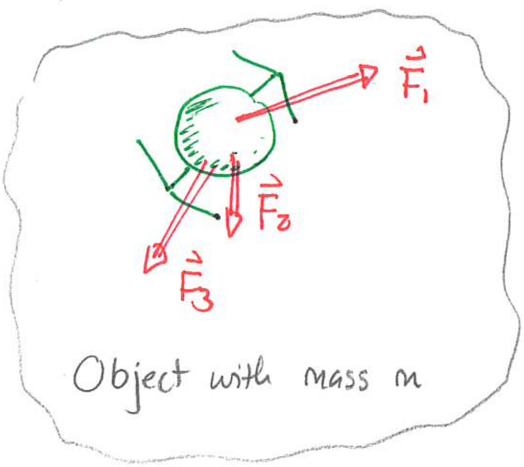
Thurs: Review I

Fri: Exam I. Ch 1→4
Lectures 1→11
HW 1→4
Quiz 1→3.

Bring one note card single side 3"x5"

## Newton's Second Law

Newton's Second Law relates the interactions between an object and its surroundings to its motion




→ Net force

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \dots = \sum \vec{F}_i$$

↓

Gives acceleration via:

$$\vec{F}_{net} = m\vec{a} \Rightarrow \begin{cases} F_{net\,x} = ma_x \\ F_{net\,y} = ma_y \end{cases}$$


Do this and algebra produces results

Note:

1) the direction of acceleration is the same as the direction of the net force

2) in terms of components:

$$F_{1x} + F_{2x} + \dots = ma_x$$
$$F_{1y} + F_{2y} + \dots = ma_y$$

Warm up 1.

Quiz 1   70% – 90%   } 50% – 90%

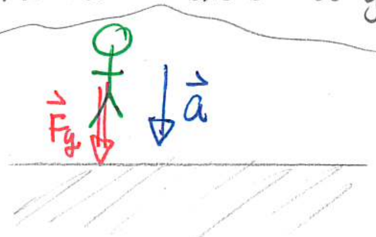
Quiz 2   40% – 80%   } 50% –

Demo: Scale + mass show

We now need rules for determining various forces

## Gravitational force (near Earth)

The Earth exerts a gravitational force on any object. Near to Earth's surface.




Observe that $\vec{a}$ points down

$a_x = 0 m/s^2$

$a_y = -9.8 m/s^2$

→ Newton's Second Law

$\Sigma F_x = ma_x = 0$

$\Sigma F_y = ma_y = -mg$

↓ Gravity is only force. So

$F_{gx} = 0N$

$F_{gy} = -mg$

Thus:

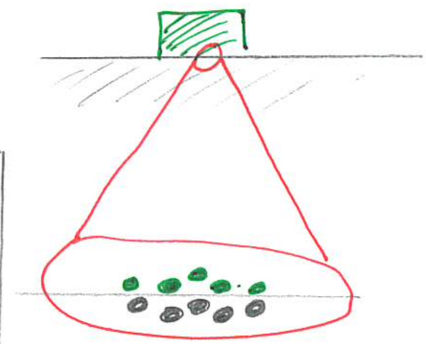
> Earth always exerts a gravitational force on any object. Near to Earth's surface the gravitational force $\vec{F}_g$:
>
> 1) points vertically down
> 2) has magnitude $F_g = mg$
>
> where m = mass of object.

Notes:

1) "$F_g$" is not "g"
2) the gravitational force is always active and only depends on the object's mass, not its motion
3) sometimes gravitational force is called weight $\vec{W}$.

# Normal forces

Normal forces result from interactions between microscopic constituents in the surfaces of objects. They generally depend on the situation:

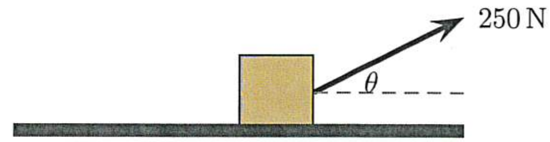


> When two objects are in contact, each exerts a normal force on the other. The normal force is:
>
> 1) perpendicular to the surface
> 2) has a magnitude that adjusts to the situation.

Warm up2

**116 Pulling a box**

A 20.0 kg box can move along a frictionless horizontal surface. A person pulls on the box with the indicated force. Initially assume that the force pulls horizontally; later we will consider a general angle. *(131Sp2023)*




a) Draw a free body diagram for the box.

b) Write Newton's Second Law in its component form, i.e. write

$$F_{\text{net } x} = \Sigma F_x = \cdots$$
$$F_{\text{net } y} = \Sigma F_y = \cdots$$

Insert as much information as possible about the components of acceleration at this stage. You will return to these equations soon; they will generate the algebra that eventually gives you the acceleration and the normal force.

c) List all the components of all the forces, using one of the two formats below.

$$F_{gx} = \cdots$$
$$F_{gy} = \cdots$$
$$n_x = \cdots$$
$$n_y = \cdots$$
$$F_{\text{person } x} = \cdots$$
$$F_{\text{person } y} = \cdots$$

| Force | $x$ comp | $y$ comp |
|---|---|---|
| $\vec{\mathbf{F}}_g$ | | |
| $\vec{\mathbf{n}}$ | | |
| $\vec{\mathbf{F}}_{\text{person}}$ | | |

Use these to determine expressions for the components of the net force.

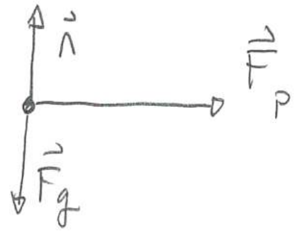
d) Use Newton's second law in component form to relate the acceleration components to the forces.

e) Determine the normal force on the box.

f) Determine the acceleration of the box.

g) Now suppose that $\theta = 25°$ and repeat the entire exercise to determine the normal force and the acceleration.

a)




b) $F_{net\,x} = \sum F_x = ma_x$

$F_{net\,y} = \sum F_y = ma_y = 0$

c) d)

| | x | y | |
|---|---|---|---|
| $\vec{F}_g$ | 0 | $-mg$ | ← vertical so $F_{gx} = 0$ |
| $\vec{n}$ | 0 | $n$ | ← vertical so $n_x = 0$ |
| $\vec{F}_p$ | 250N | 0 | ← horizontal so $F_{py} = 0$ |

$n$ = magnitude of $n$.

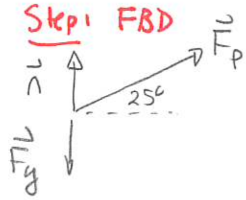
$F_{net\,x} = 0\,N + 0\,N + 250N = ma_x \Rightarrow 250N = 20kg\ a_x$

$F_{net\,y} = -mg + n + 0 = 0 \Rightarrow -mg + n = 0$

e) From y component $n - mg = 0 \Rightarrow n = mg = 20kg \times 9.8 m/s^2 = 196\ N$

f) From x component $250N = 20kg\ a_x \Rightarrow a_x = 12.5\ m/s^2$

g) Step 1 FBD




Step 2 Write Newton's 2nd Law

$\sum F_x = ma_x$

$\sum F_y = ma_y = 0$

Step 3 Components

$F_{px} = F_p \cos 25°$

$F_{py} = F_p \sin 25°$

| | x | y |
|---|---|---|
| $\vec{F}_g$ | 0 | $-mg$ |
| $\vec{n}$ | 0 | $n$ |
| $\vec{F}_p$ | $F_p \cos 25°$ | $F_p \sin 25°$ |

Step4 Use Newton's 2nd Law

$$\sum F_x = ma_x \Rightarrow F_p \cos 25° = ma_x$$

$$\Rightarrow a_x = \frac{F_p \cos 25°}{m} = \frac{250N \cos 25°}{20.0kg} \Rightarrow \boxed{a_x = 11.3 m/s^2}$$

$$\sum F_y = ma_y \Rightarrow -mg + n + F_p \sin 25° = 0$$

$$\Rightarrow n = mg - F_p \sin 25°$$

$$= 20kg \times 9.8 m/s^2 - 250N \sin 25°$$

$$\Rightarrow \boxed{n = 90.3 N}$$