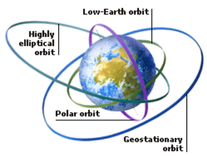
Today's Class: Motion on Earth & in Space

Professor Jack Burns
jack.burns@colorado.edu

See class syllabus at:
http://lunar.colorado.edu/~jaburns/astr2020/

- Read: Cosmic Perspective textbook Section 4.2.
- E-mail me for an office hours Zoom call.
- Complete Daily Health Form



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Why Do You Think We Explore Space Today? Class Responses

- A unifying goal for humanity.
- Using the Moon as a stepping stone to Mars & beyond.
- Pursuit of knowledge & understanding the unknown.
- The ultimate human challenge.
- Dealing with overpopulation on Earth.
- Spur technological innovation.
- Promote international cooperation.
- It is human nature to explore.
- Reduce the chance for human extinction & ensure survival of humanity.
- Mine natural resources on the Moon, asteroids, etc.
- Helps us to better understand the Earth, the environment, & surroundings for human survival.

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Our goals for learning today

- How do we describe motion?

- How is mass different from weight?

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How do we describe motion?

Precise definitions to describe motion:

- **Speed:** Rate at which object moves

$$\text{speed} = \frac{\text{distance}}{\text{time}} \quad \left(\text{units of } \frac{\text{m}}{\text{s}}\right)$$

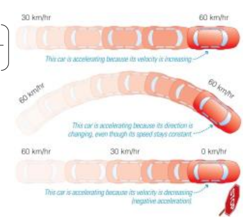
$$v = \frac{\Delta d}{\Delta t}$$

Example: 10 m/s

- **Velocity:** Speed and direction
  Example: 10 m/s, due east

- **Acceleration:** Any change in velocity
  units of speed/time (m/s^2)

$$a = \frac{\Delta V}{\Delta t} \text{ and } d = \frac{1}{2}at^2$$



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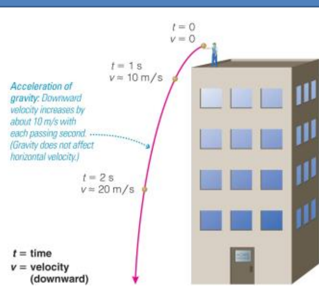
The Acceleration of Gravity

- All falling objects accelerate at the same rate (not counting friction of air resistance).
- On Earth, $g \approx 10$ m/s^2: speed increases 10 m/s with each second of falling.



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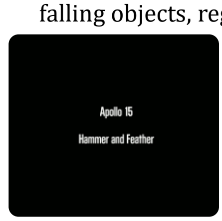
The Acceleration of Gravity (g)

- Galileo showed that *g* is the *same* for all falling objects, regardless of their mass.



Apollo 15 demonstration

Vacuum chamber demonstration
NASA Glenn Research Center

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Momentum and Force

- Momentum (p) = mass (m) × velocity (v) or p = mv.
- A **net force** (F) changes momentum (p) such that $F = \frac{\Delta p}{\Delta t}$.
- If m is constant, what is F?

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If m is constant, what is F?

$$F = \frac{\Delta p}{\Delta t} = \frac{\Delta (mv)}{\Delta t} = m\frac{\Delta (v)}{\Delta t} = ma$$

or

$$F = ma$$

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Class Exercise

For each of the following is there a net force on the object? Y/N

1. A car coming to a stop
2. A bus speeding up
3. An elevator moving up at constant speed
4. A bicycle going around a curve
5. A moon orbiting Jupiter

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Class Exercise

For each of the following is there a net force on the object? Y/N

1. A car coming to a stop: Y
2. A bus speeding up: Y
3. An elevator moving at constant speed: N
4. A bicycle going around a curve: Y
5. A moon orbiting Jupiter: Y

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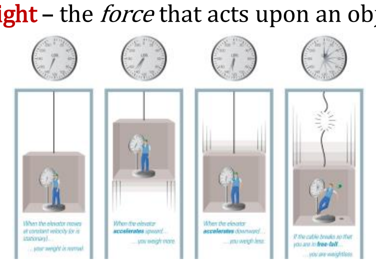
How is mass different from weight?

- **Mass** – the amount of matter in an object
- **Weight** – the *force* that acts upon an object



You are weightless in free-fall!

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Class Exercise

On the Moon:

A. My weight is the same, my mass is less.
B. My weight is less, my mass is the same.
C. My weight is more, my mass is the same.
D. My weight is more, my mass is less.

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Class Exercise

On the Moon:

A. My weight is the same, my mass is less.
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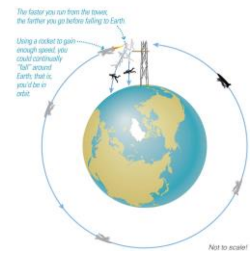
Why are astronauts weightless in space?

- There *is* gravity in space.
- Weightlessness is due to a constant state of free-fall.



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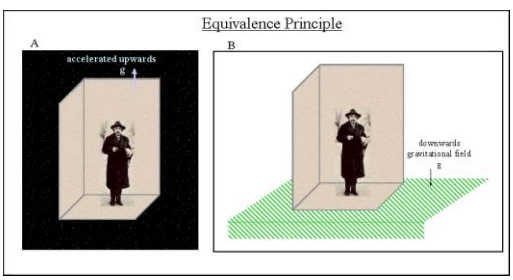
The Equivalence Principle in General Relativity



An observer cannot distinguish between the effects of gravity and acceleration with a = g.

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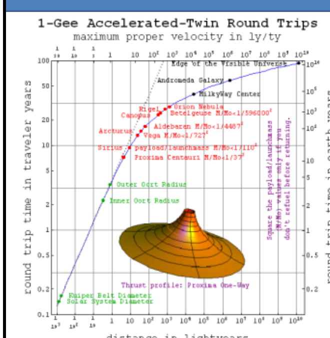
Space travel using constant (1-g) acceleration



- Continuous 1-g acceleration creates artificial gravity.
- Velocity approaches speed of light near 1 lightyear.
- Problem: cannot carry enough fuel for continuous engine burn.

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What have we learned?

- **How do we describe motion?**
  - Speed = distance/time
  - Speed and direction => **velocity**
  - Change in velocity => **acceleration**
  - **Momentum** = mass x velocity
  - **Force** causes change in momentum, producing acceleration.
- **How is mass different from weight?**
  - Mass = quantity of matter
  - Weight = force acting on mass
  - Objects are weightless in free-fall.
- **Can 1-g of constant acceleration enable interstellar travel?**

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