33-120
Science & Science Fiction

Welcome!

Today:

Finish *Classical Physics* – Newton's Laws

Begin *Modern Physics* – Einstein & Relativity

- **Quiz 1** (delayed from Friday) due today!
- **Problem 1** (acceleration) due this Friday

Announcements for Wednesday, September 6

- **Newton's Laws of Motion**
  1. **Inertia**
  2. **F = dp/dt** (or F = ma for constant mass)
  3. **Action and Reaction**

Last time…

What is the nature of space and time?

A. Classical physics and Newton's Laws

X-Men III: The Last Stand

Directed by Brett Ratner

20th Century Fox (2006)

Illustration of Newton's 1st Law of Motion

Inertia: **External force needed to change an object's state of motion or rest.**

X-Men III: The Last Stand

Magneto **pushes cars out of the way**

Consistent with Newton's 1st Law?

Yes – external force on cars

Illustration of Newton's 1st Law of Motion

Inertia: **<u>External force</u> needed to change an object's state of motion or rest.**

X-Men III: The Last Stand

***B*reaks one end of bridge away from shore while standing on bridge**

Consistent with Newton's 1st Law?

Yes – external force on one end of bridge

Illustration of Newton's 1st Law of Motion

Inertia: **<u>External force</u> needed to change an object's state of motion or rest.**

X-Men III: The Last Stand

Moves the entire bridge while standing on bridge

Consistent with Newton's 1st Law?

Only if Magneto interacts with Earth's field

Illustration of Newton's 1st Law of Motion

Inertia: **<u>External force</u> needed to change an object's state of motion or rest.**

- **Continue Major Question 1**
  - **What is the nature of space & time?**
    - **Newton's 2nd & 3rd Laws of Motion**
    - **Newton's Law of Gravitation**
    - **Newton's Concept of Time**
    - **Einstein and Modern Physics**

Today…

Star Trek V: The Final Frontier

Directed by William Shatner

Paramount (1989)

Illustration of Newton's 2nd Law of Motion

F = ma

Force = mass x acceleration

Star Trek V: The Final Frontier

Kirk, Spock, Jet Boots and F = ma

Kirk attempts to free-climb El Capitan

…

Spock arrives on "jet boots"

Illustration of Newton's 2nd Law of Motion

F = ma

Force = mass x acceleration

Star Trek V: The Final Frontier

Kirk, Spock, Jet Boots and F = ma

Kirk falls off of El Capitan

…

Spock pursues on “jet boots”

Illustration of Newton’s 2nd Law of Motion

F = ma

Force = mass x acceleration

Star Trek V: The Final Frontier

Kirk, Spock, Jet Boots and F = ma

Will Kirk survive the fall?

Illustration of Newton's 2nd Law of Motion

F = ma

Force = mass x acceleration

Star Trek V: The Final Frontier

Kirk, Spock, Jet Boots and F = ma

Make some Reasonable assumptions

...

Take a guess for Kirk's mass:

m ~ 80 kg

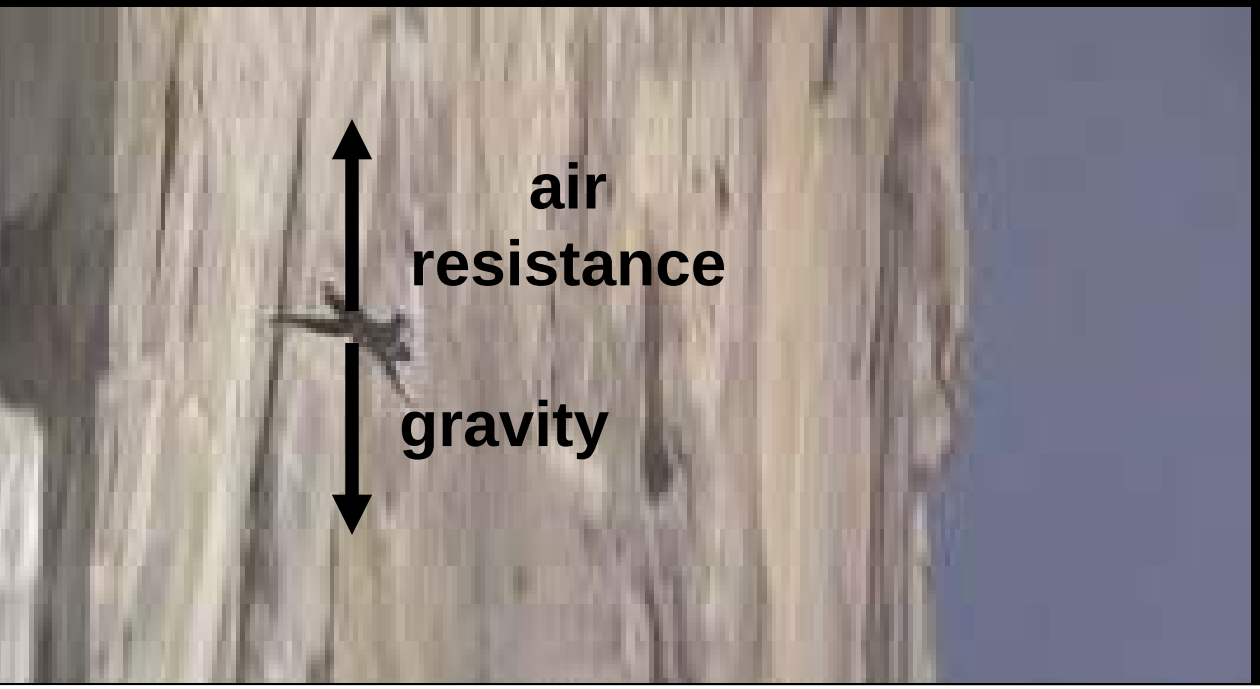
Illustration of Newton's 2nd Law of Motion

$$F = ma = m\,\Delta v/\Delta t$$

Variables: Kirk's mass, change in velocity and time

Star Trek V: The Final Frontier

Kirk, Spock, Jet Boots and F = ma



Make some **reasonable assumptions**

...

Kirk falls long enough to reach **terminal velocity**

Illustration of Newton's 2nd Law of Motion

$F = ma = m\,\Delta v/\Delta t$

Variables: Kirk's mass, **change in velocity** and time

Star Trek V: The Final Frontier

Kirk, Spock, Jet Boots and F = ma

Time for Spock to stop Kirk's fall?

Make some Reasonable assumptions

Δt ~ 1 second

Illustration of Newton's 2nd Law of Motion

$$F = ma = m\,\Delta v/\Delta t$$

Variables: Kirk's mass, change in velocity and time

Star Trek V: The Final Frontier

Kirk, Spock, Jet Boots and F = ma

Estimate force needed to stop Kirk's fall…

$$F = ma = m\,\Delta v/\Delta t$$

$$= 80\text{kg}(56\text{m/s})/(1\text{s})$$

$$= 4880\ \text{kg m/s}^2$$

= 4880 Newtons

Illustration of Newton's 2nd Law of Motion

$$F = ma = m\,\Delta v/\Delta t$$

Variables: Kirk's mass, change in velocity and time

Star Trek V: The Final Frontier

Kirk, Spock, Jet Boots and F = ma

Force needed to stop Kirk's fall…

F = 1097 lb

About ½ ton !

Illustration of Newton's 2nd Law of Motion

$$F = ma = m\,\Delta v/\Delta t$$

Variables: Kirk's mass, change in velocity and time

Kirk, Spock, Jet Boots and F = ma

Would Kirk survive the acceleration?

a ~ 5.7 x g

(very rough, but probably OK)

Illustration of Newton's 2nd Law of Motion

$$F = ma = m\,\Delta v/\Delta t$$

Variables: Kirk's mass, change in velocity and time

The Martian

Directed by Ridley Scott

20th Century Fox (2015)

Illustration of Newton's 3rd Law of Motion
Action-Reaction

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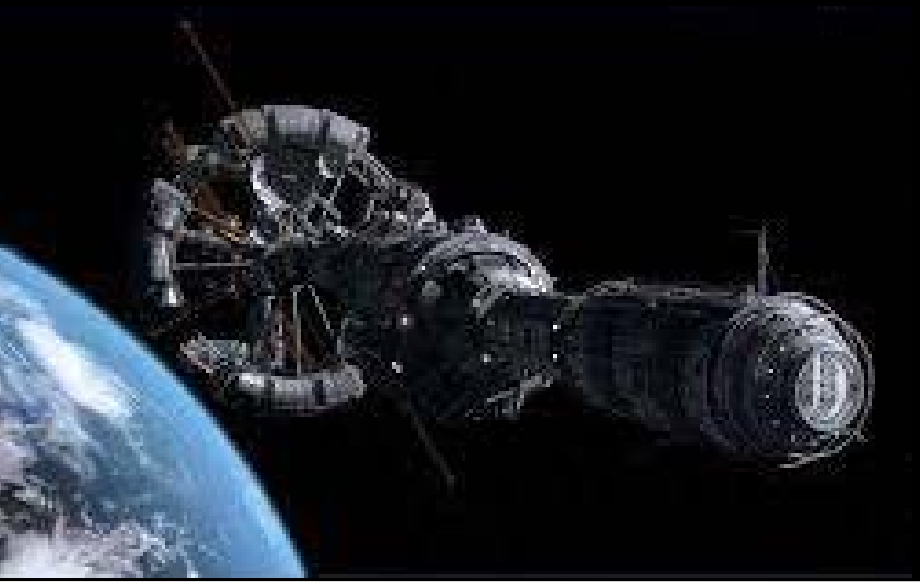
The Martian

Directed by Ridley Scott

20th Century Fox (2015)



Why does the *Hermes* slow down?

Why does Watney fly like *Iron Man*?

- **Newton's Law of Gravitation:**

$$F = \frac{Gm_1m_2}{r^2}$$

  - **Force is proportional to product of masses,**
  - **Inversely proportional to distance squared,**
  - **Acts instantaneously over any distance.**

What is the nature of space and time?

A. Classical physics and Newton's Laws

- **Newton's concept of time:**
  - **Flows continuously from past to future**
  - **Completely independent of 3-D space**
  - **An absolute concept (Everyone experiences time in the same way.)**

What is the nature of space and time?

A. Classical physics and Newton's Laws

Doctor Who
"Blink"

Written by Steven Moffat

BBC (2007)

What is time?
Is time travel possible?

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Doctor Who

The TARDIS

(a.k.a. “the blue box”)

Time And Relative Dimension In Space

What is time?
Is time travel possible?

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- **Special Theory of Relativity**
  - ***Spacetime* as a 4-dimensional "fabric"**
  - **Perception of space and time depend on relative motion**
  - **Speed of light constant for everyone**
  - **$E=mc^2$**

What is the nature of space and time?

Part 2. Modern Physics: Einstein and Relativity

- General Theory of Relativity
  - Gravity = distortion of *spacetime* near a large mass
    - gravitational time dilation
    - NOT instantaneous (effect propagates at speed of light)
  - Black Holes and Gravitational Waves

What is the nature of space and time?

Part 2. Modern Physics: Einstein and Relativity

Short excerpt from

The Time Machine

H.G. Wells

(1895)

What is time?
Is time travel possible?

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Planet of the Apes

Directed by Franklin J. Schaffner

20th Century Fox (1967)

What is time?
Is time travel possible?

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Next time…
Calculation of time dilation;
Can anything travel faster than light?
Begin General Relativity

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