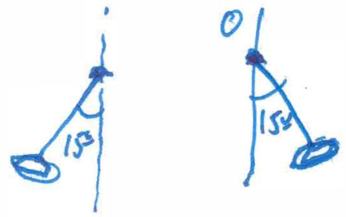
h_2
Potential (counterweigh.)
(No K.E. : system @ rest)

v_{1f}
KE for m_1
+ some small increase in potential energy for m_1

5.25

- Train takes a turn following a circular trajectory @ constant speed of $67 \frac{km}{h}$
- An unused strap makes an angle of $15°$ wrt. vertical



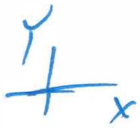


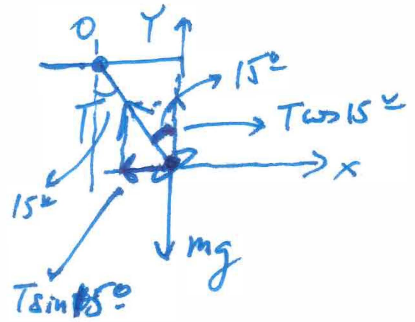
① ②

When train is turning left (sketch) the fixed point O is turning with train but the handle is not.

5 step-strategy:

1) ✓

2) Convenient coord. XY 

3) 

$67 \frac{km}{h} \frac{1}{3.6} = 18.6 \frac{m}{s}$

acceleration in a UCM.

$$F_{net_x} = T \sin 15° = m \cdot \frac{v^2}{R}$$

$$F_{net_y} = T \cos 15° - mg = m\, 0$$

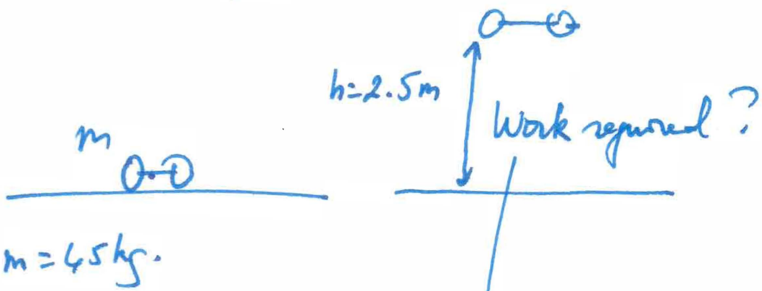
4) ✓

5) $T = \frac{mg}{\cos 15°} \rightarrow \cancel{m} g \frac{\sin 15°}{\cos 15°} = \cancel{m} \frac{v^2}{R}$

$$\rightarrow R = v^2 / (g \tan 15°) = \frac{18.6^2}{9.81 \tan 15°} = 132 m$$

6.80

- $230\ \cancel{cal}.\ \dfrac{4.186\ kJ}{\cancel{cal}} = 962.78\ kJ$

- 

$F.h = mgh = 45 \times 9.81 \times 2.5$
$= 1.1\ kJ$ (one lift)

Force applied = its weight
(minimum effort principle).

$$\#\text{ of lifts} = \frac{\text{Total energy to burn}}{\text{Energy required per lift}} = \frac{962.78\ kJ}{1.1\ kJ}$$

$= 873$ lifts.

6.20

$\vec{F} = 1.8\hat{i} + 2.2\hat{j}\ N$ (not changing with position!)

$\vec{r}_1 = 0 \longrightarrow \vec{r}_2 = 56\hat{i} + 31\hat{j}\ m$

Work done $= \underbrace{\vec{F} \odot \Delta\vec{r}}_{\text{scalar product}} = 1.8 \times 56 + 2.2 \times 31\ J$