Immaculata Week: Session II

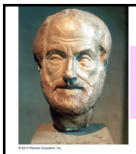
Forces

Newton's Laws (I & II)

Newton's Law of Gravitation

- Acceleration in the Crime Scenes:
  - Falling body
  - Moving bullet
  - Braking car
- What causes Acceleration? ***Forces***

- History of Understanding Motion: *Aristotle, Galileo, Newton*
- What resists Motion: Inertia
- What causes Motion: Forces
- Newton's 3 Laws of Motion
- Universal Law of Gravitation

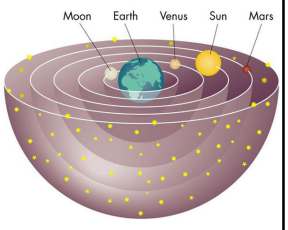


Aristotle's (4th century BC) Ideas of Motion: Natural and Violent

- Natural motion on Earth
  - Every object in the universe consisted of four elements: earth, water, air, and fire.
  - Any object not in its proper place will strive to get there.
    Examples:
    - Stones fall, smoke rises
  - Straight up or straight down for all things on Earth.
  - **Heavier objects fall faster**

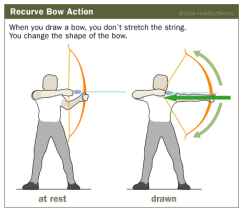
Aristotle's Ideas of Motion

- Natural motion in Universe
  - Beyond Earth, motion is circular.
    Example: The Sun and Moon continually circle Earth.



Aristotle's Ideas of Motion

- Violent Motion
  - Produced by external pushes or pulls on objects.
  - Objects needed a push or pull to move
  - Example: Wind imposes motion on ships.
  - Problems…(arrow's motion)

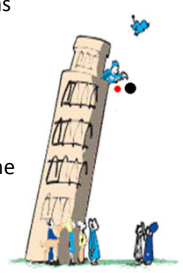


Galileo Proves Aristotle Wrong through Experimentation

Galileo demolished Aristotle's assertions in the early 1500s

Galileo's discovery:

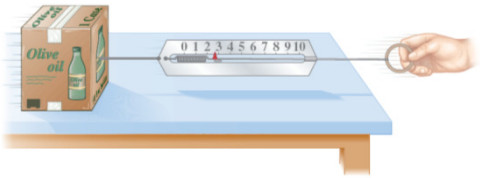
- A moving object needs no push or pull to keep it moving.
- Objects of different weight fall to the ground at the same time. (absence of air resistance).



Isaac Newton Born 1642…the year Galileo dies

What causes Motion?

Forces



Forces have both magnitude and direction.
The magnitude of a force can be measured.

Forces are Vectors

Different Kinds of Forces

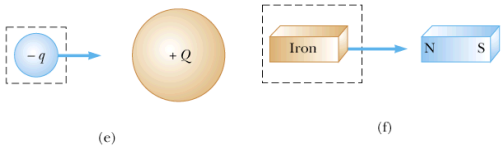
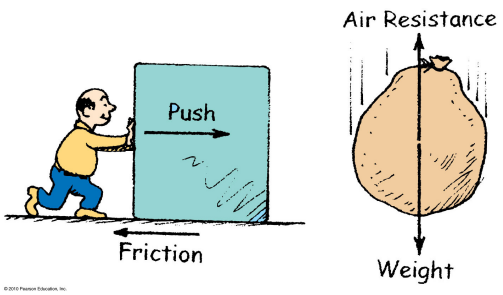


Figure 4.4

Don't Forget These Forces



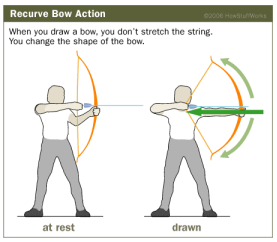
What were the forces acting on the car in Crime Scene #3?

Road Rage

Newton's First Law of Motion

$\Sigma F = 0$

When the net force is zero, an object at rest remains at rest and an object in motion continues with a constant velocity.

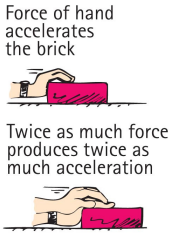


Force of string on arrow accelerates the arrow
Once arrow leaves the bow it travels forever, unless other forces act on it

Force causes Acceleration

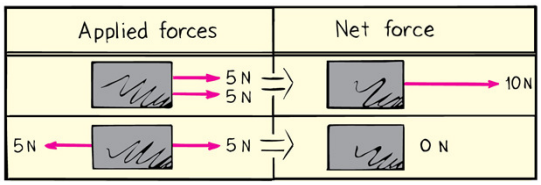
- Acceleration of an object depends on *net force.*
- To increase the acceleration of an object, you must increase the net force acting on it.

Acceleration ~ net force



Net Force

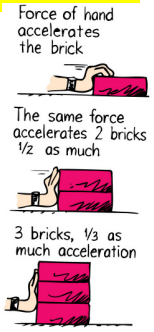
Net force is the combination of all forces that change an object's state of motion.



Forces cause Acceleration and Mass Resists Acceleration

- A force applied to a mass results in acceleration
- Twice the mass produces half the acceleration.
- 3 times the mass, produces 1/3 the acceleration.
- Acceleration is inversely proportional to mass

$$\text{Acceleration} \sim \frac{1}{\text{mass}}$$



Acceleration is directly proportional to force

Acceleration ~ net force

Greater the force, greater the muzzle speed

Firearm	Muzzle Velocity (m/s)
.357 Magnum	442
.38 Special	300
.45 ACP FMJ	250

Acceleration is inversely proportional to mass

Acceleration ~ 1/mass

Greater the mass, slower the muzzle speed

Firearm	Muzzle Velocity (m/s)
.357 Magnum	442
.38 Special	300
.45 ACP FMJ	250

Newton's Second Law of Motion

Isaac Newton was the first to connect the concepts of force and mass to produce acceleration.

$$\text{Acceleration} = \frac{\text{net force}}{\text{mass}}$$

Force = Mass X Acceleration

Units of Force

Weight measured in pounds (lb) is a unit of force

Scientific Unit of force is measured in **newtons**

We can convert from newton to lbs and back:

one pound = 4.45 newtons

The .45 ACP FMJ has a muzzle velocity of 250 m/s and a mass of 15 g. The time in the muzzle while the bullet is being accelerated is 0.00096 s. What force is imparted to the bullet?

$F = ma$

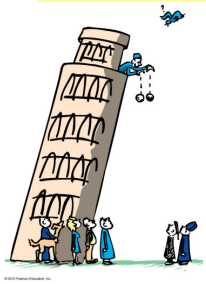
$a = (v_f - v_i) / \text{time}$

Crime Scene #3

Evelyn stated she applied her brakes for 1 full second before she hit the guard rail. The braking ability of her car would result in a deceleration of 8.83 m/s^2. If her vehicle had a mass of 1860 kg, what force did the brakes apply to the car?

Figure 4.12

Acceleration (Free Fall) due to the Force of Gravity



Objects accelerate as they fall

In the absence of air resistance, all objects fall at the same rate!

http://www.youtube.com/watch?v=5C5_dOEyAfk

Feather & hammer on Moon

Free Fall

The *greater* the mass of the object…

- the *greater* its force of attraction toward the Earth.
- the *smaller* its tendency to move
- So the acceleration is the same

Newton's Second Law:
F = ma
or
F/m = a

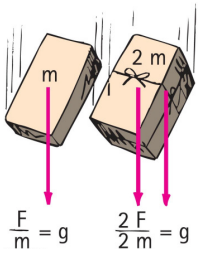
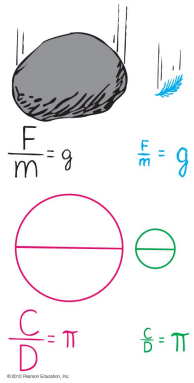


Figure 4.13



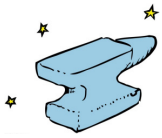
On Earth g = 9.8 m/s²

Another Example of a Constant Ratio:
π

π= 3.1416

Difference between Mass and Weight

- Mass: *The quantity of matter in an object.*
  - *Mass does not depend on gravity*
  - *Mass is the same everywhere in the universe*
- Weight: *The force upon an object due to gravity.*
  - *It depends where you are*



If Einstein's mass is 70 kg, what is his weight on earth?

F = mg

Newton's 2nd Law & Universal Law of Gravitation

Newton's Second Law: F = ma, F = mg

Universal Law of Gravitation: $F = G\frac{m_1 m_2}{d^2}$

Gravity means the moon circles the Earth and the Earth circles the Sun

The Universal Law of Gravity

- Everything pulls on everything else.
- Every body attracts every other body with a force that dependents on the masses of the bodies and the distance between them.

$$F = G\frac{m_1 m_2}{d^2}$$

What is G?
Universal Gravitational Constant

$$F = G\frac{m_1 m_2}{d^2}$$

Universal gravitational constant:

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

If Einstein weighs 686 newtons and his mass is 70 kg, what is the mass of the Earth?

(d = radius of the Earth = 6.38 X 10^6 m)

$$F = G\frac{m_1 m_2}{d^2}$$

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Net Force
CHECK YOUR NEIGHBOR

A cart is pushed to the right with a force of 15 N while being pulled to the left with a force of 20 N. The net force on the cart is

A. 5 N to the left.
B. 5 N to the right.
C. 25 N to the left.
D. 25 N to the right.

Newton's Second Law of Motion
CHECK YOUR NEIGHBOR

Push a cart along a track so twice as much net force acts on it. If the acceleration remains the same, what is a reasonable explanation?

A. The mass of the cart doubled when the force doubled.
B. The cart experiences a force that it didn't before.
C. The track is not level.
D. Friction reversed direction.

Force = Mass X Acceleration

Newton's Second Law of Motion
CHECK YOUR NEIGHBOR

Consider a cart pushed along a track with a certain force. If the force remains the same while the mass of the cart decreases to half, the acceleration of the cart

A. remains relatively the same.
B. halves.
C. doubles.
D. changes unpredictably.

Force/ Mass = Acceleration

Free Fall
CHECK YOUR ANSWER

A 5-kg iron ball and a 10-kg iron ball are dropped from rest. For negligible air resistance, the acceleration of the heavier ball will be

A. less.
B. the same.
C. more.
D. undetermined.

Gravity and Distance: The Inverse-Square Law
CHECK YOUR ANSWER

The force of gravity between two planets depends on their

A. masses and distance apart.
B. planetary atmospheres.
C. rotational motions.
D. All of the above.

$$F = G\frac{m_1 m_2}{d^2}$$