

# Introduction to Physics I

For Biologists, Geoscientists, & Pharmaceutical Scientists

# Newton's First Law

- An object at rest remains at rest *unless* acted on by an external force.
- An object in motion continues to travel with constant velocity *unless* acted on by an external force.
- This is also known as the 'Law of Inertia'.

# Newton's Second Law

- The force acting on an object is equal to its acceleration times its mass.
- Mathematically:
  - $\vec{F} = m\vec{a}$
- Furthermore:
  - $\vec{F} = m\vec{a} = m \frac{d\vec{v}}{dt} = \frac{d}{dt} (m\vec{v})$ , where  $m\vec{v}$  is the momentum.

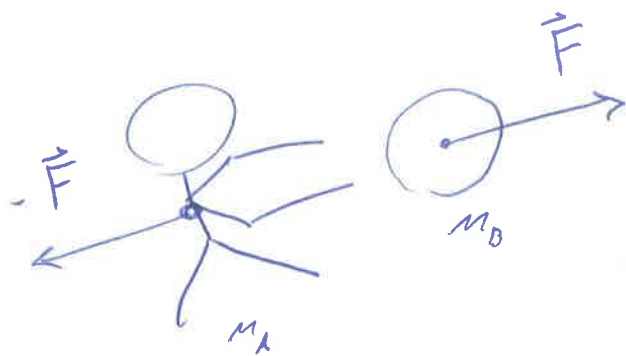
# Newton's Third Law

- When two objects A and B interact, the force  $\vec{F}_{BA}$  exerted by B on A is equal in magnitude and opposite in direction to the force  $\vec{F}_{AB}$  exerted by A on B.
- Mathematically:
  - $\vec{F}_{BA} = -\vec{F}_{AB}$

# Types of Forces

1. Gravitational Force
2. Electromagnetic Force
3. Nuclear Forces (Weak and Strong Forces)

# Newton's 3<sup>rd</sup> Law Example



$$\left. \begin{aligned} F &= m_B a_B \\ -F &= m_A a_A \end{aligned} \right\}$$

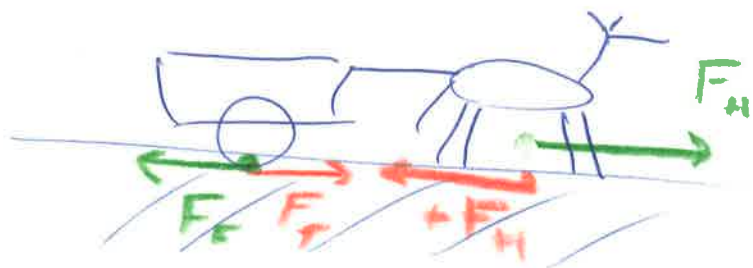
$$m_B a_B = -m_A a_A$$

$$a_A = -\frac{m_B}{m_A} a_B$$

$$a_B = -\frac{m_A}{m_B} a_A$$

If  $m_B \gg m_A$ , then  $a_A \gg a_B$ .

## Force Diagrams



Earth

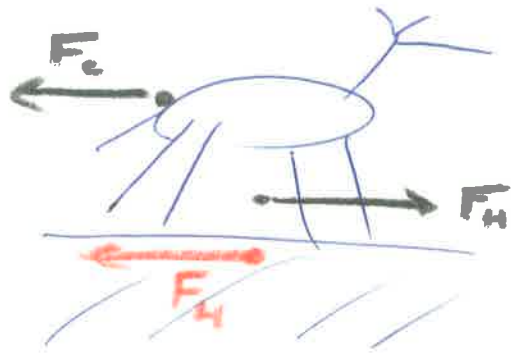
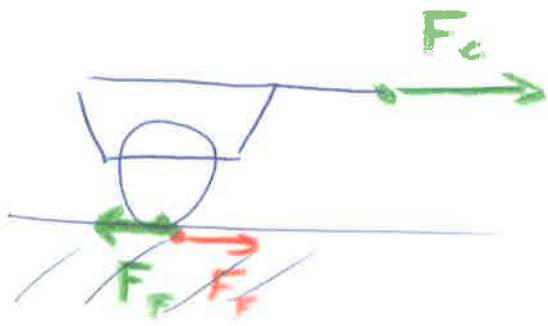
$$F = F_H - F_T$$

$$(m_H + m_C) a = F_H - F_T$$

$$F_E = -F_E + F_T$$

$$m_E a_E = -F_E + F_T$$

$$a_E = \frac{-F_E + F_T}{m_E} \approx 0$$



$$m_c a_c = F_c - F_f$$

$$m_H a_H = F_H - F_c$$

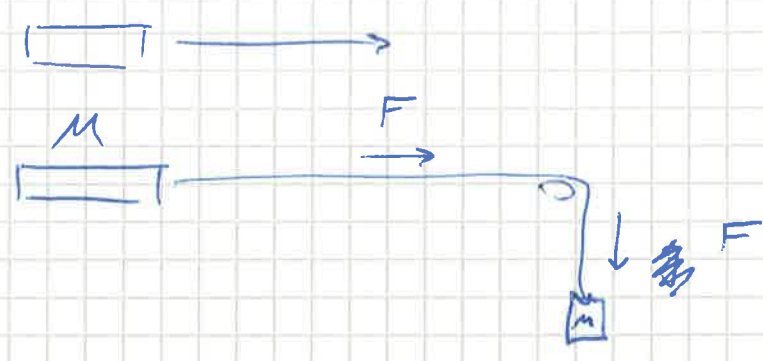
add together

$$m_c a_c + m_H a_H = \cancel{F_c} - F_f + F_H - \cancel{F_c}$$

From before:  $F_H - F_f = (m_H + m_c) a$

$$\therefore a = a_c = a_H$$

2<sup>nd</sup> Law:



$$F = mg = Ma$$

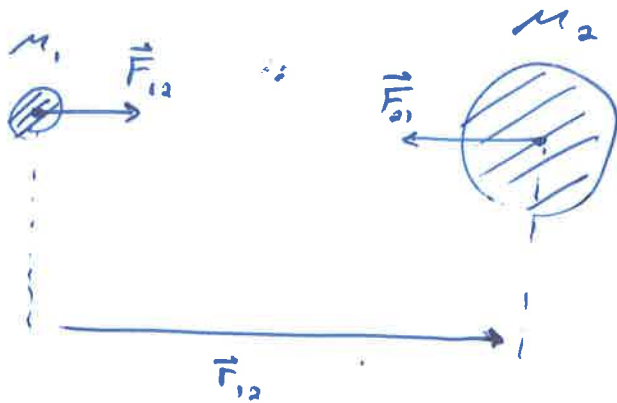
1.  $a = \frac{mg}{M}$

2.  $a = \frac{(2m)g}{M} = 2 \frac{mg}{M}$

3.  $a = \frac{(2m)g}{(2M)} = \frac{mg}{M}$



## Gravitation Force



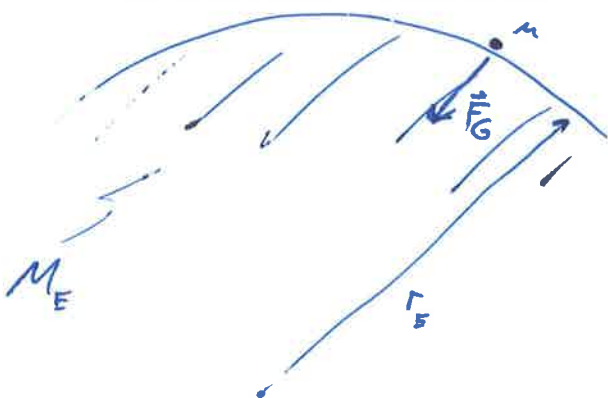
$$\vec{F}_{12} = G \frac{M_1 M_2}{r_{12}^2} \hat{r}_{12}$$

$$G = 6.67 \times 10^{-11} \frac{\text{Nm}^2}{\text{kg}^2}$$

$$|\vec{F}_{12}| = G \frac{M_1 M_2}{r_{12}^2}$$

Exp

## Gravity on Earth



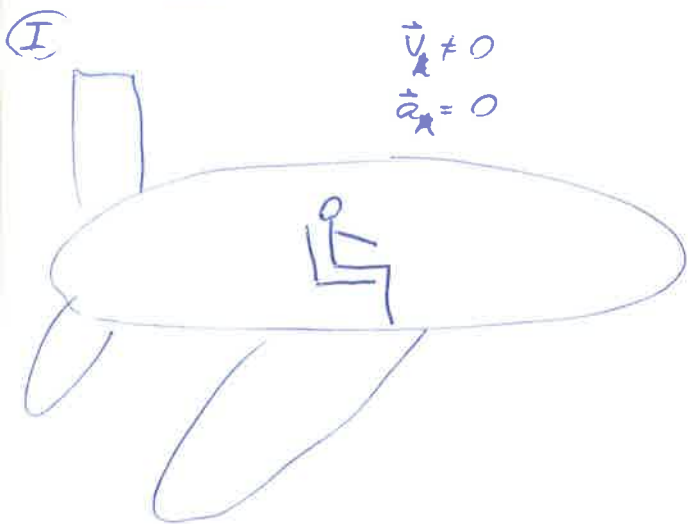
$$\vec{F}_G = G \frac{M_E m}{r_E^2} \left( -\hat{r}_E \right)$$

$$|\vec{F}_G| = m \left( \frac{G M_E}{r_E^2} \right)$$

$$= m \left( \frac{6.67 \times 10^{-11} \cdot 6 \times 10^{24}}{(6.4 \times 10^6)^2} \frac{\text{N}}{\text{kg}} \right)$$

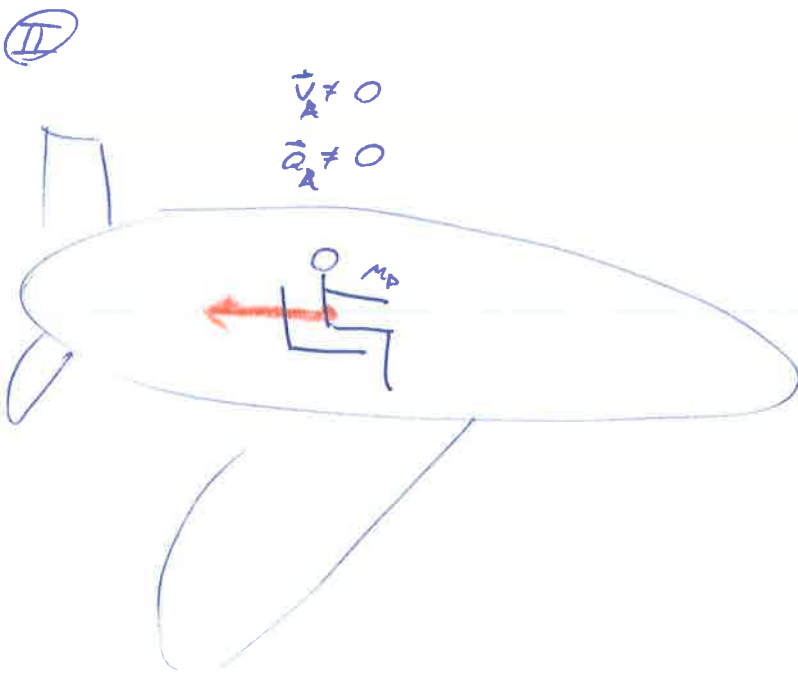
$$= m \left( 9.8 \frac{\text{m}}{\text{s}^2} \right) !$$

# Inertial Force



> Inertial Reference Frame

1st Law holds: No force on passenger:  $F = 0$



Non-inertial Reference Frame

1st Law does not hold: Fictitious force

on passenger

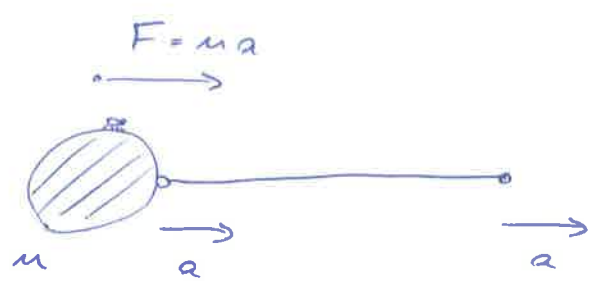
→

$$F = -m_p \vec{a}_A$$

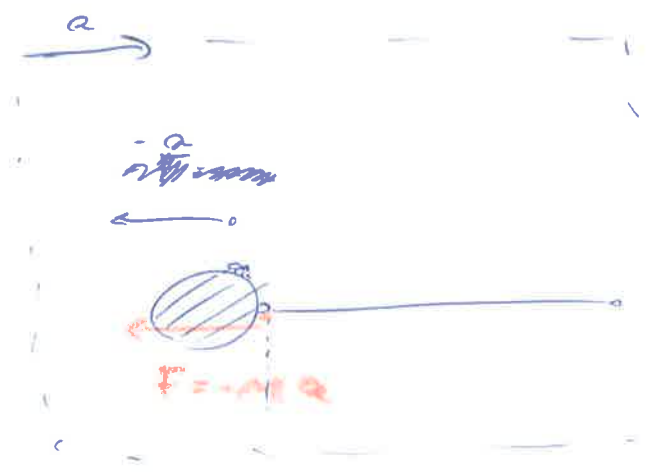
passenger mass

airplane acceleration

Exp 1



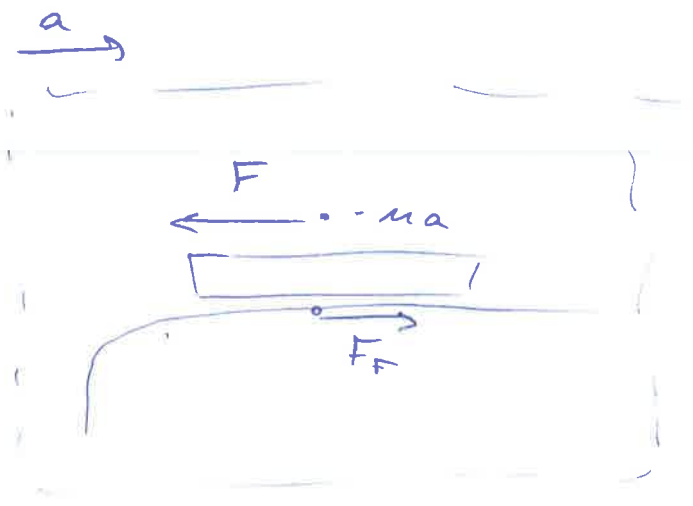
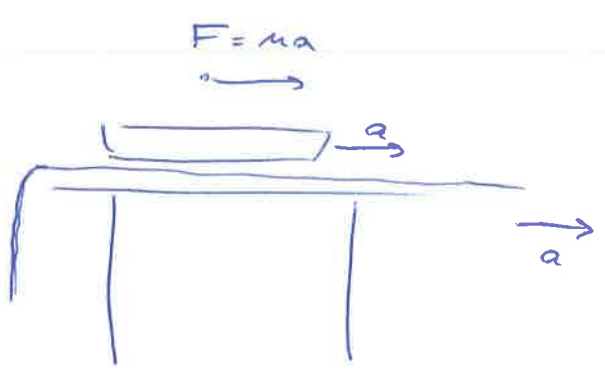
Lab Frame



Ball Frame

String will break if  $F > F_{max}$ .

Exp 1

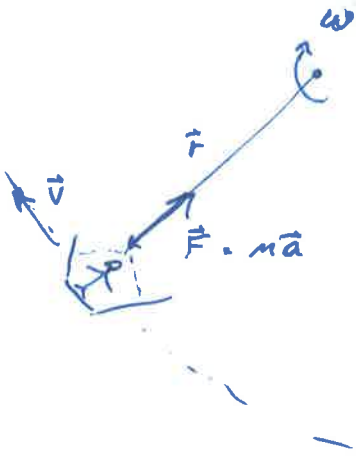


If  $F > F_f$ , plate slips.

6

# Centripetal & Centrifugal forces

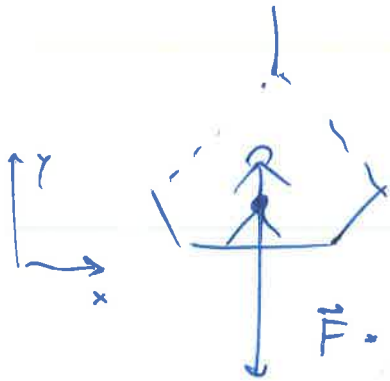
(Exp) Water, balls, spoons, centripetal mass, chain



$$\vec{a} = -\omega^2 \vec{r}$$

$$\vec{F} = -m\omega^2 \vec{r}$$

← Centripetal Force

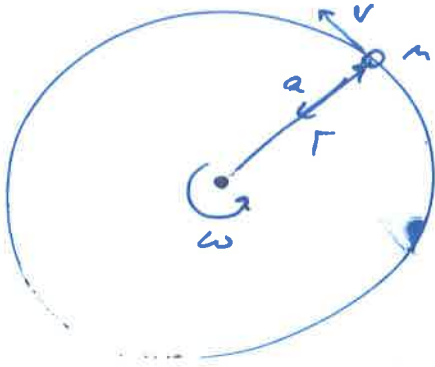


$$\vec{F} = -m\omega^2 r \hat{y}$$

← Centrifugal Force

Exp

# Measure Centripetal Force



$$a = \omega^2 r$$

$$F = m a$$

$$m = 0.4334 \text{ kg}$$

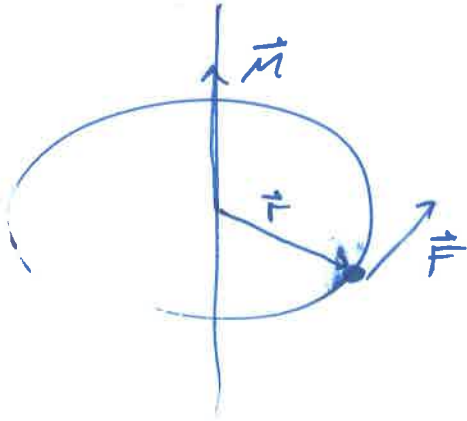
$$F = m \omega^2 r$$

$$r = .18 \text{ m}$$

$$r = .9 \text{ m}$$

Exp 1 Close

# Torque (Drehmoment)



$$\vec{M} = \vec{r} \times \vec{F} \quad [N \cdot m]$$

Exp



$$\phi(t) = \frac{1}{2} \alpha t^2$$

$$\omega = \frac{d\phi}{dt} = \alpha t$$

$$\frac{d\omega}{dt} = \alpha$$

Why? Torque ...

$$\vec{M} = \vec{r} \times \vec{F}$$



$$M = r F = r m a = r m \frac{dv}{dt}$$

$$M = r m \frac{d(\omega r)}{dt}$$

$$\vec{M} = r^2 m \frac{d\omega}{dt}$$

→ General

$v = \omega r$   
 mom of inertia  $I$   $\omega$   
 $\vec{M} = I \frac{d\omega}{dt}$