Dynamics: Newton's Laws

Kinematics: position, velocity, acceleration }

Math desc. of HOW things move.

Dynamics: What causes motion?? Forces ⟹ Acceleration

Newton's Three Laws of Motion

1'st Law: No Forces.

2'nd + 3'rd: Body + Forces Acting

Galileo: Started Modern Mechanics

Free Falling Objects: $\vec{a}$ = constant

a: Independent of weight

Tower of Pisa Expts.

Newton: (1642 - 1727)

①

"Principia Mathematica"

Newton Mechanics

- Laws of Motion
- Law of Universal Gravitation

- invented calculus
- white light → colors

Newton's Laws: Approximate

i) Atoms, Nuclei, Fund Particles

"Quantum Theory" (1920+'s)

ii) Motion at High Velocities

v ≈ Speed of Light

Theory of Relativity: Einstein (1900+)

Forces

- Something exerting a push or a pull
- Vector quantity (magnitude + direction)

Contact Forces

Spring Rubber Bands Cables

Ropes Liquids Gases

Action-at-a-Distance

②

Gravity: 8.01 $1/r^2$

Electromagnetic: 8.02 $1/r^2$

Fundamental Forces in Nature (4-Kinds)

Gravity:

- Always attractive
- Acts between masses
- Weakest in nature
- Exchange particle: graviton.

Does accelerating mass radiate energy?

LIGO

Lecture 8, Blackboard #1

②

Newton's Laws: Approximate
i) Atoms, Nuclei, Fund Particles
"Quantum Theory" (1920++)
ii) Motion at High Velocities
v ~ Speed of Light
Theory of Relativity: Einstein (1900+)

Forces

- Something exerting a push or a pull
- Vector quantity (magnitude + direction)

Contact Forces

Spring Rubber Bands Cables
Ropes Liquids Gases

Action-at-a-Distance

Gravity: 8.01 $1/r^2$
Electromagnetic: 8.02 $1/r^2$

Fundamental Forces in Nature (4-Kinds)

i) Gravity:
- Always attractive
- Acts between masses
- Weakest in nature
- Exchange particle: graviton.

Does accelerating mass radiate energy?
LIGO

③

ii) Electromagnetic
- Acts between charged bodies
- Attractive or Repulsive
- Except for gravity, all macroscopic forces are em.
- Exchange particle: photon
- Accelerating charges radiate photons.

iii) Strong Force
- Between Nucleons (protons, neutrons, quarks)
- Nuclear glue attractive/repulsive

Exchange particles: mesons/gluons

iv) Weak Force
- Between elementary particles
- Neutron Decay

$n \rightarrow p + e^- + \bar{\nu}$

β-decay ~1000 s

Exchange Particles
$W^\pm$, Z° (~90 GeV)
1984 1991

	Range	Str.	Field Particle
Strong Force	10^{-15} m	1	mesons/gluons
Electromagnetic	∞	10^{-2}	photon
Weak Force	10^{-17} m	10^{-13}	$W^\pm$, Z°
Gravitational	∞	10^{-38}	graviton?

Rel Strength →
2-protons 10^{-15} m apart

Lecture 8, Blackboard #2

Gauge Theories

Elect Mag + Weak } Electro-weak

High Energies ⇒ Common Desc.

GUTS: Grand Unified Theories

Strong, EM, Weak } ??

Newton's First Law: Law of Inertia

"Every body continues in a state of rest or in uniform motion in a st. line unless it is compelled to change that state by forces impressed on it"

$\vec{F} = 0 \Longrightarrow \vec{V} = \text{constant}$ – fixed direction – fixed magnitude

$\vec{a} \equiv 0$ Particles in vacuum/celestial obj.

Reference Frames

(4)

Law valid only in Inertial Frames.

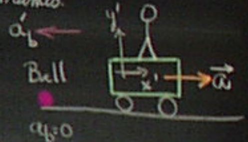
Ball on ground
No net forces

Person on Train: $a'_B \neq 0$??

Test: Free Body (No Forces)

If Uniform Motion ($\vec{V}$ = const) ⇒ Inertial Ref Frame.

Ref Frames in uniform translation also IRF!!



Newton's 2nd Law: $\vec{F} = m\vec{a}$

Force → acceleration of a mass

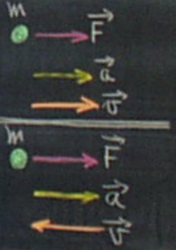
"The change in motion (accel) is proportional to the motive force impressed, and is made in the direction of the st. line in which the force is impressed".

$$\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt}$$

$F = ma$

$[N] = [kg]\left[\frac{m}{s^2}\right]$ newtons

$m = 1\,kg$, $a = 1\,m/s^2 \Rightarrow F = 1\,N$



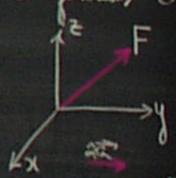
$\vec{F} = m\vec{a}$ (Vector Equation)

(5)

$F_x = m a_x$

$F_y = m a_y$

$F_z = m a_z$



Lecture 8, Blackboard #3

Newton's 2nd Law: $\vec{F} = m\vec{a}$

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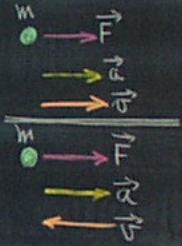
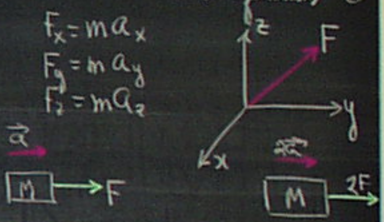


$\vec{F} = m\vec{a}$ (Vector Equation) ⑤

$F_x = ma_x$

$F_y = ma_y$

$F_z = ma_z$



Definition of Mass

- Standard mass: $m_s = 1\,kg$
- Compare by balancing

- Not good if $g \equiv 0$ (space)
- Use common force and Newton's 2'nd Law
- Inertial Frame.

m_s, a_s Stnd Mass

m, a Unknown

$F = ma$ $\quad F = m_s a_s$ — same

$$\frac{m}{m_s} = \frac{a}{a_s}$$

Mass: Resistance of body to change in velocity ⟷ Inertia.

Large M → Small $\vec{a}$ $\quad M = M_1 + M_2$ ← Exp.

Example

$F_x = ma_x$

$$a_x = \frac{F_x}{m} = \frac{20}{4} = 5\,m/s^2$$

Example: ⑥

Mass (0.2kg) slides along table. Initial $v = 2.8\,m/s$. Stops in 1.0m. What force is acting?

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

$$v_f^2 = v_0^2 + 2a_x(x - x_0)$$

$$a_x = \frac{v_f^2 - v_0^2}{x - x_0} = \frac{0 - 2.8^2}{1.0^2} = -3.9\,m/s^2$$

$f = ma_x$

$= 0.2 \times -3.9$

$= -0.78\,N$

Lecture 8, Blackboard #4

Newton's 2nd Law: $\vec{F} = m\vec{a}$

Force → acceleration of a mass

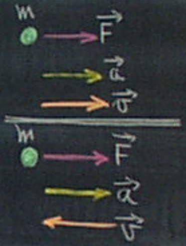
"The change in motion (accel) is proportional to the motive force impressed, and is made in the direction of the st. line in which the force is impressed".

$$\vec{F} = m\vec{a} = \frac{d\vec{p}}{dt}$$

$F = ma$

$[N] = [kg]\left[\frac{m}{s^2}\right]$ newtons

$m = 1kg$, $a = 1 m/s^2 \Rightarrow F = 1N$

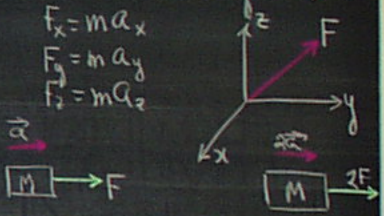


$\vec{F} = m\vec{a}$ (Vector Equation) (5)

$F_x = m a_x$

$F_y = m a_y$

$F_z = m a_z$



Definition of Mass

- Standard mass: $m_s = 1kg$
- Compare by balancing

m O ↑ O m_s

- Not good if $g \equiv 0$ (space)
- Use common force and Newton's 2nd Law
- Inertial Frame.

m_s, a_s Stnd Mass

m, a Unknown

$F = ma$ $F = m_s a_s$ — same

$$\frac{m}{m_s} = \frac{a}{a_s}$$

Mass: Resistance of body to change in velocity ↔ Inertia.

Large M → Small $\vec{a}$ $M = M_1 + M_2$ ← Exp.

Example

x → [M=4kg] → F=20N

$F_x = m a_x$

$$a_x = \frac{F_x}{m} = \frac{20}{4} = 5 m/s^2$$

Example: (6)

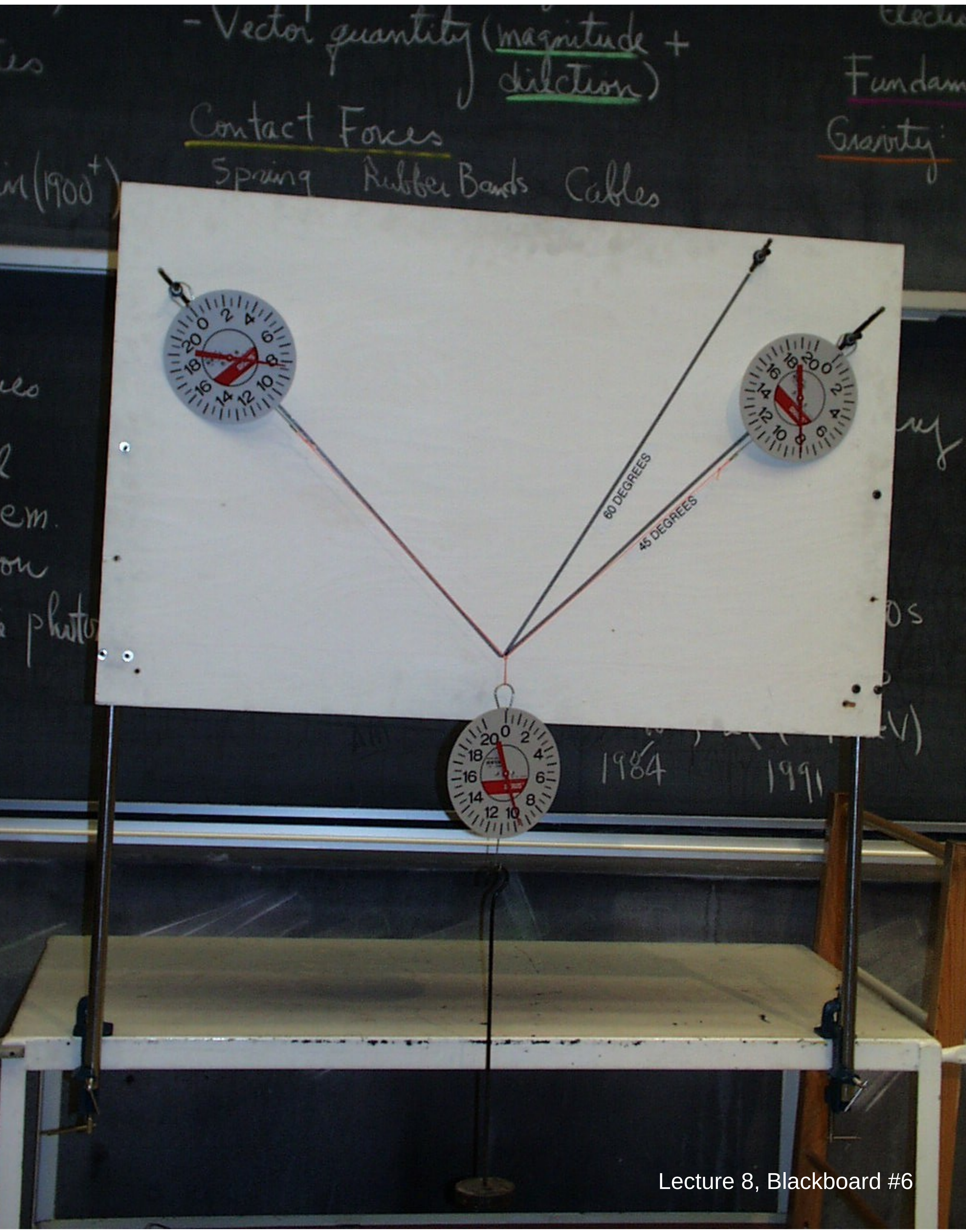
Mass (0.2kg) slides along table. Initial $v = 2.8 m/s$. Stops in 1.0m. What force is acting?

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

$v_f^2 = v_0^2 + 2a_x(x - x_0)$

$$a_x = \frac{v_f^2 - v_0^2}{x - x_0} = \frac{0 - 2.8^2}{1.0^2} = -3.9 m/s^2$$

$f = m a_x$
$= 0.2 \times -3.9$
$= -0.78 N$



Lecture 8, Blackboard #6