# Introduction to Physics I

For Biologists, Geoscientists, & Pharmaceutical Scientists

# Newton’s First Law

- An object at rest remains at rest *unless* acted on by and 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

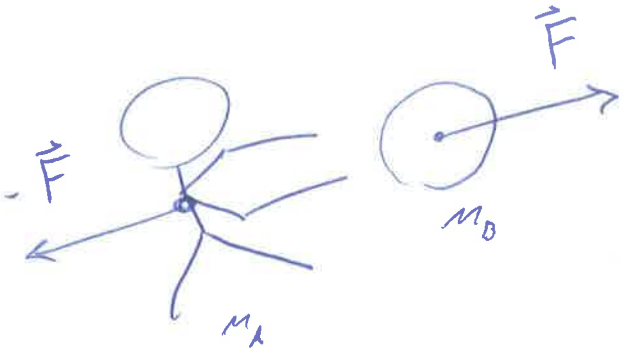
- When two objects A and B interact, the force $\vec{F}_{BA}$ exerted by B on A is equal in magnitude and opposite in direction to the force $\vec{F}_{AB}$ exerted by A on B.

- 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 3rd Law: Example




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

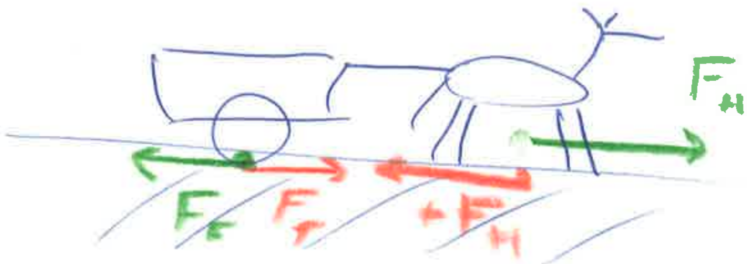
$$m_B a_B = -m_A a_A$$

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

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

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

# Force Diagrams




Earth

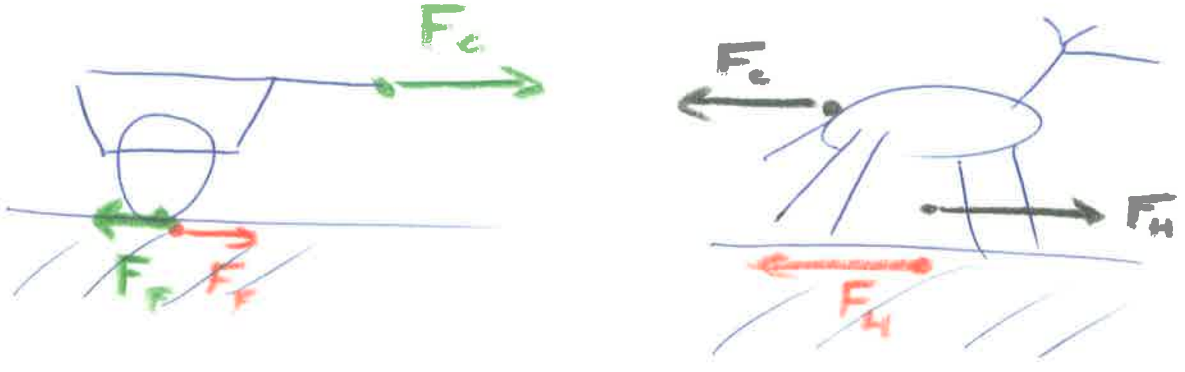
$$F = F_H - F_F$$

$$(m_H + m_C)\, a = F_H - F_F$$

$$F_E = -F_E + F_F$$

$$m_E a_E = -F_E + F_F$$

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




$$m_c a_c = F_c - F_f \qquad m_H a_H = F_H - F_c$$

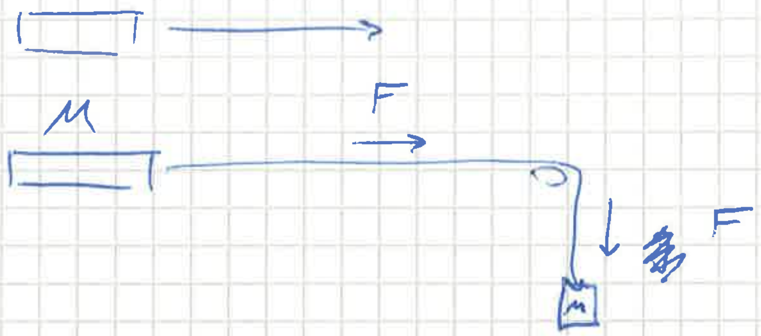
add together

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

From before: $F_H - F_F = (m_H + m_c)\, a$

$$\therefore \quad a = a_c = a_H$$

2-nd Law:



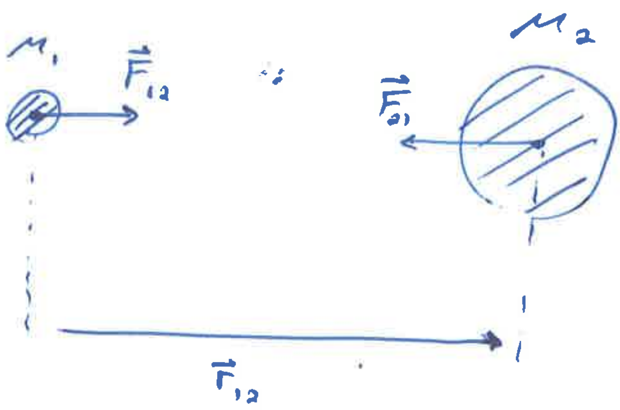

$$F = mg = Ma$$

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

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

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

## Gravitation Force

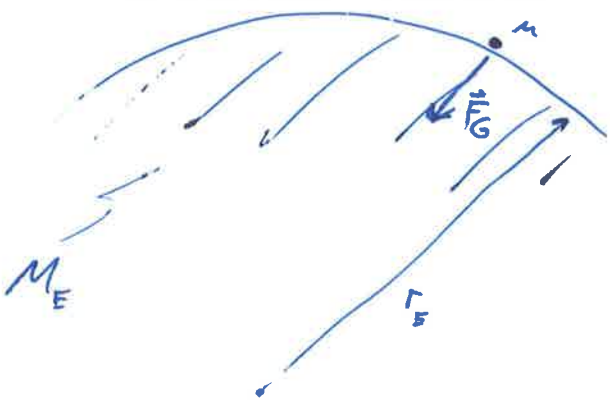



$$\vec{F}_{12} = G\,\frac{m_1 m_2}{r_{12}^2}\,\hat{r}_{12} \qquad\qquad G = 6.67\times10^{-11}\,\frac{Nm^2}{kg^2}$$

$$|\vec{F}_{12}| = G\,\frac{m_1 m_2}{r_{12}^2}$$

$\boxed{\text{Exp}}$

## Gravity on Earth




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

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

$$= m\left(\frac{6.67\times10^{-11}\cdot 6\times10^{24}}{(6.4\times10^{6})^2}\,\frac{N}{kg}\right)$$

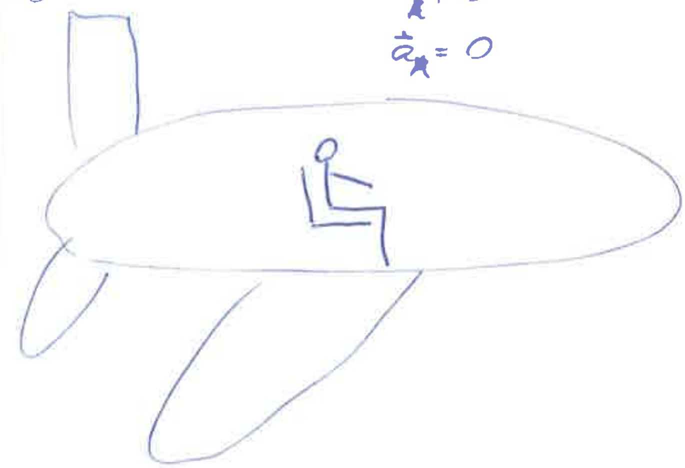
$$= m\,\underbrace{\left(9.8\ m/s^2\right)}_{g} \quad !$$

# Inertial Force

(I)

$\vec{v}_A \neq 0$

$\vec{a}_A = 0$



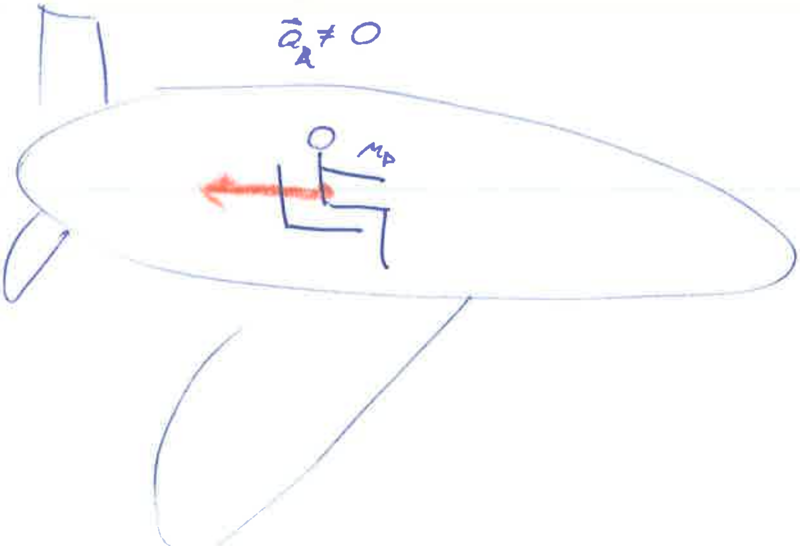
↳ **Inertial Reference Frame**

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

(II)

$\vec{v}_A \neq 0$

$\vec{a}_A \neq 0$

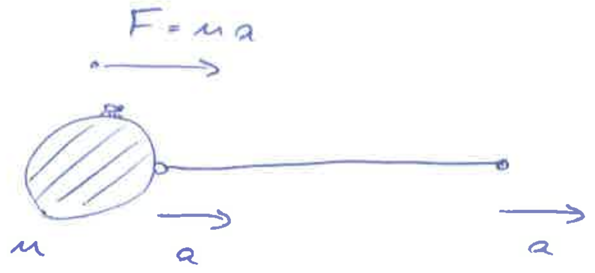


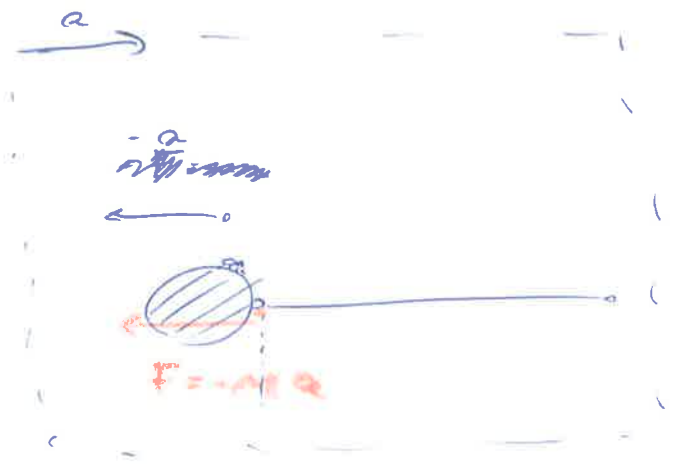

**Non-inertial Reference Frame**

1st Law does <u>not</u> hold : Fictitious force on passenger $\longrightarrow$ $F = -m_p \vec{a}_A$

passenger mass    Airplane acceleration

$\boxed{\text{Exp}}$

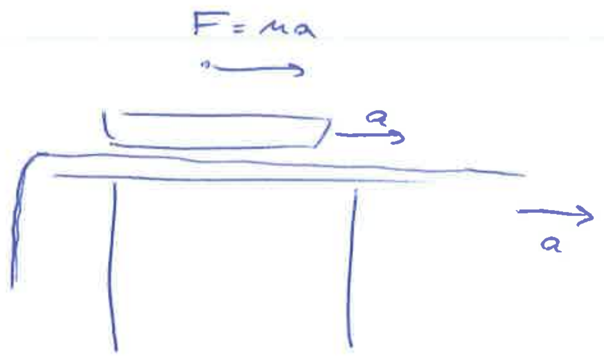


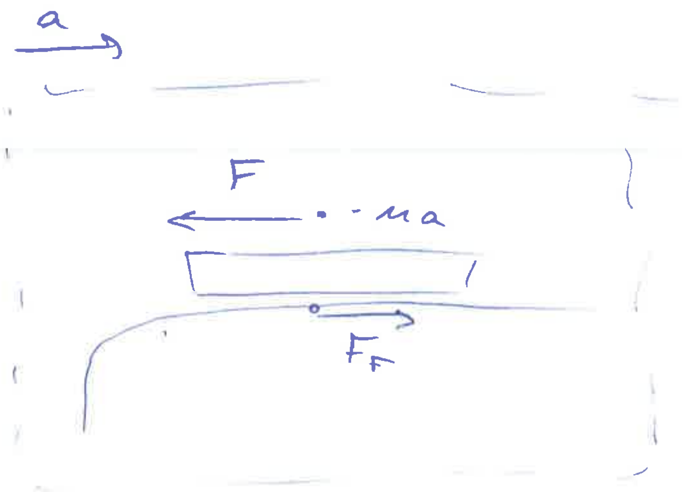




Lab Frame          Ball Frame

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

$\boxed{\text{Exp}}$

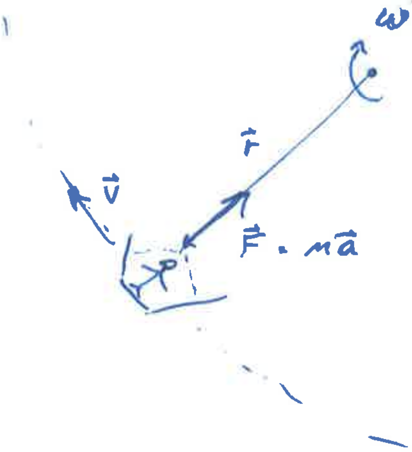



If $F > F_F$, plate slips.

# Centripetal & Centrifugal forces

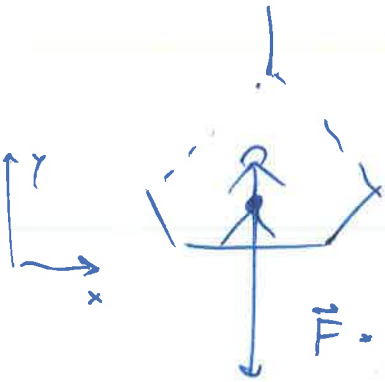
[Exp] water, balls, sparks, centripetal measure, chain




$\vec{F} = m\vec{a}$

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

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




$\vec{F} = m\vec{a}$

$\vec{F} = -m\omega^2 r\, \hat{y}$ ← Centrifugal Force

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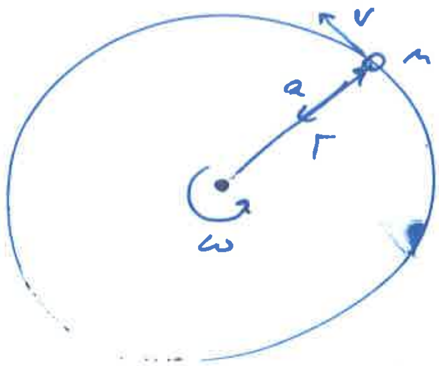
## $\boxed{\text{Exp}}$ Measure Centripetal Force




$a = \omega^2 r$

$F = m a$

$F = m \omega^2 r$

$m = 0.4334$ kg

$r = .18$ m

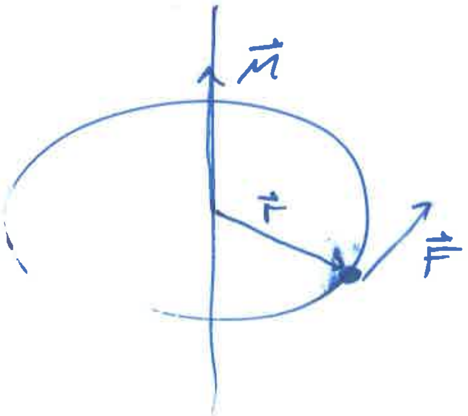
$r = .9$ m

## $\boxed{\text{Exp}}$ Chain

a

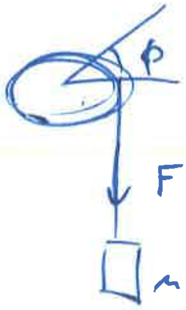
$\boxed{Exp}$ class

# Torque (Drehmoment)




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

$\boxed{Exp}$




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

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

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

Why? Torque...

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


$$M = rF = rma = rm\frac{dv}{dt}$$

$v = \omega r$

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

$$\boxed{M = r^2 m \frac{d\omega}{dt}} \longrightarrow \text{General}$$

mom of inertia | ang. acc.

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