Lab 5 is in SCI 134

Please, login into webassing, locate LectureMCQ_L10 (PY105) and answer question 1 (but ONLY Q1!)

And sign in (the sheets are on the bench)

Note: exam room change:
Exams 2,3 take place in STO B50

Good morning!

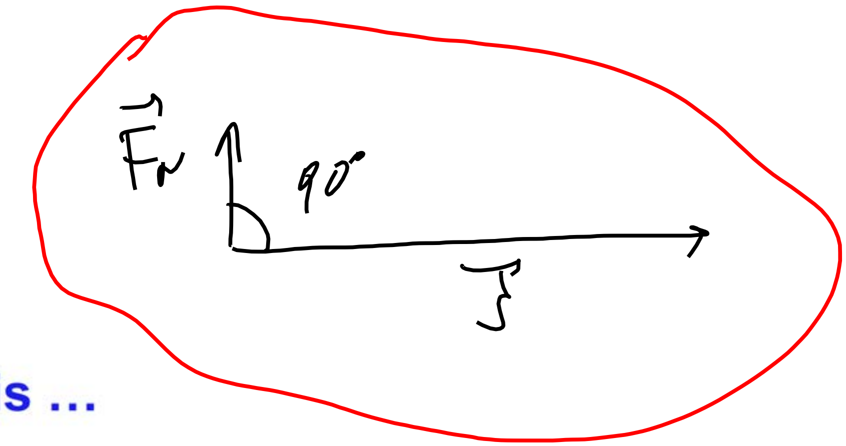
Work done by a *normal* force

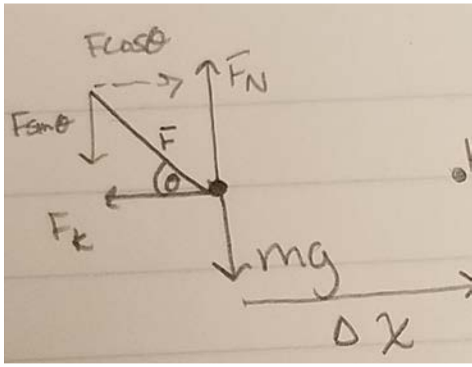
$$W_{cF} = |\vec{F}| * |\vec{S}| * \cos\theta$$

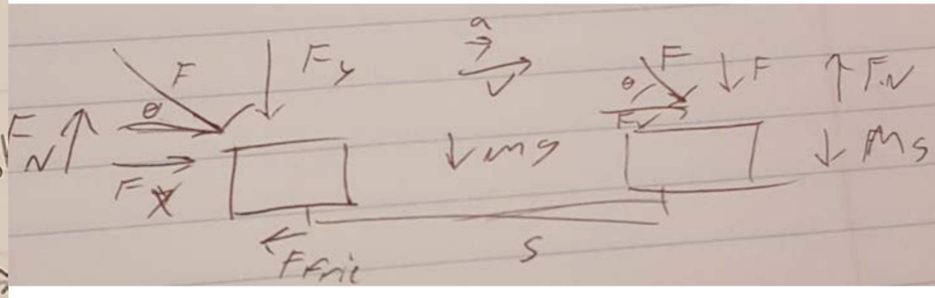
You push a box applying a force (as shown in the picture).

The work done by the *normal* force is …

1. < 0 2. = 0 3. > 0





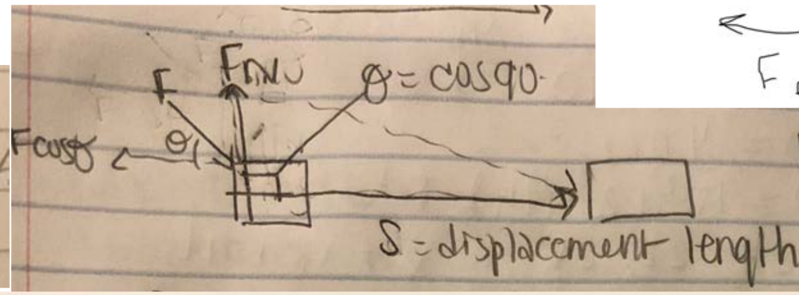


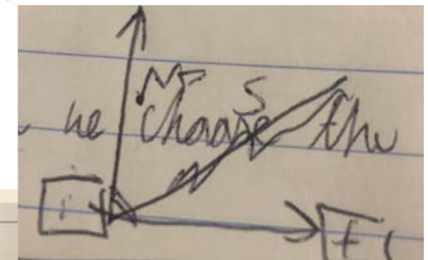
Lecture 9

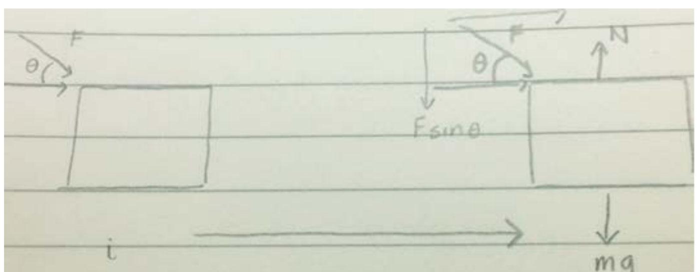
Tuesday, June 5, 2018 8:37 AM

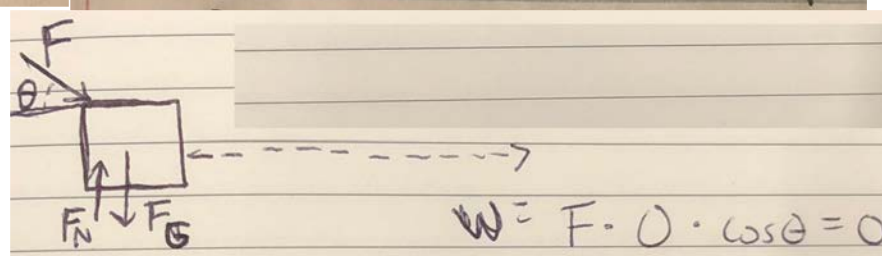
New Material

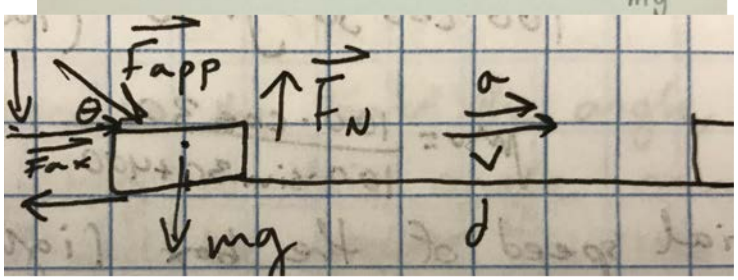
You push a box applying a force
The work done by the normal f
1. <0 (2) =0 3. >0.

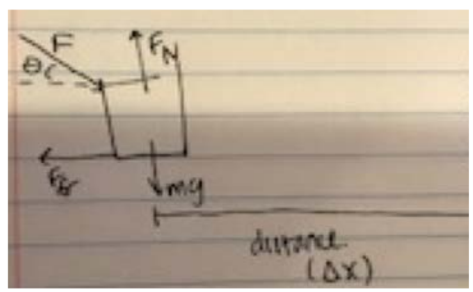


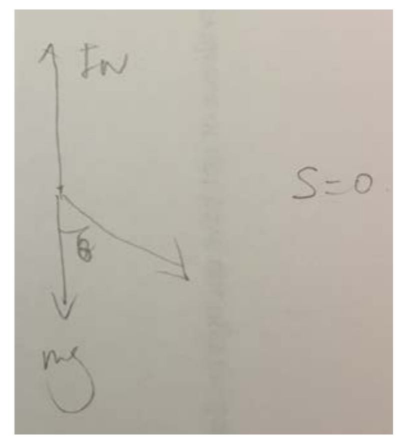


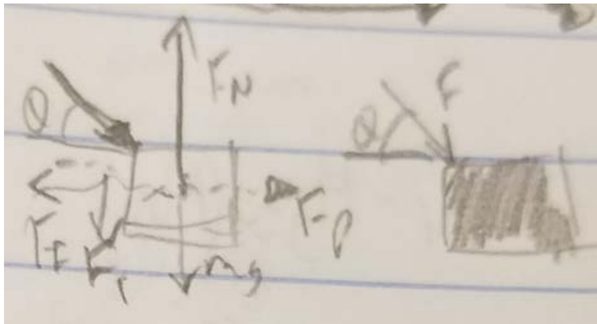


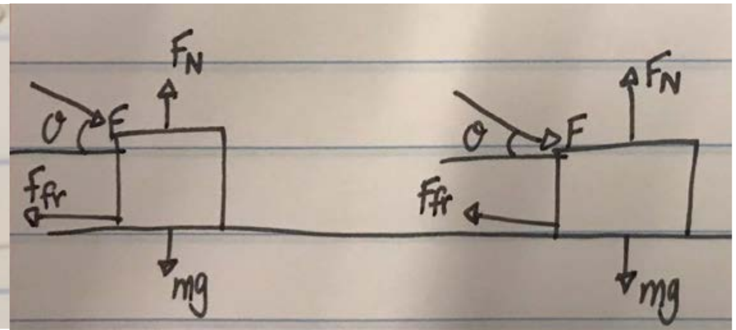


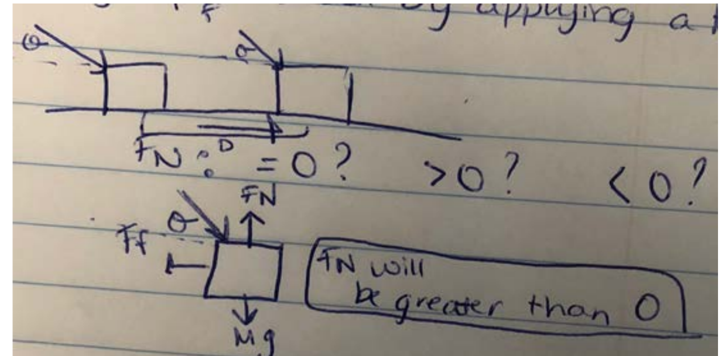


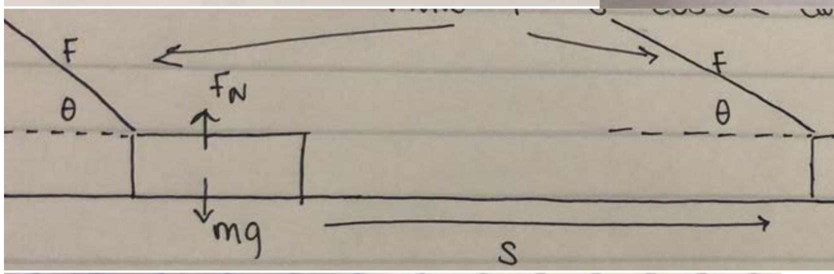


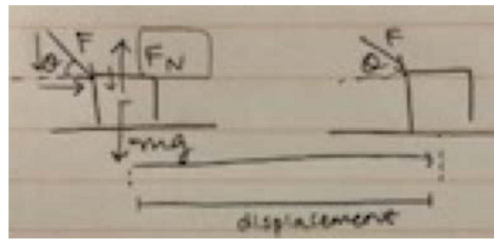


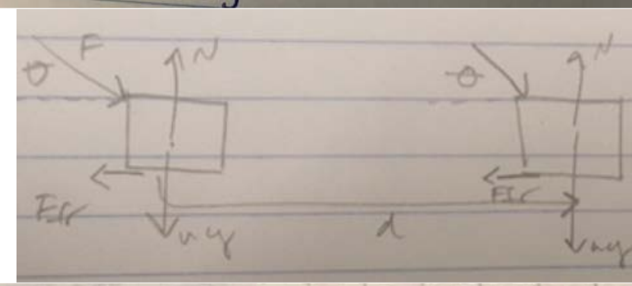

F_N
θ
F
mg

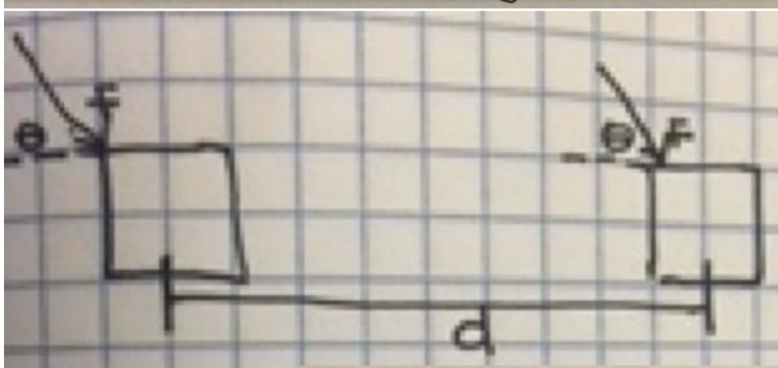

F_N
θ
F
f_fr
mg

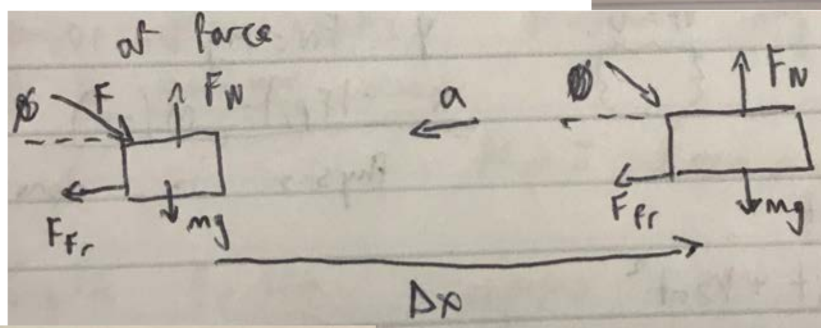

F_N = 0? >0? <0?
F_N
Ff
Mg
F_N will be greater than 0

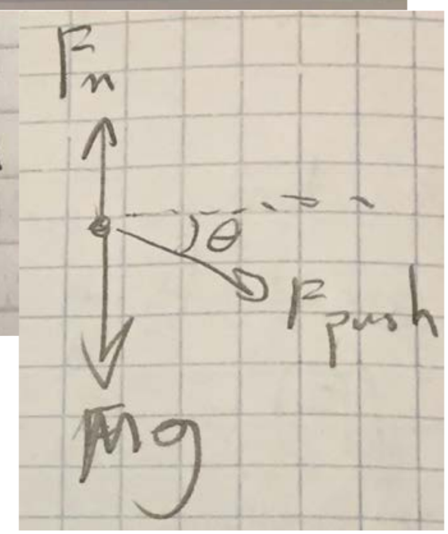

F
θ
F_N
mg
S

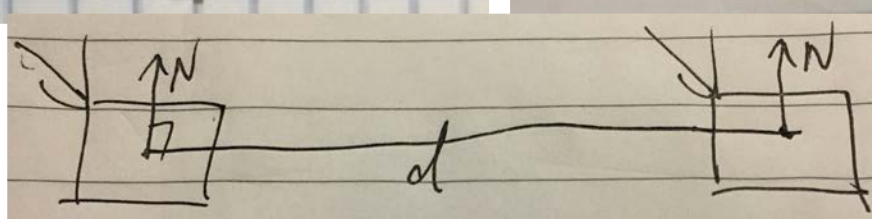

F
F_N
mg
displacement

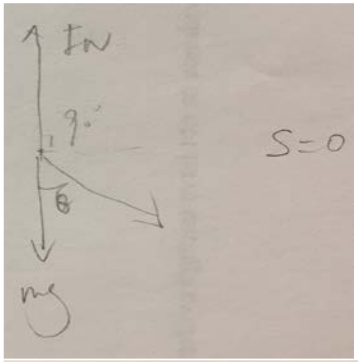

F
N
θ
d

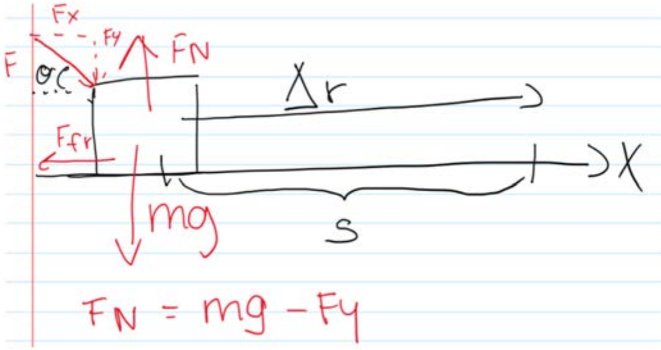

θ
F
d

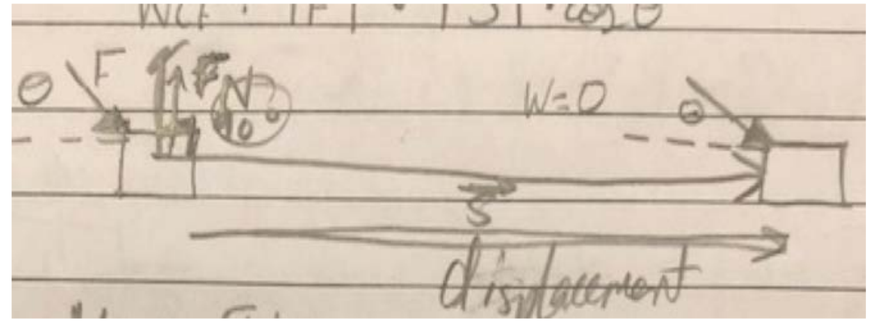

at force
F
F_N
a
F_fr
mg
Δx

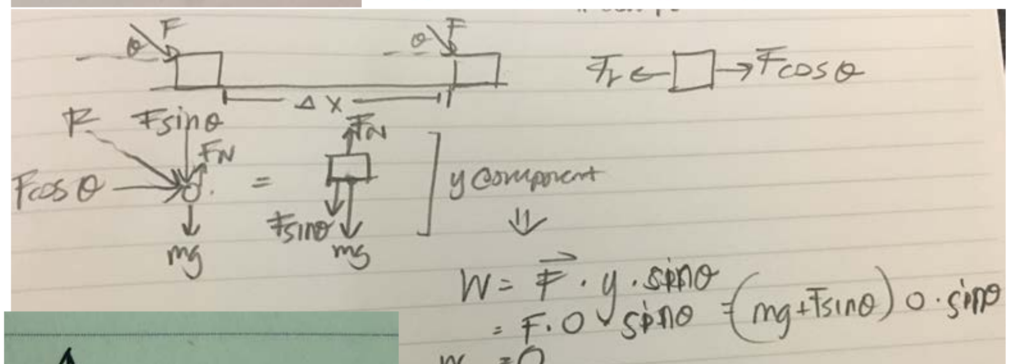

F_n
θ
F_push
Mg

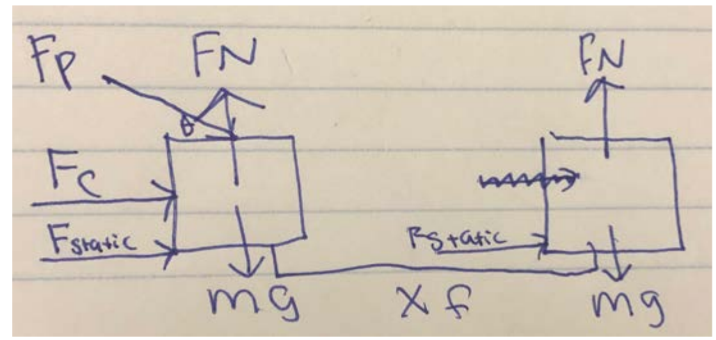

N
d

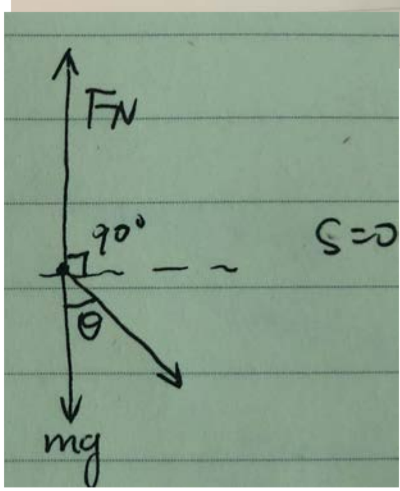

FN
90°
θ
mg
S=0

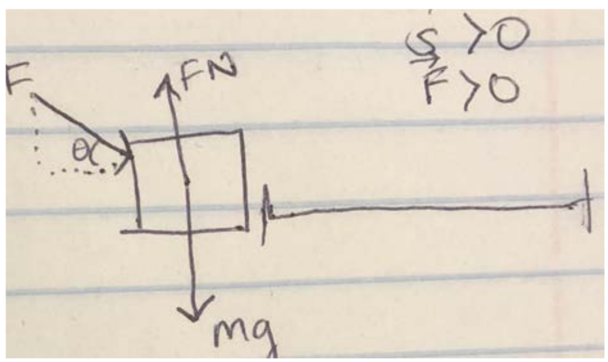

Fx
Fy
F
θ
FN
Δr
Ffr
X
mg
S
FN = mg − Fy

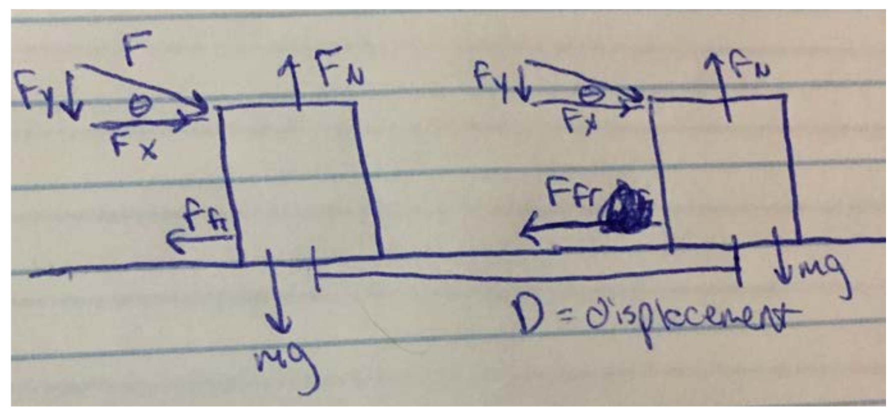

θ
F
W=0
S
displacement

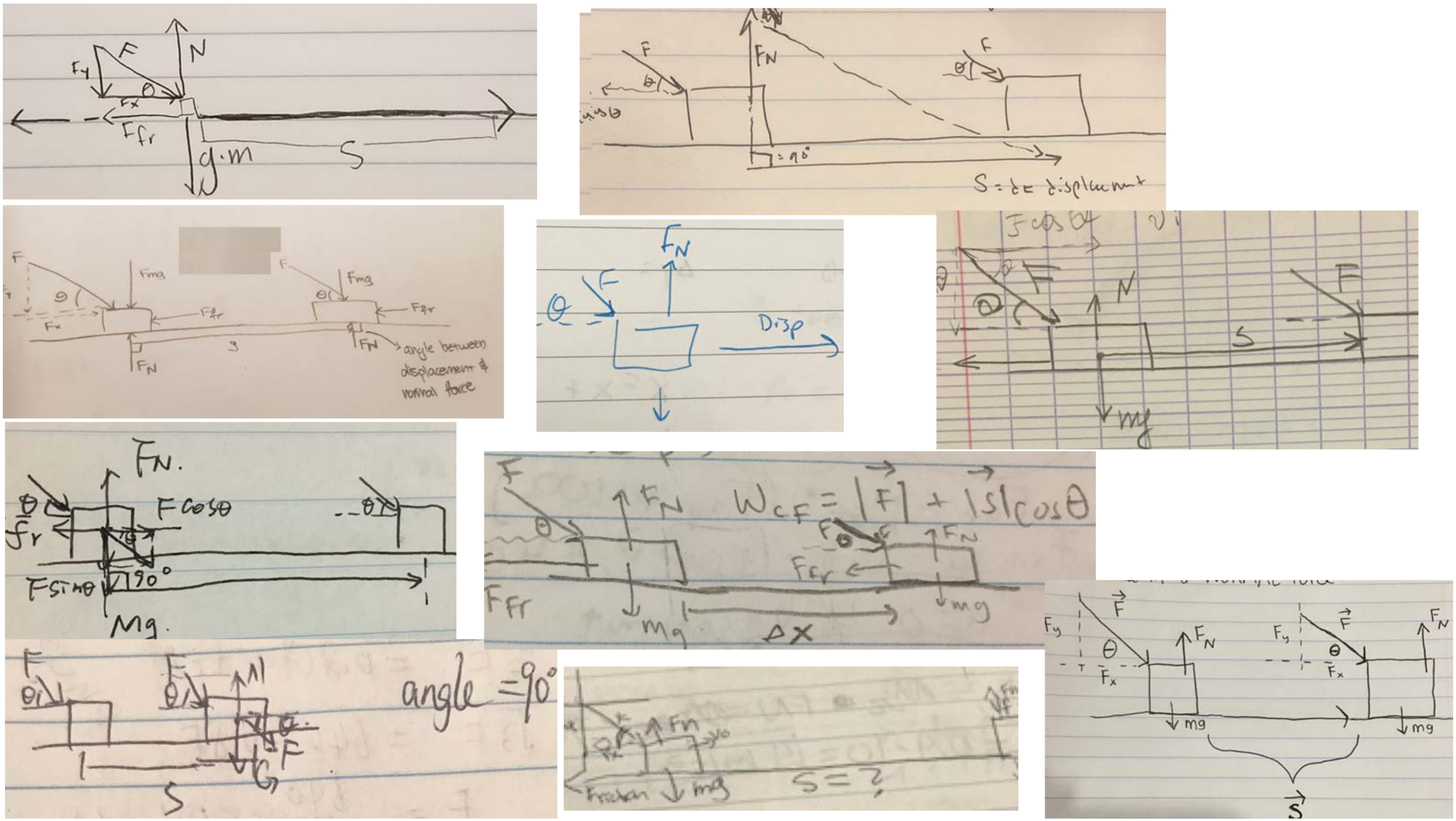

F
θ
Δx
Fr
Fcosθ
Fsinθ
FN
mg
y component
W = F · y · sinθ
= F · 0 · sinθ
(mg + Fsinθ) 0 · sinθ


Fp
FN
θ
Fc
Fstatic
mg
X f

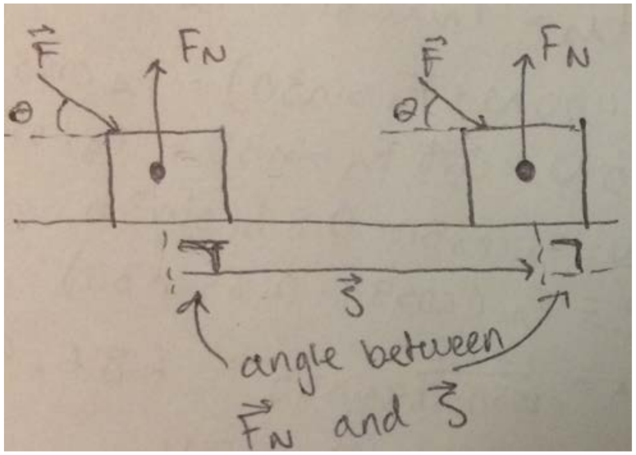

FN
90°
θ
S=0
mg

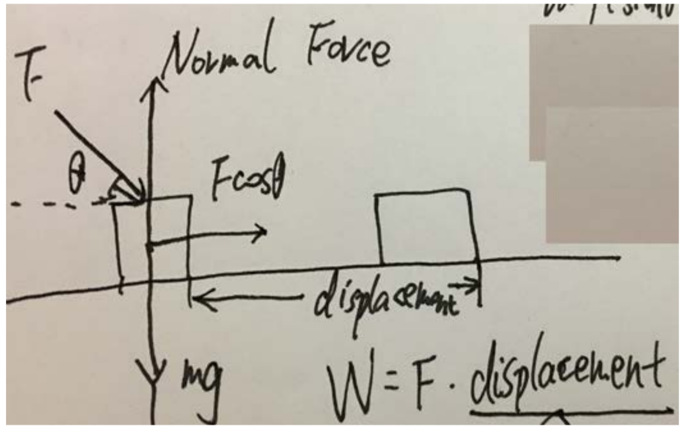

S>0
F>0
F
θ
FN
mg

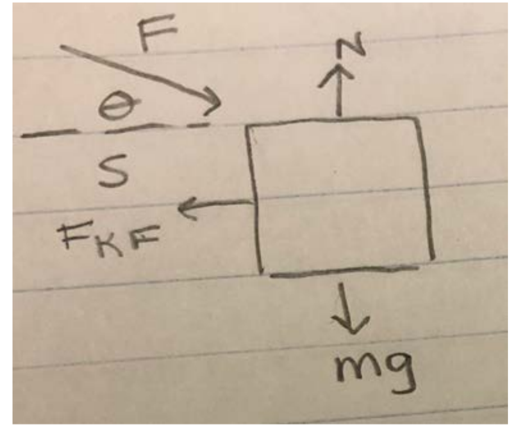

F
Fy
θ
Fx
FN
Ffr
mg
D = displacement

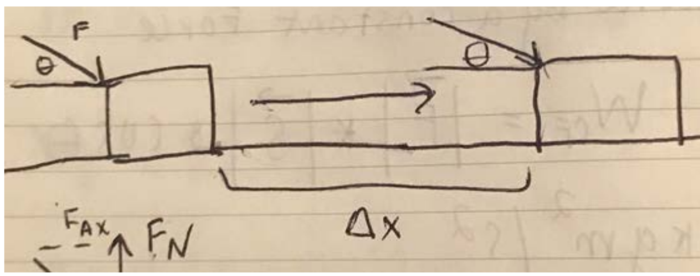


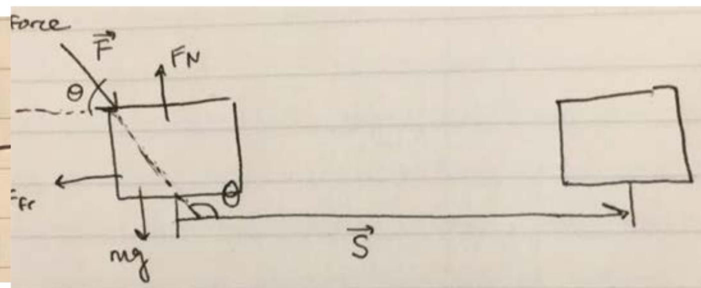
F
N
Fy
Fx
θ
Ffr
g·m
S
FN
S = the displacement
Fmg
Ffr
angle between displacement & normal force
FN
Disp
F cos θ
mg
FN.
F cosθ
fr
F sinθ
90°
Mg.
$W_{cF} = |\vec{F}| + |\vec{s}|\cos\theta$
Ffr
mg
ΔX
$\vec{F}$
Fy
Fx
mg
$\vec{S}$
angle = 90°
S
Friction
mg
Fn
S = ?

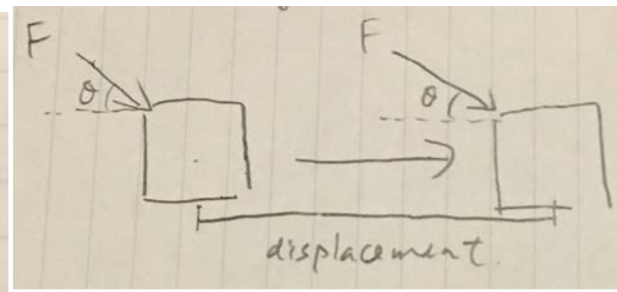

$\vec{F}$
F_N
θ
$\vec{F}$
F_N
θ
$\vec{s}$
angle between $\vec{F}_N$ and $\vec{s}$

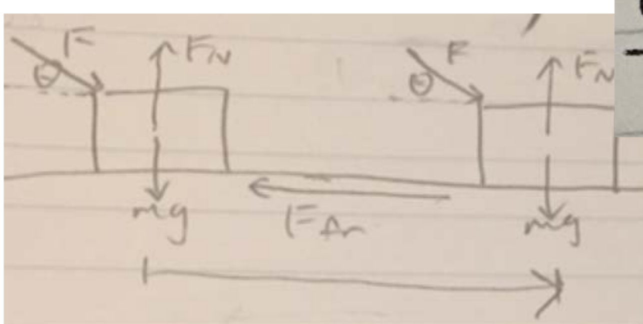

F
Normal Force
θ
Fcosθ
displacement
mg
W = F · displacement

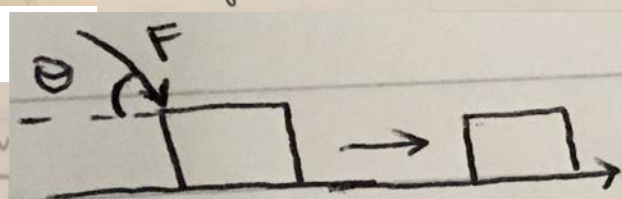

F
N
θ
S
F_{KF}
mg

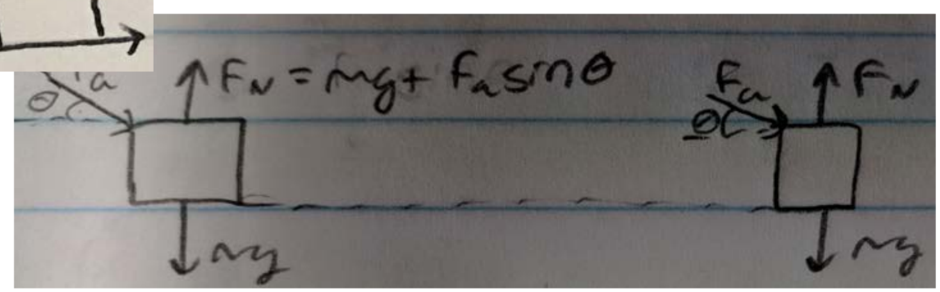

F
θ
θ
Δx
F_{AX}
F_N

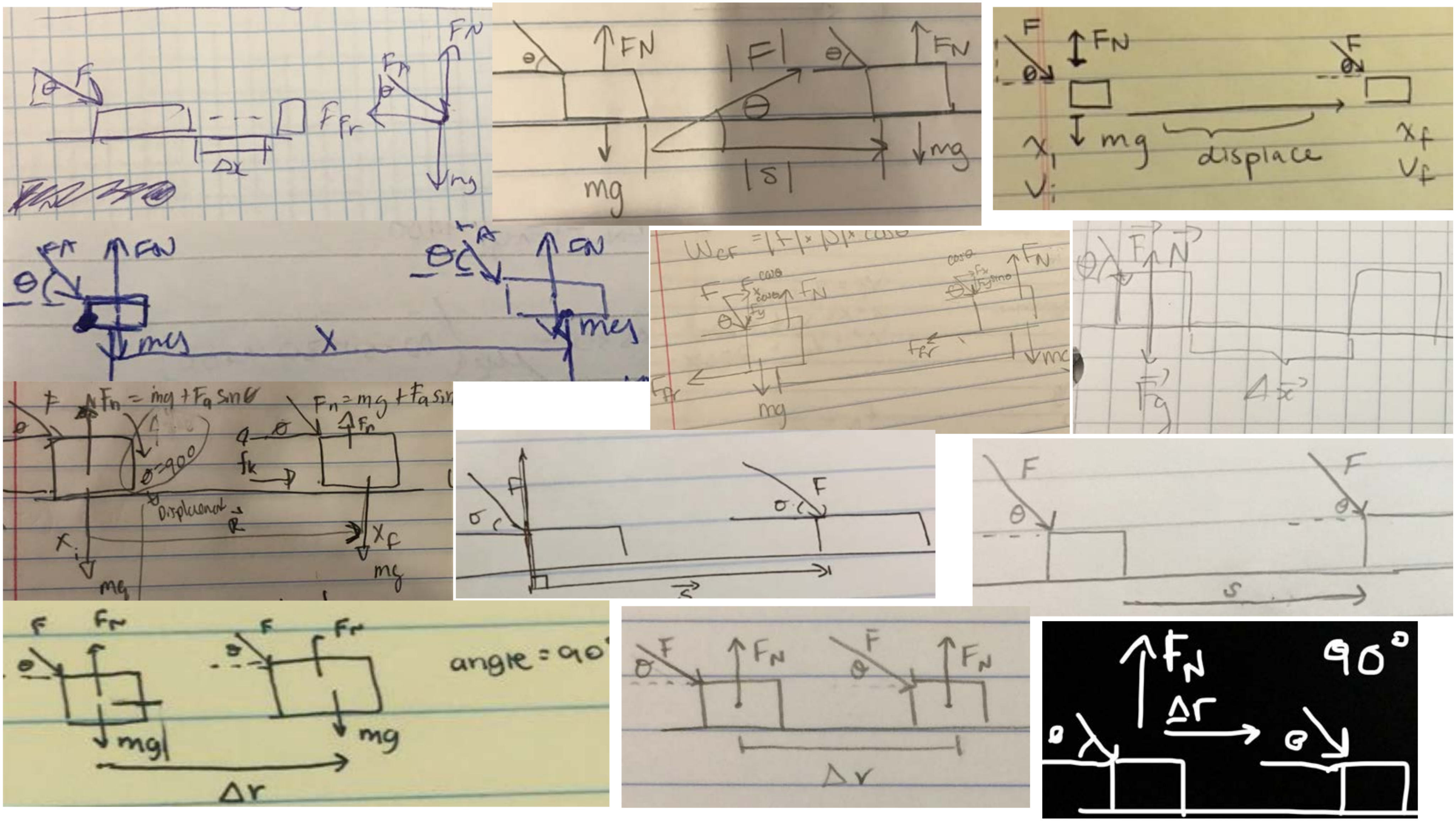

Force
$\vec{F}$
F_N
θ
F_{fr}
mg
θ
$\vec{s}$


F
F
θ
θ
displacement

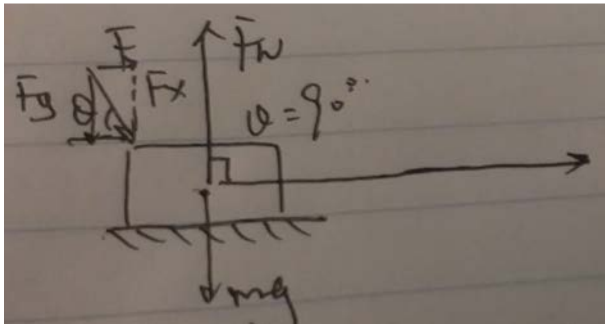

F
F_N
θ
F
θ
F_N
mg
F_{Ar}
mg

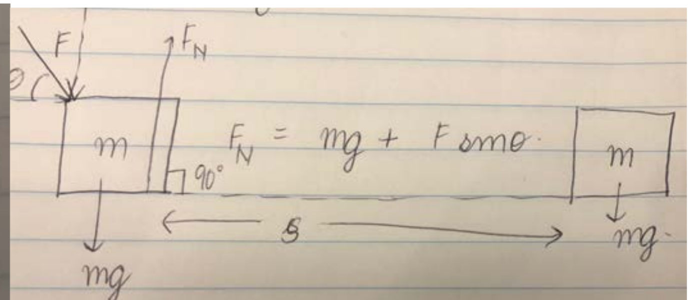

θ
F

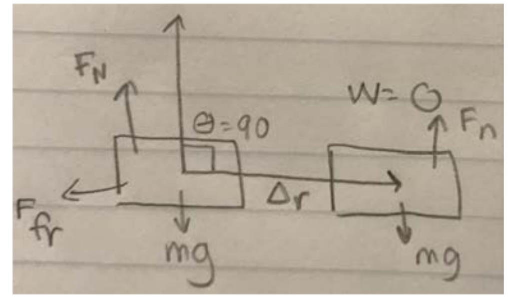

F_a
θ
$F_N = mg + F_a \sin\theta$
F_a
F_N
θ
mg
mg

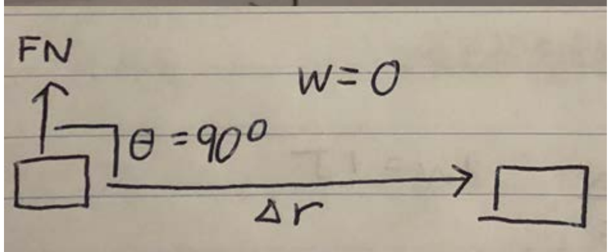


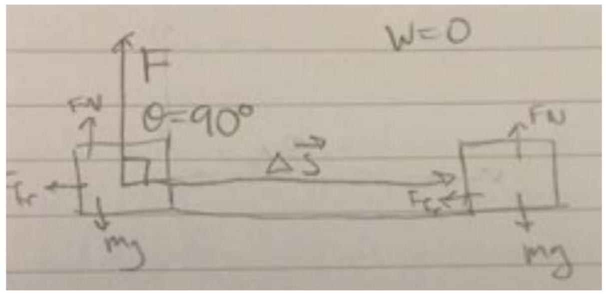
F
FN
Ffr
Δx
mg
|F|
|s|
displace
Xf
Vf
Xi
Vi
FA
X
Wcf = |F| × |S| × cosθ
Fn = mg + Fa sinθ
Displacement
fk
θ=90°
Δx
Fg
s
angle = 90°
Δr
90°

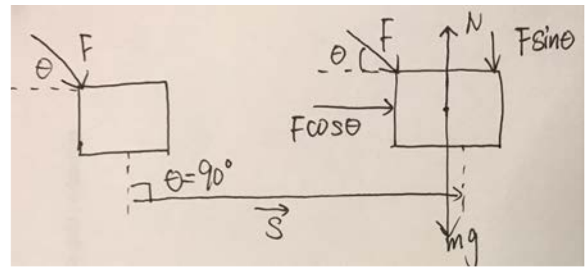

F
FN
Fy
Fx
θ = 90°
mg

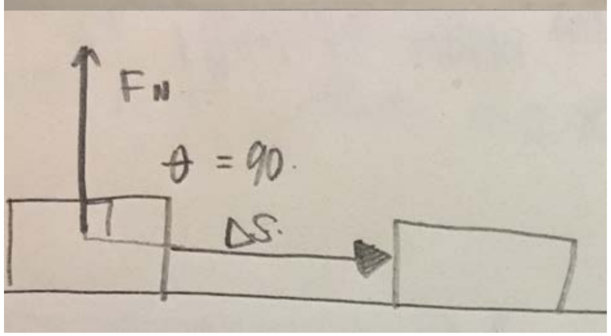

F
θ
FN
m
FN = mg + F sinθ
90°
m
S
mg
mg

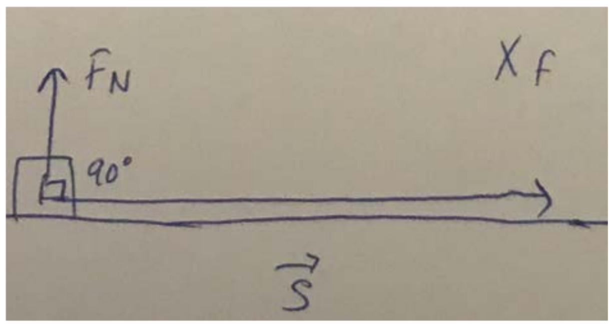

FN
W = 0
θ = 90
Fn
Δr
Ffr
mg
mg

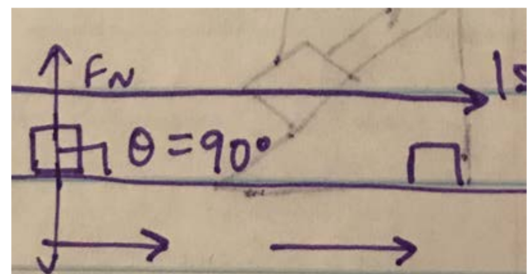

FN
W = 0
θ = 90°
Δr

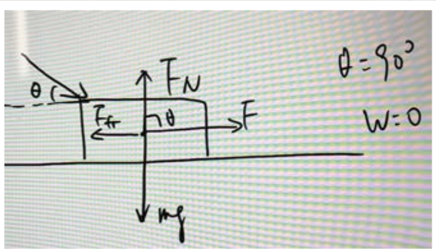

W = 0
F
FN
θ = 90°
FN
ΔS
Ffr
mg
mg

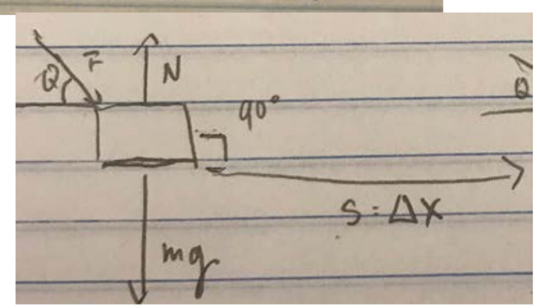

θ
F
θ
F
N
Fsinθ
Fcosθ
θ = 90°
S
mg

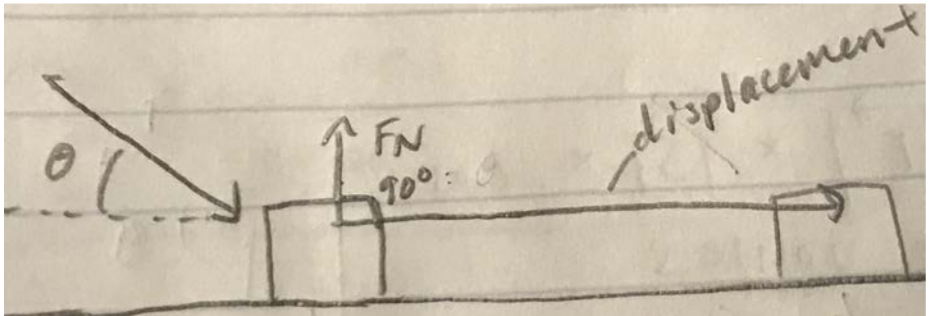

FN
θ = 90
ΔS

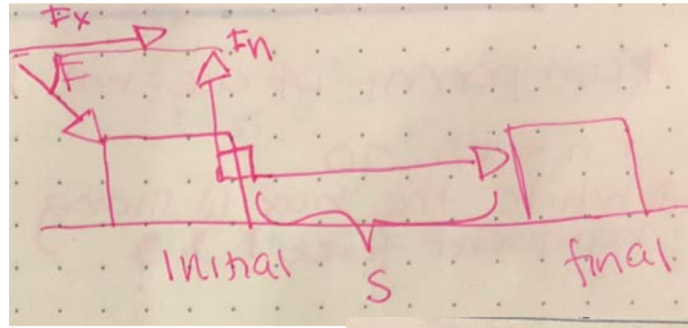

FN
X F
90°
S

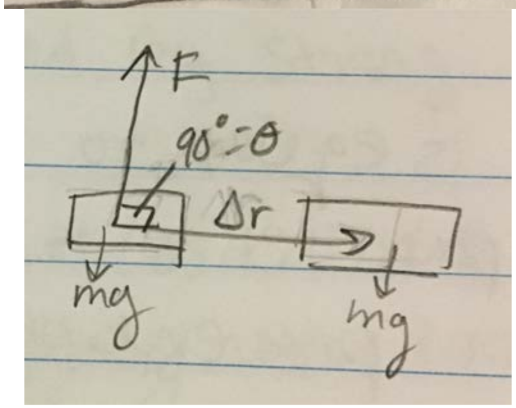

FN
θ = 90°

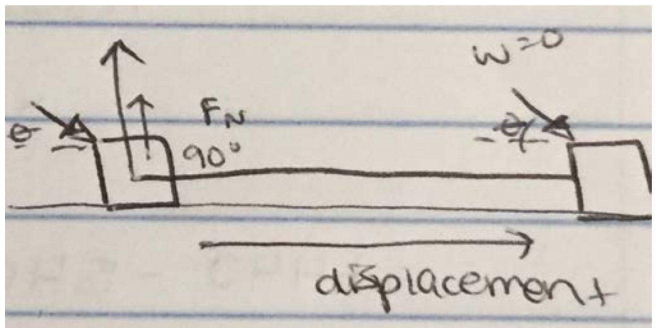

θ
FN
Ffr
θ
F
θ = 90°
W = 0
mg

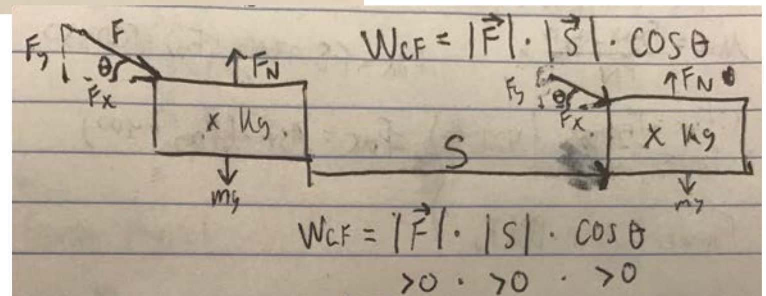

θ
F
N
90°
S = ΔX
mg

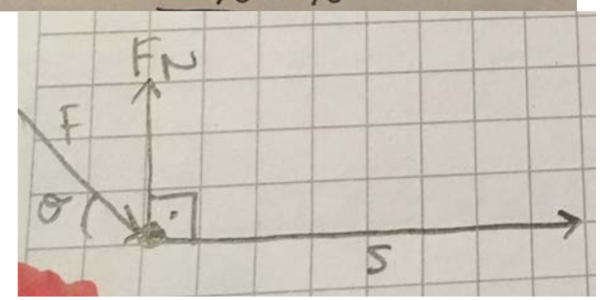

θ
FN
90°
displacement

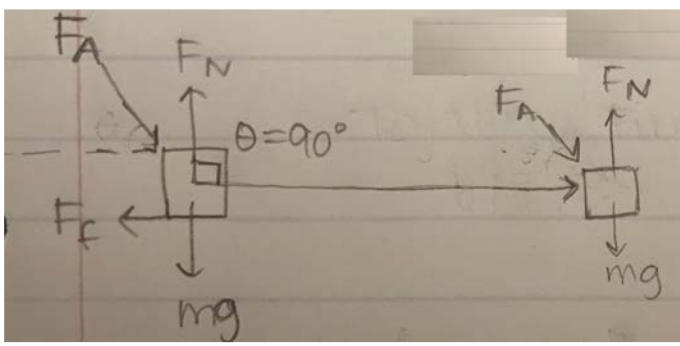

Fx
F
Fn
Initial
S
final

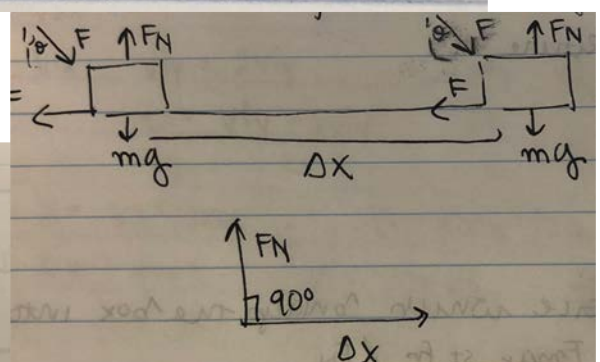

F
90°=θ
Δr
mg
mg


θ
FN
90°
w=0
displacement


Fy
F
θ
Fx
FN
x kg
WcF = |F⃗| · |S⃗| · cos θ
S
mg
WcF = |F⃗| · |S| · cos θ
>0 · >0 · >0


FN
F
θ
S


FA
FN
θ=90°
Ff
mg
FA
FN
mg


θ
F
FN
F
mg
ΔX
mg
FN
90°
ΔX

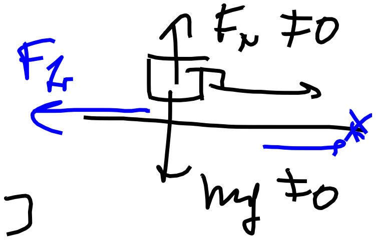
You push<u>ed</u> the box. The initial speed of the box *right after the push* was 15 m/s. If the coefficient of kinetic friction is 0.4, compare the change in KE and the work done by all the forces.

You pushed the box. The initial speed of the box *right after the push* was 15 m/s. If the coefficient of kinetic friction is 0.4, compare the change in KE and the work done by all the forces.

$KE = \frac{mv^2}{2}$

$KE_i = \frac{40 \cdot 15^2}{2} = 4500\,J$

$KE_f = \emptyset$



$W_{F_N} = \emptyset$

$W_{mg} = \emptyset$

~~$W_{APF} = ?$~~

~~Yes or No~~

$W_{F_{fr}} = -\mu F_N \cdot L =$

$= -\mu m g \cdot L = -40 \cdot 10 \cdot 28.125 \cdot .4$

$= -11250\,J \cdot .4 = -4500\,J$

$F_N = mg$: N2L (y:)

N2L (x): $-F_f = m(-|a|)$

$\mu \cdot F_N = m \cdot |a|$

$0.4 \cdot \cancel{m} \cdot g = \cancel{m} \cdot |a|$

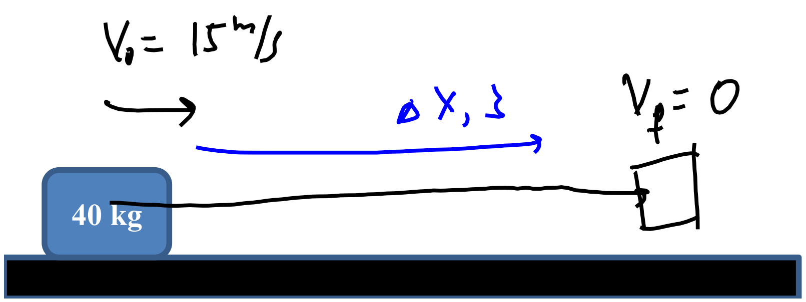
$|a| = 4\ m/s^2$

$v_f^2 = v_0^2 + 2 \cdot \overset{-4}{a} \cdot L$

$v_f \to 0$, $v_0 \to 15$

$0 = 15^2 - 2 \cdot 4 \cdot L$; $L = \frac{15^2}{2 \cdot 4} = 28.125\,m$

$\Delta KE = KE_f - KE_i = 0 - 4500\,J = -4500\,J = W + \emptyset + \emptyset$



Work done by a const *F* $W_{cF} = |\vec{F}| * |\vec{S}| * \cos\theta$

Kinetic Energy: $KE = \dfrac{mv^2}{2}$

To change KE of an object net WORK must be done.

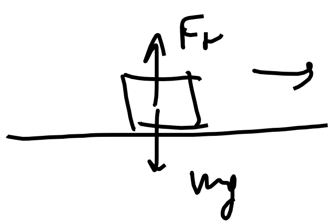
The Work – Kinetic energy Theorem ***(WKET)***

Every force does some work

$$\boxed{\Delta KE = KE_f - KE_i = W_{net} = W_{total} = W_1 + W_2 + \ldots}$$

You push<u>ed</u> the box. The initial speed of the box *right after the push* was 15 m/s. If the coefficient of kinetic friction is 0, compare the change in KE and the work done by all the forces.

$KE = \text{const}$



$KE_i = KE_f$

$W_g = \emptyset$ $\quad W_{F_N} = \emptyset$ $\quad W_{F_f} = \emptyset$

40 kg

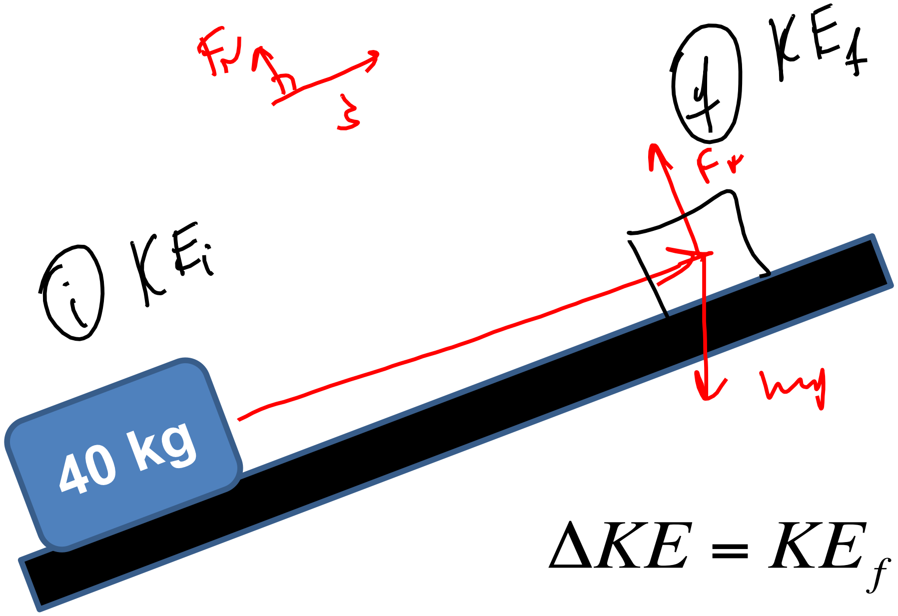
$$\Delta KE = KE_f - KE_i = W_{net} = W_{total} = W_1 + W_2 + \ldots = \emptyset$$

You pushed the box up an incline. In the absence of friction, what is happening to KE?

$$\Delta KE = KE_f - KE_i = \underbrace{W_{net}}_{\sum \text{all Forces}} = \cancel{W_{F_N}}^{\,0} + \cancel{W_{Fr}}^{\,0} + W_{mg} = mg(y_i - y_f)$$

$$KE_f + mgy_f = KE_i + mgy_i$$

$$KE + U = ME$$



$$\Delta KE = KE_f - KE_i = W_{net} = W_{total} = W_1 + W_2 + \ldots$$

GPE = U - potential energy of a system

<u>Mechanical Energy</u>

$$ME = \frac{mv^2}{2} + mgy$$

ME = KE + GPE = K + U

The law of conservation of *mechanical* energy (I).

In the <u>absence</u> of **friction** (mostly)

<u>*ME* = const</u>

i.e. *ME* does not change; $ME_1 = ME_2$

i.e. *ME* is conserved*!*

The law of conservation of mechanical energy (II).

In the ***presence*** of friction (mostly)
Mechanical Energy ***changes***!

Work done by <u>Friction</u> changes ME

$$ME_1 + W_{fr} = ME_2$$ **LCME**

$$K_1 + U_1 + W_{fr} = K_2 + U_2$$ **“Master Equation”**

$$\Delta KE = KE_f - KE_i = W_{net}$$

WKET ⇔ LCME !!!

Three forms of the same relationship

$$\Delta KE = KE_f - KE_i = W_{net} = W_{total} = W_1 + W_2 + \ldots$$

WKET ⬄ **LCME !!!**

$$ME_1 + W_{fr} = ME_2$$ **LCME**

$$K_1 + U_1 + W_{fr} = K_2 + U_2$$ **"Master Equation"**

WKET

$$\Delta KE = KE_f - KE_i = W_{net} = W_{total} = W_1 + W_2 + \ldots$$

OR

LCME

$$K_1 + U_1 + W_{fr} = K_2 + U_2$$

??????????

The rule of a thumb

NO friction

LCME

$$K_1 + U_1 + \cancelto{0}{W_{fr}} = K_2 + U_2$$

$$K_1 + U_1 = K_2 + U_2$$

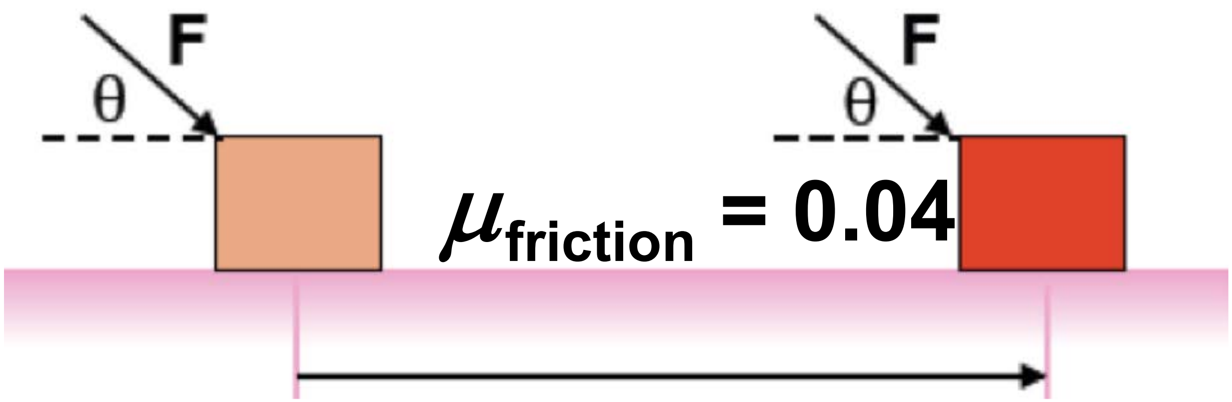
“YES” friction

WKET

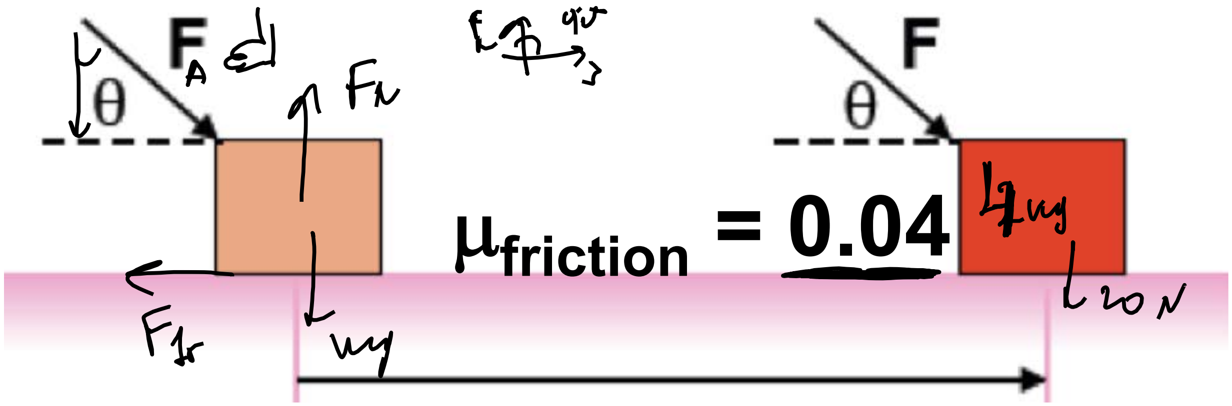
$$KE_f - KE_i = W_{net}$$

WKET

$$\Delta KE = KE_f - KE_i = W_{net} = W_{total} = W_1 + W_2 + \ldots$$



You have been pushing a 4 kg box from rest 2 m to the right applying 14 N force at 60^0 (as shown in the picture). Find box's final speed.



You have been pushing a 4 kg box from rest 2 m to the right applying 14 N force at 60^0 (as shown in the picture). Find box's final speed.

WKET; $\Delta KE = W_{Net} = W_{done} = W_{All\ Forces} = W_{F_N} + W_{mg} + W_{Ap} + W_{Ff} =$

$KE_f - KE_i$

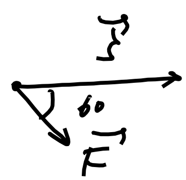
? 0

$= \emptyset + \emptyset + 14 \cdot 2 \cdot \cos 60° + -\mu \cdot F_N \cdot L =$

$= 14 - 0.04 \cdot (mg + F_{yA}) \cdot L =$

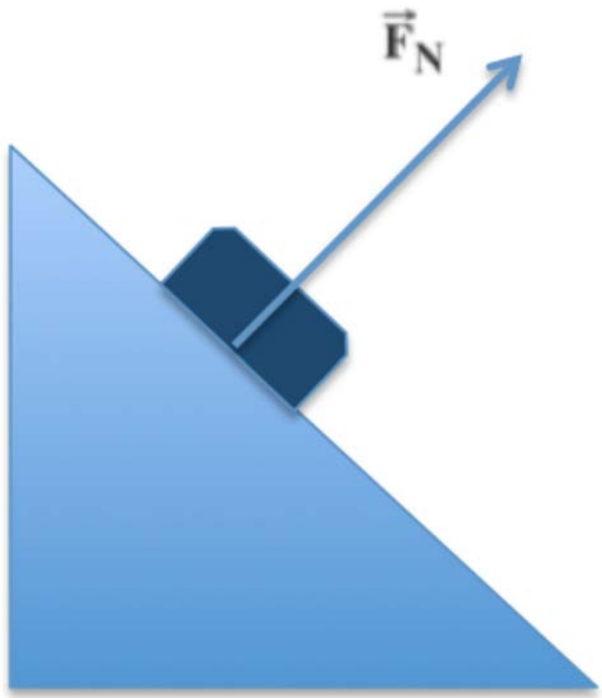
$= 14 - 0.04(4 \cdot 10 + 14 \cdot \sin 60) \cdot 2 =$

$= \ldots$



$KE = \frac{mv^2}{2} \Rightarrow V = \sqrt{\frac{2 \cdot KE}{m}}$

$W = |F| \cdot |S| \cdot \cos\theta$

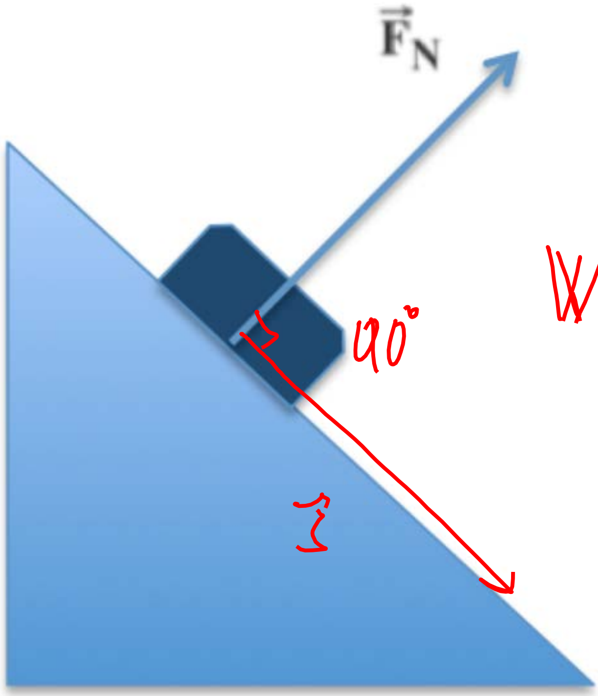


Webassign: L10 Q2

For a box sliding down the ramp, the work done by the normal force is …

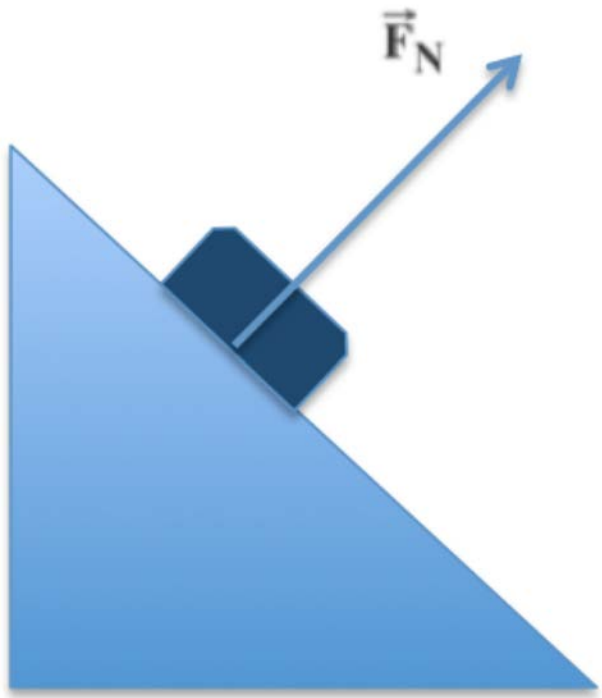
1. > 0
2. $= 0$
3. < 0

(P.S. also think about Work of mg, $F_{friction}$)



$W_{F_N} = |F_N| \cdot |s| \cdot \cos 90 = \phi$

For a box sliding down the ramp, the work done by the normal force is …



For a box sliding down the ramp, the work done by the normal force is …

1. ~~> 0~~
2. = 0
3. ~~< 0~~

(P.S. also think about Work of mg, $F_{friction}$)

A block slides down from rest from the top of a 3-4-5 ramp. Coefficient of kinetic friction is 0.05. Find the final speed of the block.

$$KE = \frac{mv^2}{2}$$

$$W_{cF} = |\vec{F}| * |\vec{S}| * \cos\theta$$

$$W_g = mg(y_1 - y_2)$$

$$W_{fr} = -|F_{fr}| * L$$

$$\Delta KE = W_{net}$$

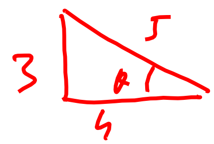
A block slides down from rest from the top of a 3-4-5 ramp. Coefficient of kinetic friction is 0.05. Find the final speed of the block.

$$KE = \frac{mv^2}{2} \qquad W_{cF} = |\vec{F}| * |\vec{S}| * \cos\theta$$

$$W_g = mg(y_1 - y_2)$$

$$W_{fr} = -|F_{fr}| * L$$

$$\Delta KE = W_{net}$$



$\cos\theta = 4/5$

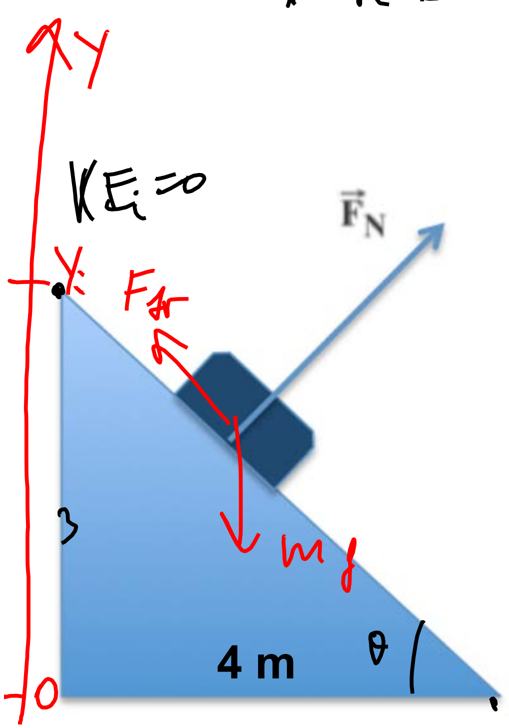
WKET: $\Delta KE = W_t = W_{F_N} + W_{F_{fr}} + W_{mg} =$

$= \phi - \mu \cdot F_N \cdot L + mg(y_1 - y_2) \Rightarrow$

$\frac{mv_f^2}{2} - \phi = -0.05 \cdot mg \cdot \cos\theta \cdot 5 + m \cdot 10 \cdot (3 - 0) \Rightarrow$

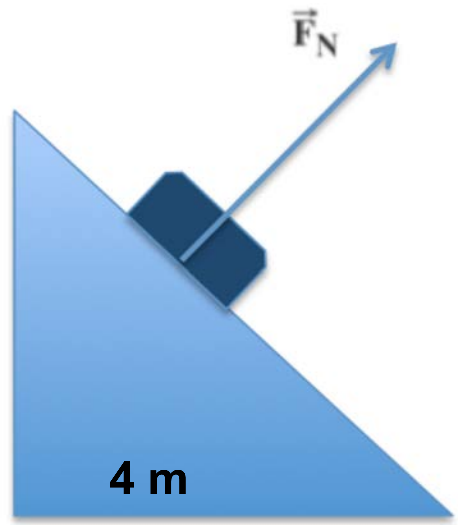
$\frac{\cancel{m} v_f^2}{2} = -0.05 \cdot \cancel{m} \cdot 10 \cdot \frac{4}{5} \cdot 5 + \cancel{m} \cdot 10 \cdot 3$

$\Rightarrow \ldots$

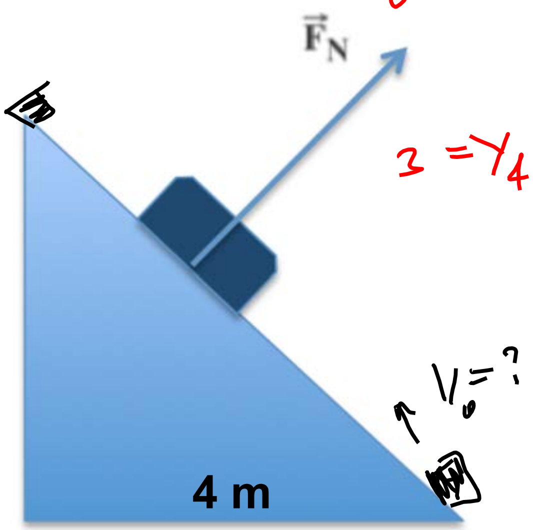


$KE_f = \frac{mv_f^2}{2} \Rightarrow v_f = \sqrt{\frac{2 \cdot KE_f}{m}}$

A 2 kg block is at the bottom of a 3-4-5 ramp. The coefficient of kinetic friction is 0.05. Find the minimal initial speed we have to supply to the block so it would reach the top of the ramp when pushed from the lowest point.



A 2 kg block is at the bottom of a 3-4-5 ramp. The coefficient of kinetic friction is 0.05. Find the minimal initial speed we have to supply to the block so it would reach the top of the ramp when pushed from the lowest point.



$3 = y_f$

$y_i = 0$

$$\cancel{KE_f} - KE_i = W_{F_N} + W_{mg} + W_{fr} \Rightarrow -\frac{mV_i^2}{2} = mg(y_i - y_f) + (-1)\cdot\mu\cdot F_N\cdot L$$

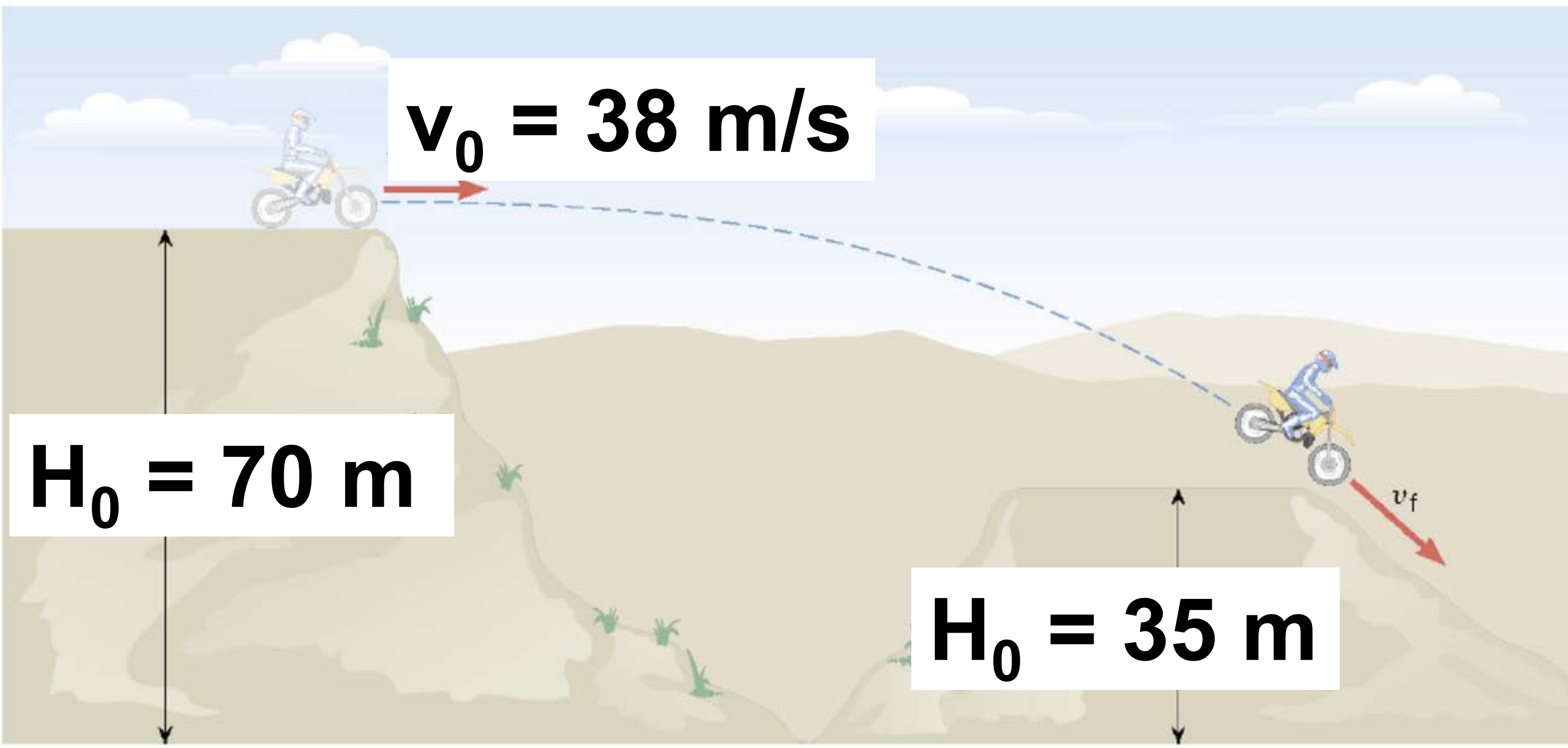
KE_f: 0 $\quad KE_i$: ? $\quad W_{F_N}$: 0

$$-\frac{mV_i^2}{2} = mg(0-3) - 1\cdot 0.05\cdot m\cdot g\cdot\cos\theta\cdot L$$

$$-\frac{\cancel{m}V_i^2}{2} = -\cancel{m}\cdot 10\cdot 3 - 0.05\cdot\cancel{m}\cdot 10\cdot\frac{4}{5}\cdot 5 \quad \Big|\times(-1)$$

$$V_i = \sqrt{2\cdot 10\cdot 3 + 0.05\cdot 10\cdot\frac{4}{5}\cdot 5}$$

A motorcyclist is trying to leap across the canyon by driving horizontally off a cliff 38.0 m/s. Ignoring air resistance, find the speed with which the cycle strikes the ground on the other side.



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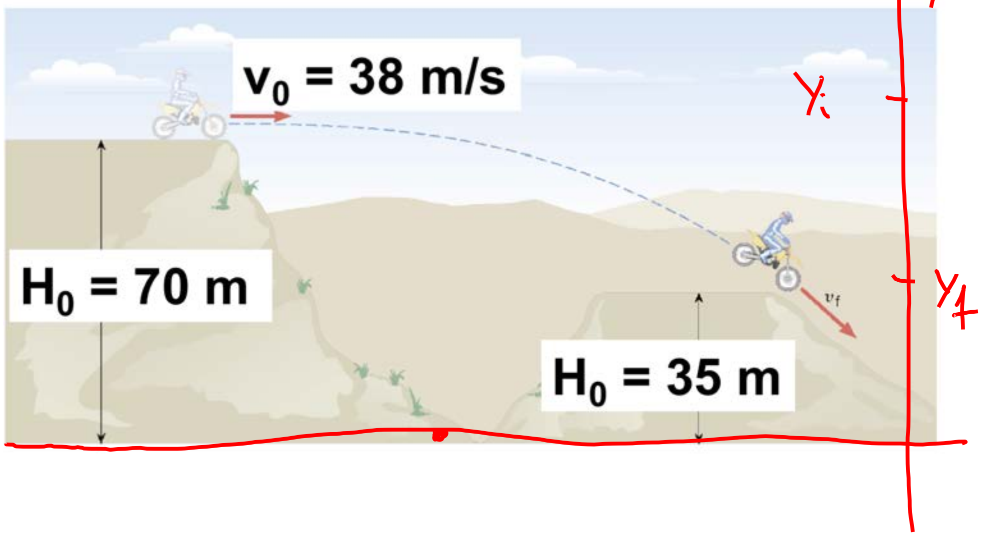
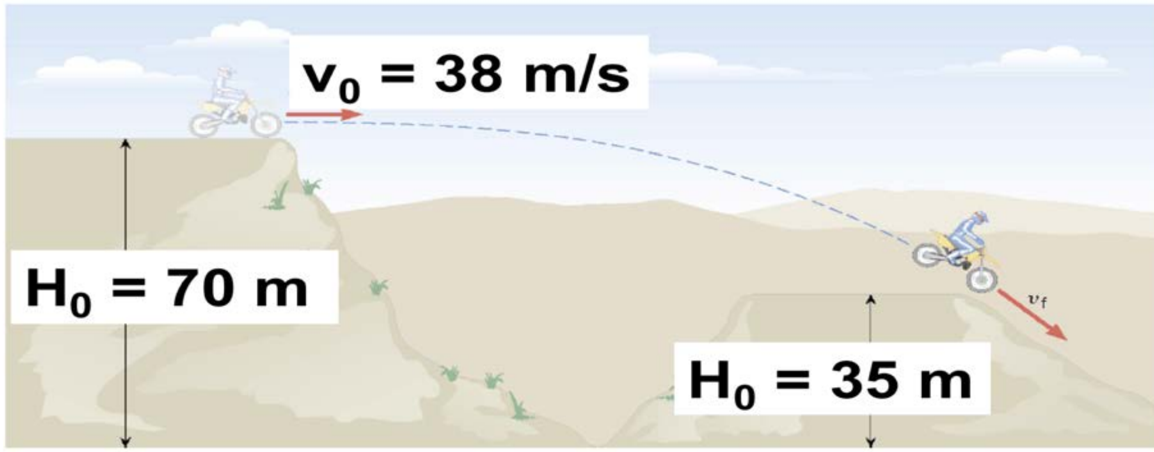


No $F_f \Rightarrow$ $K_i + P_i = K_f + P_f$

$$\frac{\cancel{m}v_i^2}{2} + \cancel{m}\cdot g\cdot 70 = \frac{\cancel{m}v_f^2}{2} + \cancel{m}g\cdot 35$$

$$\frac{38^2}{2} + 10\cdot 70 = \frac{v_f^2}{2} + 10\cdot 35$$

A motorcyclist is trying to leap across the canyon by driving horizontally off a cliff 38.0 m/s. Ignoring air resistance, find the speed with which the cycle strikes the ground on the other side.



$$gh_f + \frac{1}{2}v_f^2 = gh_i + \frac{1}{2}v_i^2$$

$$v_f = \sqrt{2g\left(h_i - h_f\right) + v_i^2}$$

$$v_f = \sqrt{2\left(9.8\,\mathrm{m/s^2}\right)\left(35.0\,\mathrm{m}\right) + \left(38.0\,\mathrm{m/s}\right)^2} = 46.2\,\mathrm{m/s}$$

Crush the can

A heavy weight is dropped from a height of 1.2 m on a soda can, crushing it (after crashing with it). Is mechanical energy conserved in this process?

1) Yes

2) No

3) Impossible to answer

4) There is a Law which forbids this experiment

Webassign: L10 Q3

Crush the can

A heavy weight is dropped from a height of 1.2 m on a soda can, crushing.   Is mechanical energy conserved in this process?

1) Yes

2) No

3) Impossible to answer

4) There is a Law which forbids this experiment

Crush the can

A heavy weight is dropped from a height of 1.2 m on a soda can, crushing it (after crashing with it). Is *energy* conserved in this process?

1) Yes

2) No

3) Impossible to answer

4) There is a Law which forbids this experiment

Crush the can

A heavy weight is dropped from a height of 1.2 m on a soda can, crushing it (after crashing with it). Is *energy* conserved in this process?

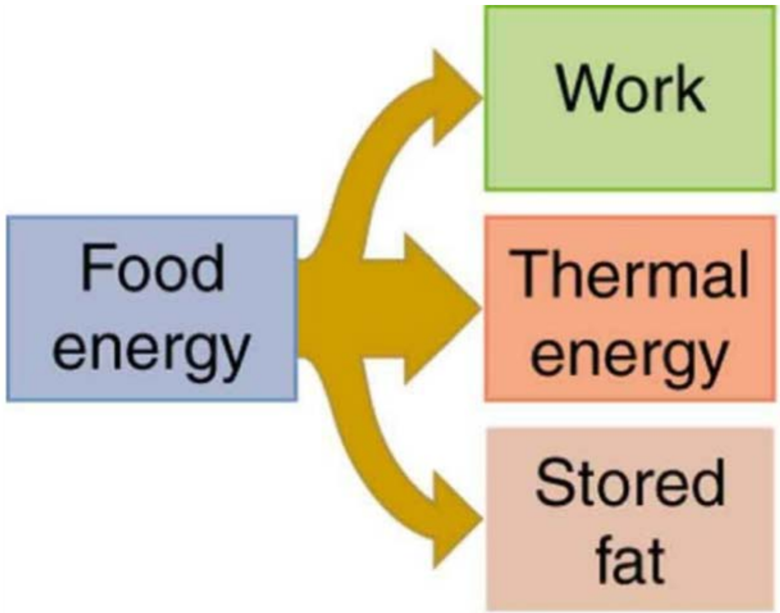
1) **Yes - Always!!**
2) **No**
3) **Impossible to answer**
4) **There is a Law which forbids this experiment**

Law of conservation of *Energy*

1. Energy ***cannot*** be destroyed or created.

2. Energy ***can*** be stored/released.

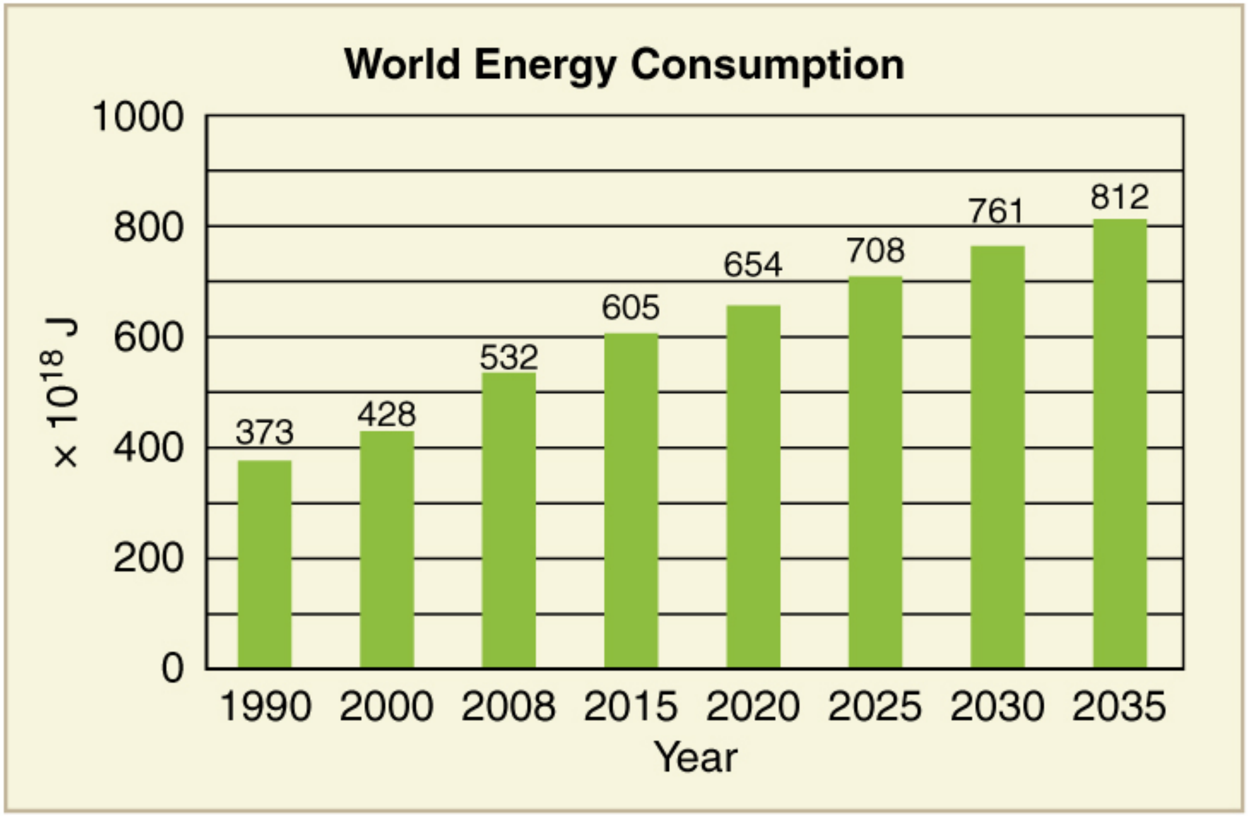
3. Energy ***can*** be transferred from one object/form to another.



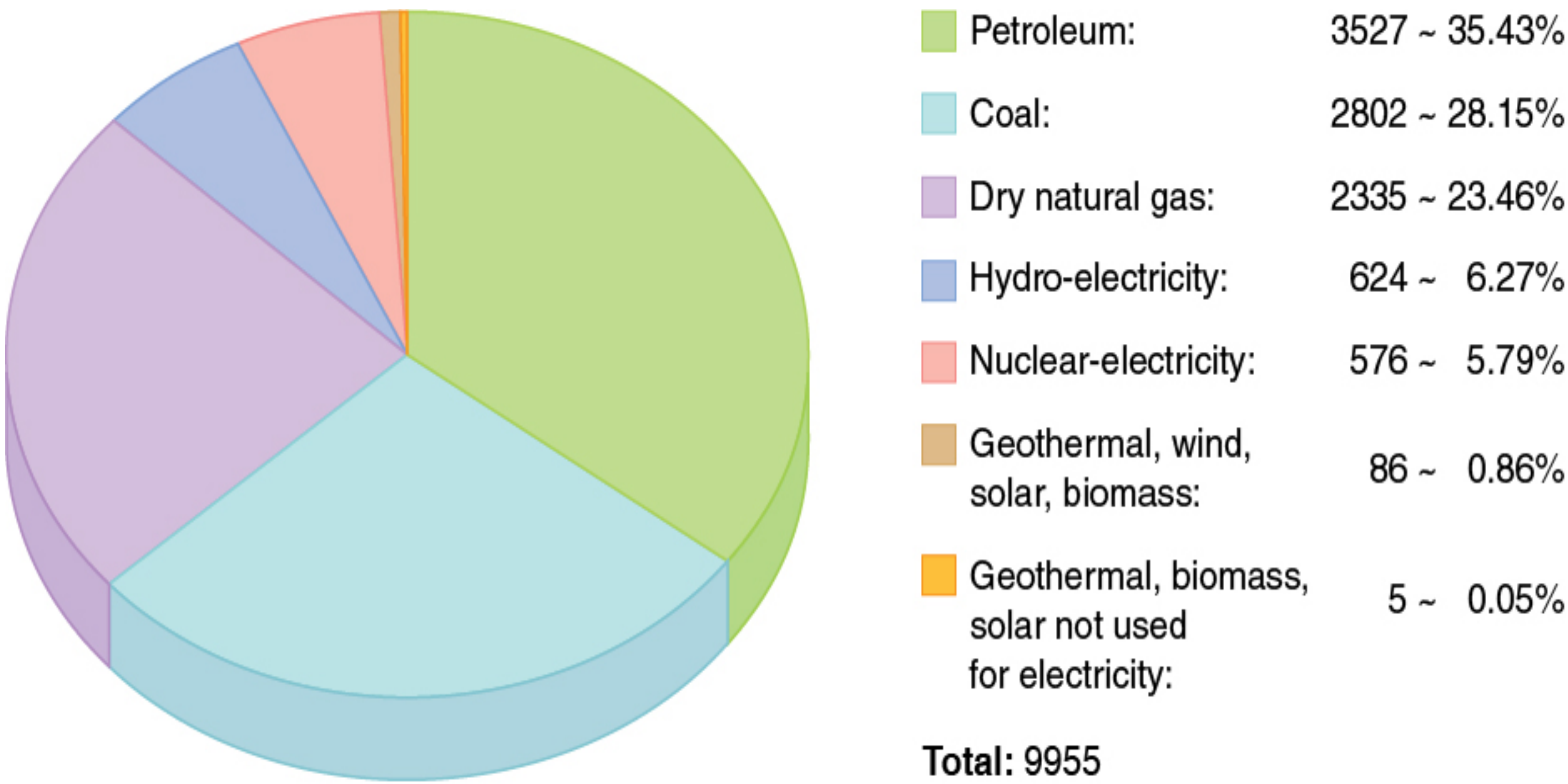
For humans energy is Everything!

1 calorie = 4.18400 joules

Energy consumed by humans is converted to work, thermal energy, and stored fat. By far the largest fraction goes to thermal energy, although the fraction varies depending on the type of physical activity.



Past and projected world energy use (source: Based on data from U.S. Energy Information Administration, 2011)

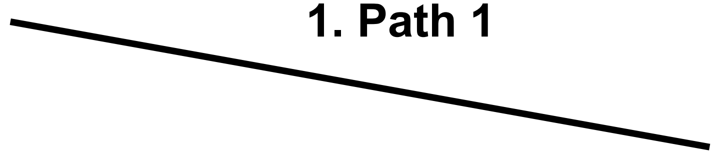


World energy consumption by source, in billions of kilowatt-hours: 2006. (credit: KVDP)

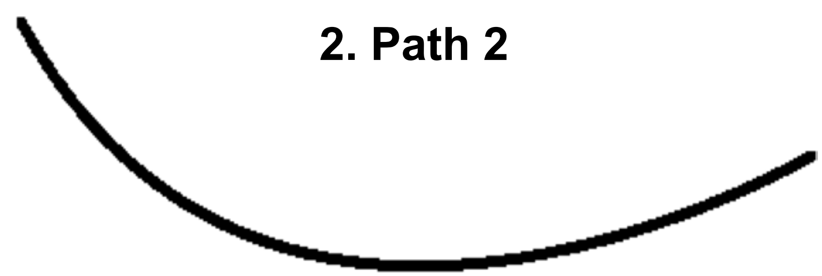
A race

Two small cars start their ride from rest from the same height, race each other, and finish again at the same height. The first car runs down an incline ramp. The second car runs down the deep curved path. **Which car wins the race if the both start running from rest at the same time (neglect the friction)?**

1. Path 1

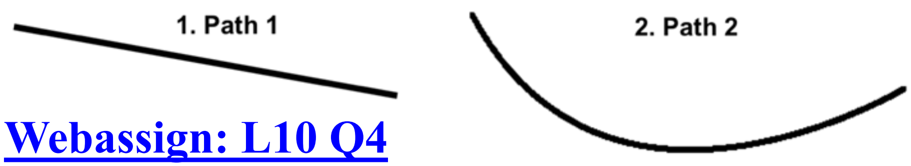


2. Path 2



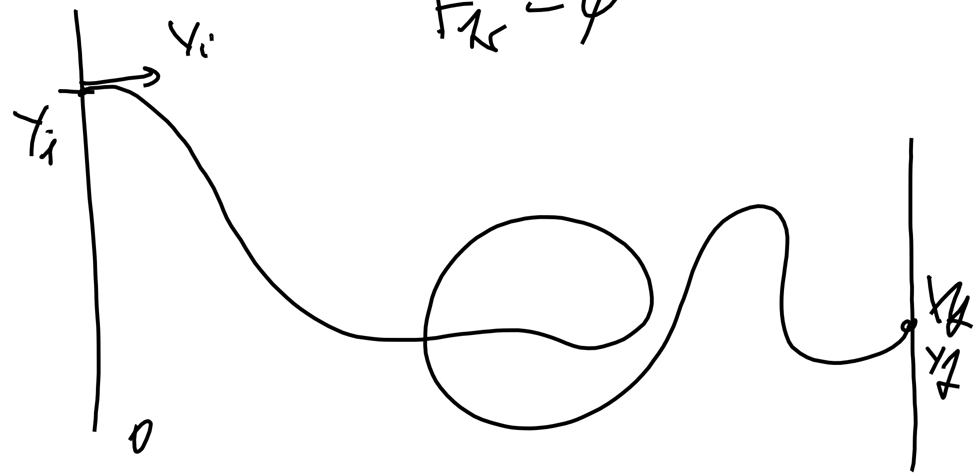
[Webassign: L10 Q4]()

Two small cars start their ride from rest from the same height, race each other, and finish again at the same height. The first car runs down an incline ramp. The second car runs down the deep curved path. **Which car wins the race if the both start running from rest at the same time (neglect the friction)?**



[Webassign: L10 Q4]

$F_{nc} = \phi$



$\cancel{KE_i} + mg\underline{y_i} = KE_f + mg\underline{y_f}$

$\downarrow$

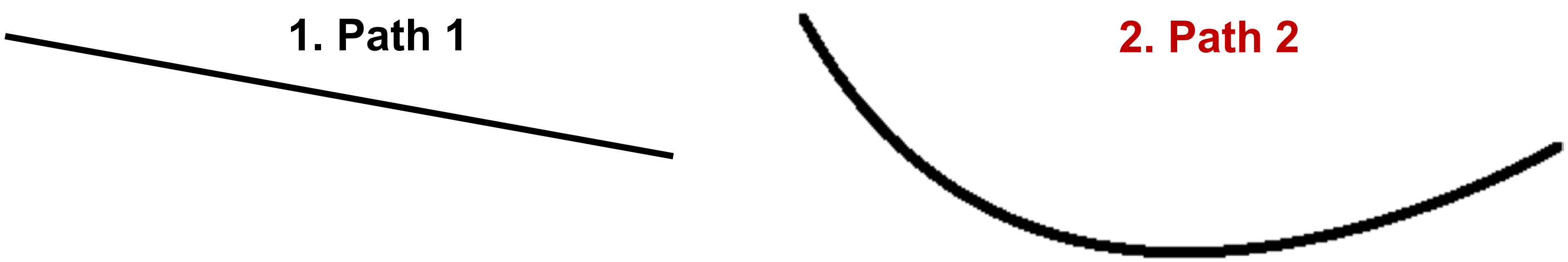
$\underline{V_f} = \ldots\ldots$

Energy is not related t

A race

Two small cars start their ride from rest from the same height, race each other, and finish again at the same height. The first car runs down an incline ramp. The second car runs down the deep curved path. **Which car wins the race if the both start running from rest at the same time (neglect the friction)?**

Time is NOT related (directly) to energy



DONE

Summary

Kinetic energy of an object: $K = \frac{mv^2}{2}$

Work done by a constant force: $W = F \cdot \Delta r \cdot \cos\theta$

In general: $W = \text{Area}_{\text{under-the-graph-F-vs.-}\Delta r}$

The total work: $W_{total} = W_1 + W_2 + W_3 + \ldots$ or $W_{total} = F_{Net} \cdot \Delta r \cdot \cos\theta_{Net}$

Work – Kinetic Energy Theorem: $K_2 - K_1 = W_{total}$

$E = K + U$ is ***mechanical energy***

U is ***potential energy***

$$U = mgy + \frac{kx^2}{2}$$

(*y*-axis is UP, *x* is measured from equilibrium)

Work done by a conservative force: $W_{cons} = U_1 - U_2$

Master Equation: $E_2 - E_1 = W_{non\text{-}cons}$ or $E_2 = E_1 + W_{non\text{-}cons}$

Master Equation (full form): $K_2 + U_2 = K_1 + U_1 + W_{non\text{-}cons}$

Conservation of mechanical energy: If there are conservative forces only (no friction!) $E_2 = E_1$

Impulse: $\vec{J} = \vec{F}_{ave} * \Delta t$ **Linear Momentum:** $\vec{p} = m * \vec{v}$

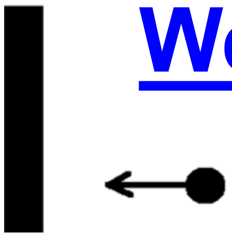
N *II* L: $\vec{J} = \Delta\vec{p} = Area[\vec{F}(t)]$

LCLM: **If** $\sum_{external} \vec{F} = 0$ => $\sum \vec{p} = const$

Linear momentum, Center of Mass, Collisions

$$X_{cm} = \frac{x_1 m_1 + x_2 m_2 + x_3 m_3 + \ldots}{m_1 + m_2 + m_3 + \ldots}$$

Webassign: L10 Q5



A 100 g ball flying at 10 m/s hits a wall as shown. The collision is ideal (***no friction, no spinning, no gravity***) and lasts 0.01 s.

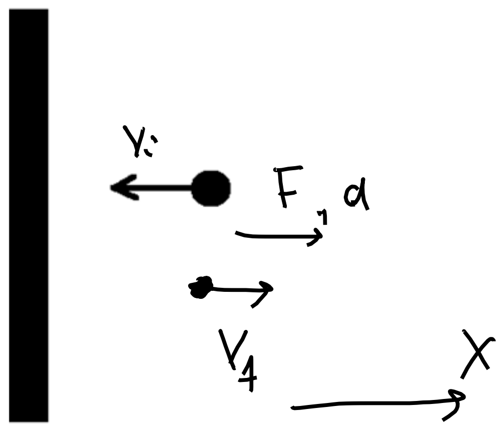
The magnitude of the acceleration of the ball during the collision is

1. 1000 m/s^2
2. 2000 m/s^2
3. 3000 m/s^2
4. Etc. …

0. none of the above

Webassign: L10_Q5

A 100 g ball flying at 10 m/s hits a wall as shown. Assuming the collision is ideal (no friction, no spinning, no gravity) and lasts 0.01 s, *find the force acting from the ball on the wall.*



The magnitude of the acceleration of the ball during the collision is

1. 1000 m/s^2
2. 2000 m/s^2
3. 3000 m/s^2
4. Etc. …

0. none of the above

$|F| = m\cdot|a|$; $\boxed{F = m\cdot a}$, $a = \dfrac{V_f - V_i}{t}$

$a = \dfrac{10 - -10}{0.01} = \dfrac{20}{.01} = 2000\ m/s^2$

$F = 0.1\cdot 2000 = 200\ N$ $\quad \vec{J} \quad \vec{P} = m\cdot\vec{V}$

$F = m\dfrac{V_f - V_i}{t} \Rightarrow F_{Ave}\cdot t = mV_f - mV_i$

$\vec{J} = \Delta\vec{P}$ $\quad$ N2L

Impulse and Momentum

average

$$\overline{\boldsymbol{F}}_{\text{net}} = \text{m}\overline{\boldsymbol{a}} = m\frac{\Delta V}{\Delta t} = m\frac{V_2 - V_1}{\Delta t} \quad \text{hence} \quad \boxed{\overline{\boldsymbol{F}}_{\text{net}}\Delta\text{t} = \text{m}\boldsymbol{v}_2 - \text{m}\boldsymbol{v}_1}$$

N2L

BTW: this is how Newton wrote it

<u>Two new physical quantities:</u>

Impulse of the force $\boldsymbol{J} = \overline{\boldsymbol{F}}_{\text{net}}\Delta\text{t}$	Linear Momentum of the object $\boldsymbol{P} = \text{m}\boldsymbol{v}$

The unit is the same: N s = kg*m/s

Relationships for impulse and momentum:

$$\overline{\boldsymbol{J}} = \overline{\boldsymbol{F}}_{\text{net}}\Delta\text{t}$$

$$\boldsymbol{P} = \text{m}\boldsymbol{v}$$

$$\boxed{\vec{F}_{Net\ Ave} = \frac{\Delta\vec{p}}{\Delta t} = \frac{\vec{p}_f - \vec{p}_i}{\Delta t}} \Leftrightarrow \overline{\boldsymbol{F}}_{\text{net}}\Delta\text{t} = \boldsymbol{P}_2 - \boldsymbol{P}_1 \Leftrightarrow \boxed{\overline{\vec{J}} = \Delta\vec{p}}$$

IMT = 2NL !

Impulse – Momentum Theorem (IMT) "works" for <u>***any***</u> system

$$\vec{J} = \vec{p}_2 - \vec{p}_1$$

If $J \neq 0$

$$\vec{p}_2 = \vec{p}_1 + \vec{J}$$

If $J = 0$

$$\vec{p}_2 = \vec{p}_1$$

$$\vec{J} = \vec{F}_{Net\ Ext\ Ave}\Delta t$$

$$\vec{F}_{Net\ Ext\ Ave} = \frac{\vec{J}}{\Delta t}$$