Ch. 5 + Recap — March 4, 2019

Recap

→ a catalog of different forces
→ Free-body diagrams (FBDs)

Newton's First law → if $\Sigma\vec{F}=0$ ($\vec{F}_{net}=0$), then $\vec{a}=0$

Newton's 2nd Law → $\vec{a}=\frac{\Sigma\vec{F}}{m}$ or $\Sigma F = m\vec{a}$ ($\vec{F}_{net}=m\vec{a}$)

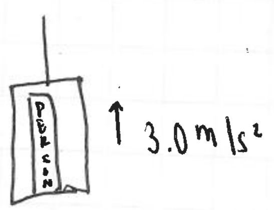
$\Sigma\vec{F}=m\vec{a}$ → $\Sigma F_x = ma_x$
→ $\Sigma F_y = ma_y$

$1N = 1\frac{kg\,m}{s^2}$

Problem Solving Strategy

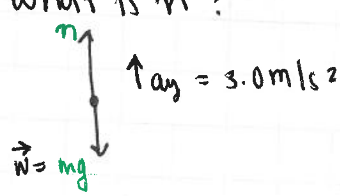
1) Identify all forces acting on an object
2) Draw a FBD and a motion diagram (if object is moving)
3) Break forces up into x- and y-components & redraw FBD
4) Apply $\Sigma F_x = ma_x$ and $\Sigma F_y = ma_y$
5) Solve for unknown quantities
6) Make sure answers seem reasonable (units, magnitudes, sign, etc).

Ex



m person: 50.0 kg

What is n?



$\Sigma F_y = ma_y$

$n - mg = ma_y$

$n = m(g + a_y)$

$n = 50kg(9.80\,m/s^2 + 3.0\,m/s^2)$

$n = 640N$

Ch. 6 March 4, 2019

NORMAL FORCE

* direction is always ⊥ to the surface
* You must solve for the magnitude using $\Sigma \vec{F} = m\vec{a}$
* NOT always equal to the weight.

When is $n = mg$?
Object on a flat surface with no other vertical forces other than $\vec{n}$ & $\vec{w}$ and $a_y = 0\, m/s^2$

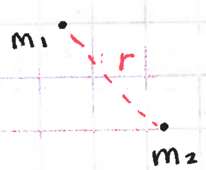
MASS, Force of Gravity & Weight

mass → An intrinsic property of an object that describes its inertia
↓
Resistance to acceleration

→ measure of how much matter an object is made of

→ mass is measured in kg and is the same everywhere

Gravity → long-range attractive force between any two objects with mass



Force of gravity: $F_{1 on 2} = F_{2 on 1} = \dfrac{G m_1 m_2}{r^2}$

m_1 + m_2 → masses in kg
r → distance between the centers of the masses

$G = 6.67 \times 10^{-11} \dfrac{N\, m^2}{kg^2}$

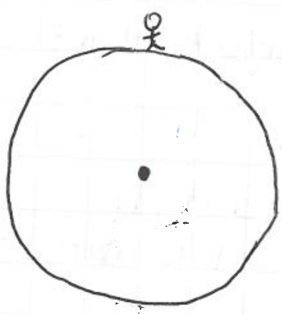
Ch 6. March 4, 2019

→ Force of gravity between everyday objects is so small that we ignore it.

Weight (w) → force of gravity on an object from a planet.

NOTE: what your book is calling apparent weight by most other textbooks

↓ How much it "appears" you weight because of acceleration



$$w = mg$$

w → weight in Newtons
m → mass in kg
g → 9.80 m/s² (on earth)

$M_{Earth} = 5.98 \times 10^{24}$ kg
$R_{Earth} = 6.37 \times 10^{6}$ m

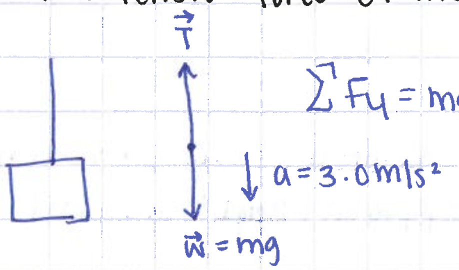
$$F = \frac{G m_1 m_2}{r^2} \rightarrow w = \frac{G M_{Earth} m}{R_{Earth}^2}$$

$$w = \left(\frac{G M_{Earth}}{R_{Earth}^2}\right) = \frac{(6.67 \times 10^{-11} Nm^2/kg^2)(5.98 \times 10^{24} kg)}{(6.37 \times 10^6 m)^2} m = 9.83 \text{ m/s}^2$$

$w = m \cdot g \quad g = 9.83$ m/s²

* 9.80 m/s² is the average value on the earth taking into account the rotation of the earth.

1Q: A 5kg block is suspended by a rope from the ceiling of an elevator as the elevator accelerates downward at 3.0 m/s². The Tension force of the rope on the block is?



$\sum F_y = ma_y$

$T - mg = ma_y$

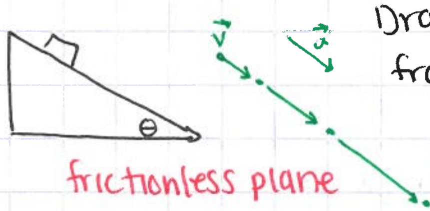
$T = m(g + a_y)$

$= (5.0\,kg)(9.80\,m/s^2 - 3.0\,m/s^2)$

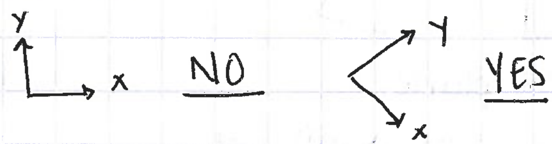
$= \boxed{3.4\,N}$

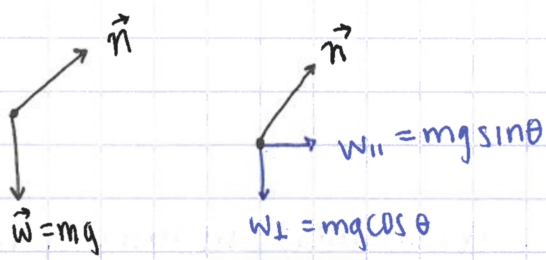
Inclined Planes

Draw a motion diagram if the object starts from rest & the incline is frictionless:

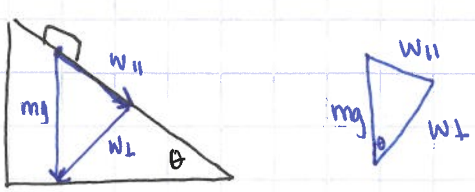


Is this one-dimensional motion?





* The component of weight down the incline is $w_{\parallel} = mg\sin\theta$
* The component of weight ⊥ to the incline is $w_{\perp} = mg\cos\theta$



$w_{\parallel} = mg\sin\theta$

$w_{\perp} = mg\cos\theta$

March 5, 2019

Recap

$\sum \vec{F} = m\vec{a}$ → $\sum F_x = ma_x$; → $\sum F_y = ma_y$

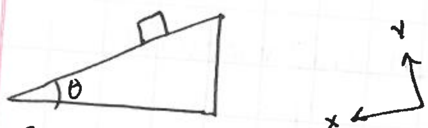
→ Problem solving strategy for Newton's law problems

→ mass, weight, & gravity → your book calls "apparent weigh" weight

$W = mg$ → Force of gravity F_G

$g = 9.80\ m/s^2$

Inclined Planes



frictionless plane

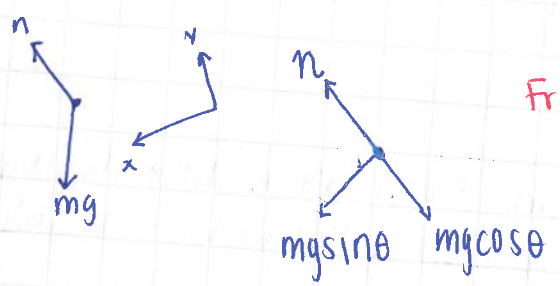
* Rotate your x- & y-axes

x- ↓ ∥ to plane

y-axes ↓ ⊥ to plane

$W_{\parallel} = mg\sin\theta$ * down the incline

$W_{\perp} = mg\cos\theta$



Frictionless inclined plane

$a = g\sin\theta$

$\sum F_y = ma_y = 0$ $(a_y = 0)$

$n - mg\cos\theta = 0$

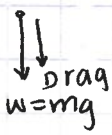
$n = mg\cos\theta$ → $\begin{cases} \theta = 0° & n = mg \\ \theta = 90° & n = 0 \end{cases}$

$\sum F_x = ma_x$ $\theta = 0°$ $a = 0$

$mg\sin\theta = ma_x$ $\theta = 90°$ $a = g$

$a_x = g\sin\theta$

Ball thrown up with air resistance:

way up: 

way down: 

FRICTION

Kinetic friction ($\vec{f}_k$) → friction between 2 objects in motion relative to each other.

↗ one object is moving relative to the other

$f_k = \mu_k n$

μ_k → coefficient of kinetic friction

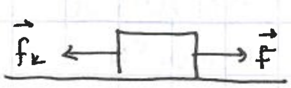
↓

unitless number that describes how much friction there is between two surfaces

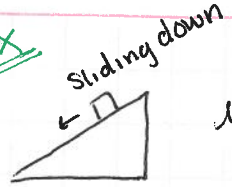
→ Bigger μ_k → more friction

* The direction of $\vec{f}_k$ is always in the opposite direction of relative motion

→ To a good approximation, f_k is independent of speed or area of contact



EX.



$\mu_k = 0.45$

What is the acceleration of the block down the plane?

$\sum F_y = ma_y = 0$

$n - mg\cos\theta = 0$

$n = mg\cos\theta$

$\sum F_x = ma_x = 0$

$mg\sin\theta - f_k = ma_x$

$f_k = \mu_k n$

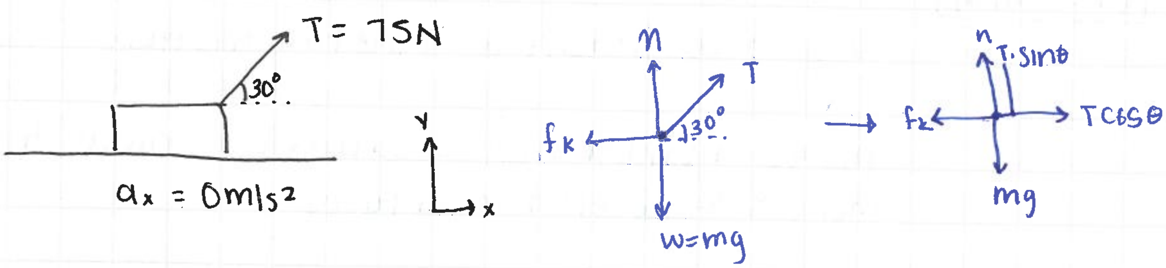
$f_k = \mu_k (mg\cos\theta)$

$\boxed{a_x = g\sin\theta - \mu_k g\cos\theta}$

$a_x = g(\sin\theta - \mu_k \cos\theta = (9.80 \text{ m/s}^2)[\sin 30° - (0.45)\cos 30°]$

$= \boxed{1.08 \text{ m/s}^2}$

PROBLEM 6.52



$\sum F_y = ma_y = 0$

$n + T\sin\theta - mg = 0$

$n = mg - T\sin\theta$

$= (60.6 \text{ kg})(9.80 \text{ m/s}^2) - (75 \text{ N})\sin 30°$

$n = 550.5 \text{ N}$

$\sum F_x = ma_x = 0$

$T\cos\theta - f_k = 0$

$T\cos\theta - \mu_k n = 0$

$\mu_k = \frac{T\cos\theta}{n}$

$\mu_k = \frac{(75 \text{ N})\cos 30°}{550.5 \text{ N}}$

$\boxed{\mu_k = 0.12}$

Which is easier?
Push or pull with same force at the same angle?
(constant velocity)
B) PULL

Static friction ($\vec{f_s}$) → friction between 2 objects at rest relative to each other.

* f_s acts as needed to prevent motion & can have value up to a maximum value given by $F_{s,max} = \mu_s n$

μ_s → coefficient of static friction.

Properties of f_s:

1) Direction of $\vec{f_s}$ is such as to oppose motion
2) f_s adjusts itself so that the net force is zero & the object doesn't move
3) f_s can not exceed $f_{s,max} = \mu_s n$
4) object slips when $f_s = f_{s,max}$

↓

Object is actually on the verge of slipping

Q: A crate is moving to the right on a conveyor belt without slipping. The conveyor belt maintains a constant speed. The force of friction on the crate is
zero   Due to Newton's 2nd law; Inertia

Problem 6.26

$\sum F_{ax} = ma_x$

$f_s = ma_x$

$ma_x \vec{a} \to max\ \vec{f_s}$

$f_{s,max} = m \cdot a_{max}$

$\mu_s n = m a_{max}$

$\sum F_y = ma_y = 0$

$n - mg = 0$
$+mg \quad +mg$

$n = mg$

$\mu_s (mg) = m a_{max}$

$a_{max} = \mu_s g$
$= (0.50)(9.80\,\frac{m}{s^2})$

$a_{max} = 4.9\ m/s^2$

ch. 6

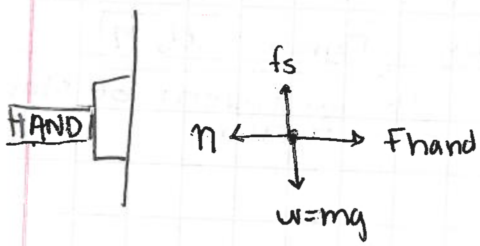
march 5, 2019

Rolling Friction → friction between a rolling wheel & a surface

$$f_r = \mu_r n$$

μ_r → coefficient of rolling friction

$\mu_s > \mu_k > \mu_r$



pushing harder ↑ n, but not f_s