

## Astronomy 150: Killer Skies



This Class (Lecture 7):  
The Atmosphere and Meteors

Next Class:  
Dino Killer

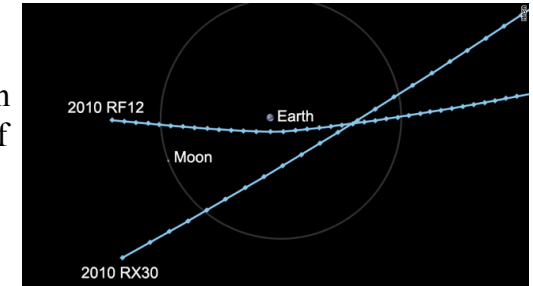
**HW1 & 2 due tonight.**  
**HW3 due Monday night.**

Music: *Shooting Star*– Bob Dylan

## Almost Killer Asteroids



- Detected Sunday!
- Will pass between Earth and Moon today!
- 2010 RX30 (32 to 65 feet), passed within 154,000 miles of Earth at 4:51 a.m.
- 2010 RF12 (20 to 46 feet), will pass within 49,088 miles of Earth at 4:12 pm.



## You need to Register You Clicker



- Go to **link on syllabus** to register your clicker by **September 13<sup>th</sup>**.
  - Register with first part of your illinois email (NetID)
- Grade points **lost** if not registered by that date.
- Your responsibility that participation grades are being recorded properly. I will update as much as I can this week.

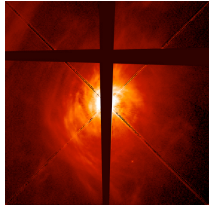


## Outline

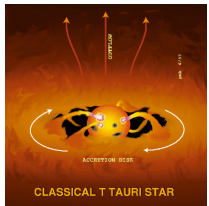


- Meteorites and the Earth
- Why do they hurt?
- Why do they slow down?

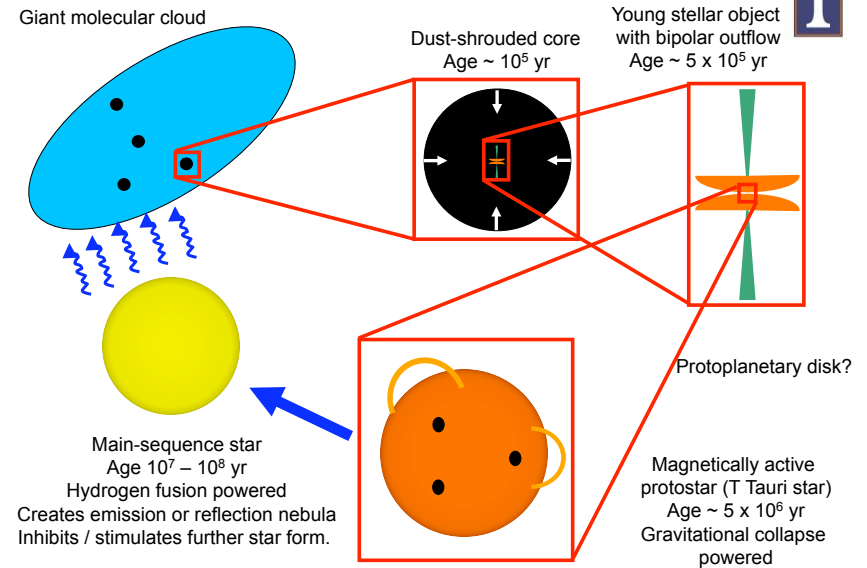
## On to the Main Sequence: A Star is Born!



- For 1 solar mass star, process takes about 10 million years
- Density increase, temperature increases until fusion can occur.
  - Blows away most of its natal circumstellar material.
  - Becomes a hydrogen burning star
  - <http://www.youtube.com/watch?v=jhYEQgLW5NM>
  - <http://www.youtube.com/watch?v=mZL7VBmeFxY&feature=related>  
1:33



## Star Formation - Summary



## Question



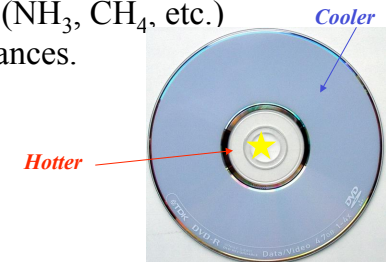
Where did killer rocks from space come from?

- Objects in the deepness of space interact with Earth's gravity field.
- Little bits and pieces left over from the formation of the Solar System.
- Rocks that break off of planets and go rogue in the Solar System.
- The Sun is constantly creating dust that can grow inside the asteroid belt.

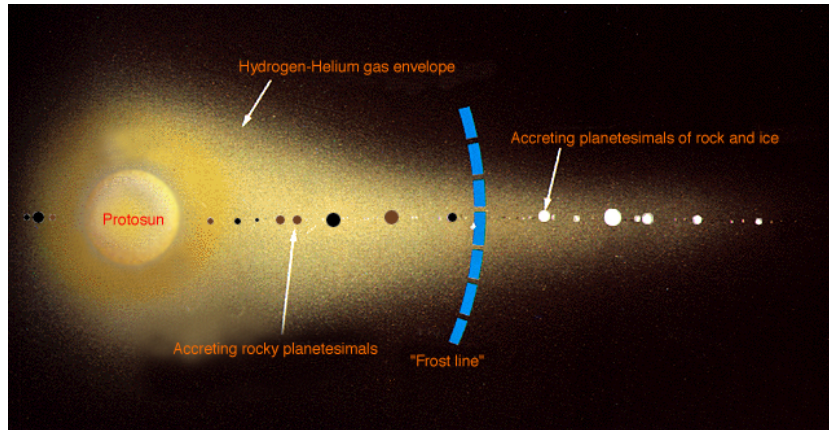
## Everyone Loves Disks



- As the star forms, the inner region of the disk gets much hotter than the outer regions, creating a temperature gradient.
- The inner part of the disk had a higher density than the outer regions.
- Icy mantles of dust grains ( $\text{NH}_3$ ,  $\text{CH}_4$ , etc.) evaporated at varying distances.



## Why are the Planets so Different?



Temperature is the key factor!

## Why are the Planets so Different?

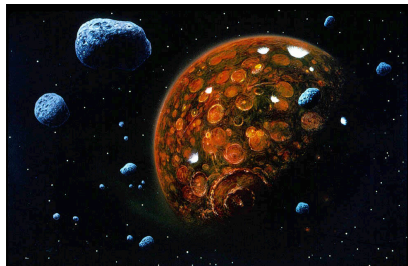


- Temperature is the key factor
- Inner Solar System: Hot
  - Light gasses (H, He) and “ices” vaporized
  - Blown out of the inner solar system by the solar wind
  - Only heavy elements (iron & rock) left
  - Asteroids!
- Outer Solar System: Cold
  - Too cold to evaporate ices to space
  - Rock & ice “seeds” grew large enough to pull gasses (H, He) onto themselves
  - Comets!

## Heavy Bombardment



- There were billions of planetesimals in the early solar system
- Many collided with the young planets
  - Look at the Moon & Mercury!
  - Period of **heavy bombardment**
  - Lasted for about the first 800 million years of the Solar System
  - And speaking of the Moon....



## Formation of the Moon: Smack



- Collision of Earth with a Mars-sized body early in the solar system's history
- Iron-rich core of the impactor sank within Earth
- Earth's rotation sped up
- Remaining ejecta thrown into orbit, coalesced into the Moon

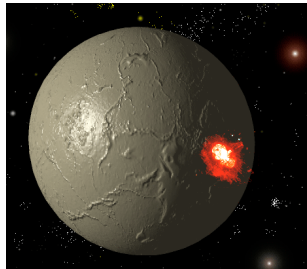


• <http://www.youtube.com/watch?v=ibV4MdN5wo0&feature=related>

## Implications



- **Hot, Hot, Hot!** Even if the moon theory is incorrect, other smaller bodies were playing havoc on the surface.
- When they impact, they release kinetic energy and gravitational potential.
- The planetesimals melt, and the Earth went through a period of differentiation.



<http://www.udel.edu/Biology/Wags/wagart/worldspace/impact.gif>

## Early Earth



- No atmosphere
- No water
- High temp
- No life.....
- Big rocks keep falling on my head...



<http://www.black-cat-studios.com/catalog/earth.html>

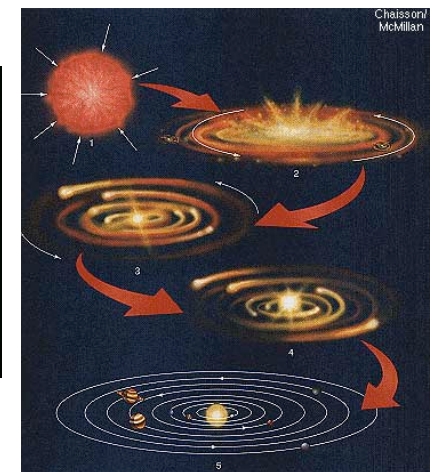
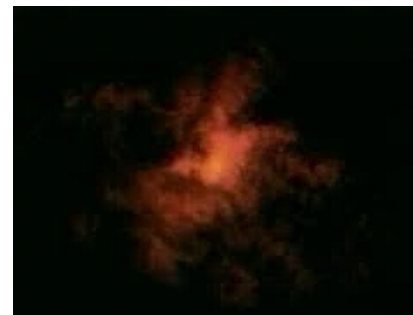
## Fates of the Planetesimals



- Between Mars and Jupiter
  - Remain as the asteroids
- Near Jupiter & Saturn
  - Ejected from the solar system
- Near Uranus & Neptune
  - Ejected to the Oort Cloud
- Beyond Neptune
  - Remain in the Kuiper Belt



## Formation of the Solar System 4.6 billion years ago

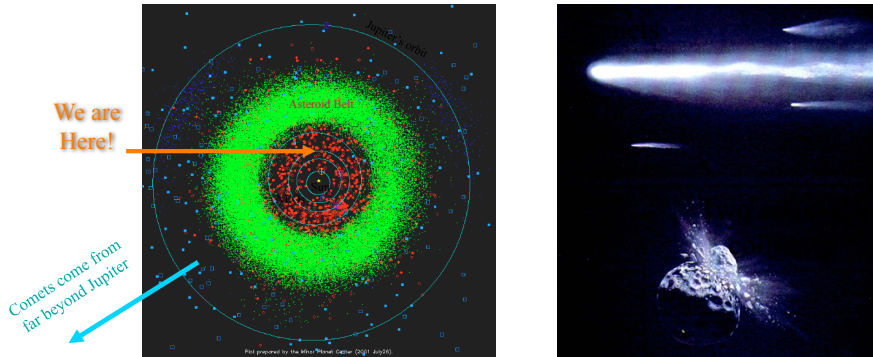




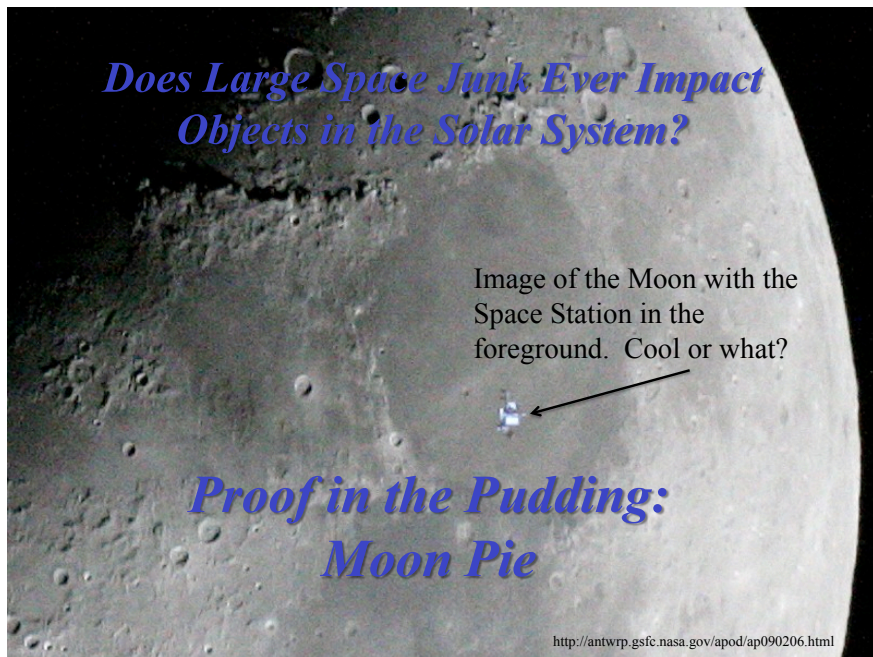
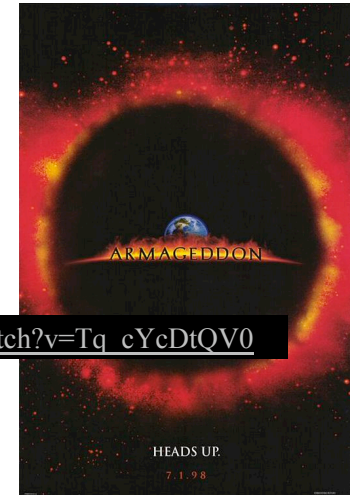
# NEOs: Comets and Asteroids

“NEOs” =  
Near- Earth  
Objects.

The processes that formed the planets 4.6 billion years ago left many small remnants: comets (beyond the outer planets) and asteroids (in a “belt” between the orbits of Mars and Jupiter). Some of them occasionally cross the Earth’s orbit and can strike our planet...if it happens to be there at the same time.

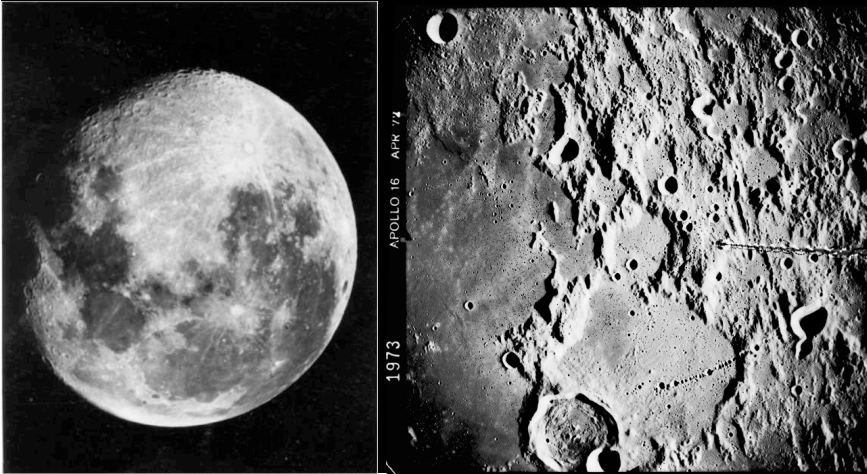


# Is the impact threat a real danger or just media hype?





- Full Moon (telescope view) with lighter highlands and darker basalt plains, filling multi-ringed basins
- Apollo 16 view of Descartes Highlands, with impact craters on all scales



## Group Discussion



The Moon clearly has had some LARGE impacts over its lifespan of ~4.5 billion years. Why didn't the Earth? I didn't fall into a crater on the way over here today.

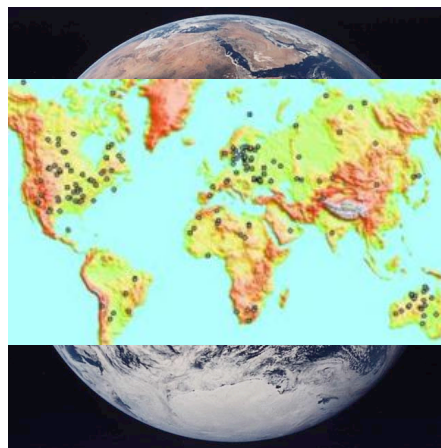
- a) When your group has a good answer click A on your Iclicker.



## Meteorites and the Earth



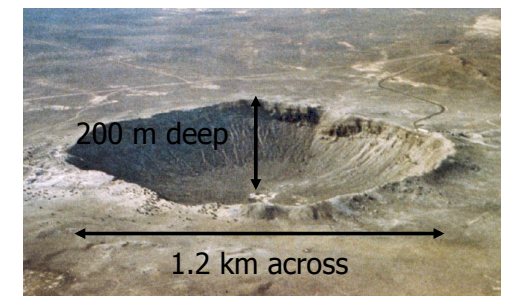
- Many bodies in the solar system show massive amounts of cratering
- Earth is relatively crater free
- But we do know of many impact sites (~200)



## Meteor Crater



- Near Winslow, Arizona
- Only realized to be a meteor crater by Shoemaker in the 1950's.
- Occurred 50,000 years ago
- A 50 meter meteoroid struck the ground at 40,000 km/hr
- The energy of a 20 megaton hydrogen bomb!



## Why Does it Hurt So?



- But how can they impart so much energy?
- Space Junk is moving at high speeds.



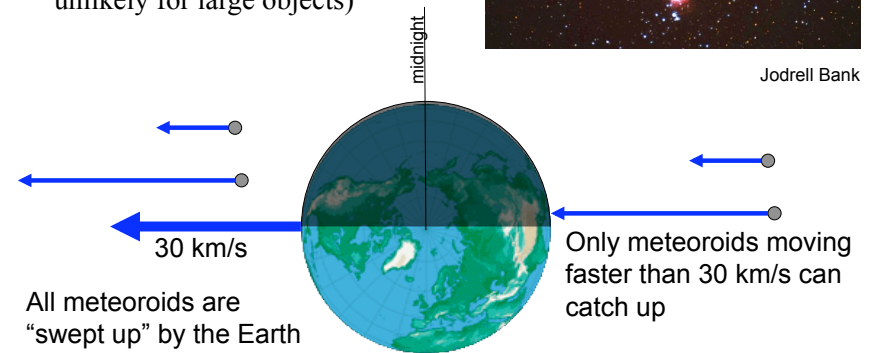
## Meteors



- The Earth's orbital velocity is 30 km/s (67,000 mph)
- Typical meteorite speed as it hits the atmosphere (50 km up) is around 11-70 km/s (high velocity unlikely for large objects)



Jodrell Bank



## Nature of Gravity



- Gravity is a force, producing acceleration
- On the surface of the Earth, the acceleration due to gravity is 9.8 meters per second per second
- Drop two balls (one heavy, one light) off the leaning tower of Pisa:



Time (seconds)	Velocity (m/s)	Accel. (m/s <sup>2</sup> )
0	0	9.8
1	9.8	9.8
2	19.6	9.8
3	29.4	9.8

They both fall at the same rate!

## Nature of Gravity



- Even a non-moving meteor should speed up to 11 km/s.
- From Earth's gravity....



Time (seconds)	Velocity (m/s)	Accel. (m/s <sup>2</sup> )
0	0	9.8
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3	29.4	9.8

## Question



A hammer and a feather are dropped on the Moon, which one hits the ground first?

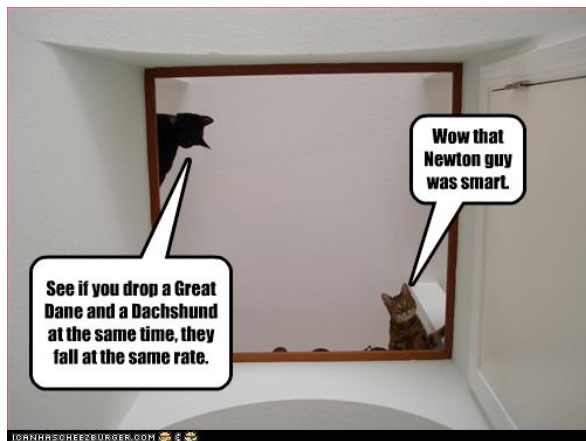
- a) Hammer
- b) Feather
- c) Hit at the same time
- d) The feather floats up and never hits the ground. At least during our lifetime.

## A Feather and a Hammer



[http://www.hq.nasa.gov/office/pao/History/alsj/a15/a15v\\_1672206.mpg](http://www.hq.nasa.gov/office/pao/History/alsj/a15/a15v_1672206.mpg)

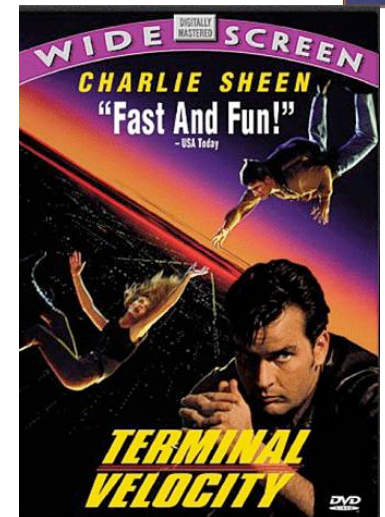
## Other Fun Experiments



## Terminal Velocity



- But... if we are not in a vacuum, the air causes resistance.
- A given object falling in the atmosphere will have gravity pulling downward, and air resistance pushing upward.
- When the two cancel, the object reaches its maximum velocity, or its terminal velocity.

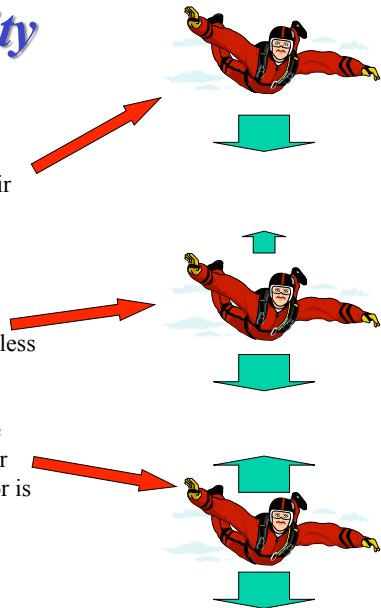




# Terminal Velocity

Consider a skydiver:

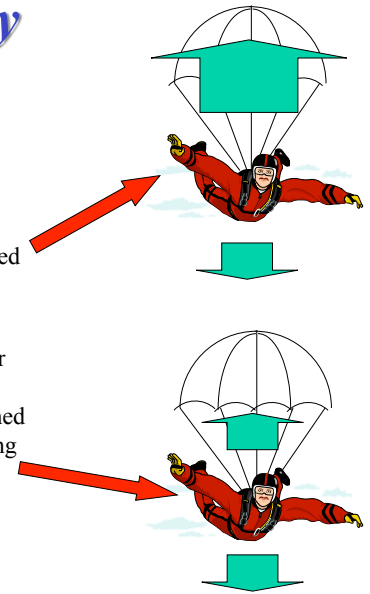
- 1) At the start of the jump, there is no air resistance, so object accelerates downwards, speed increasing.
- 2) As the speed increases, air resistance increases. Object still accelerates, but less than before, speed still increasing.
- 3) Eventually the air resistance equals the pull of gravity, and the object no longer accelerates. The speed is maxed out, or is at the Terminal Velocity-- depends on shape of object.



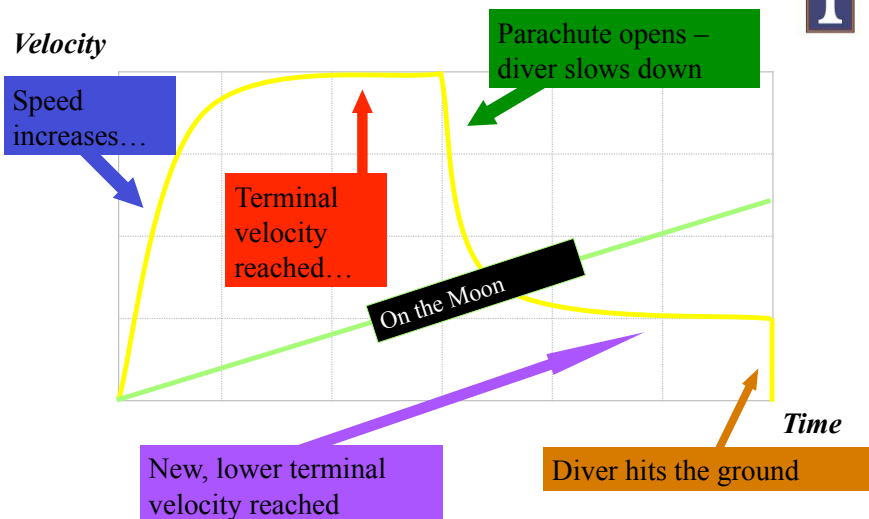
# Terminal Velocity

Still considering a skydiver:

- 4) When opening the parachute, shape changes, and there is a lot more air resistance suddenly, so decelerate, speed decreases.
- 5) Because object is slowing down the air resistance decreases until it balances gravity. Then, skydiver has now reached a new, lower terminal velocity, allowing them to land safely.

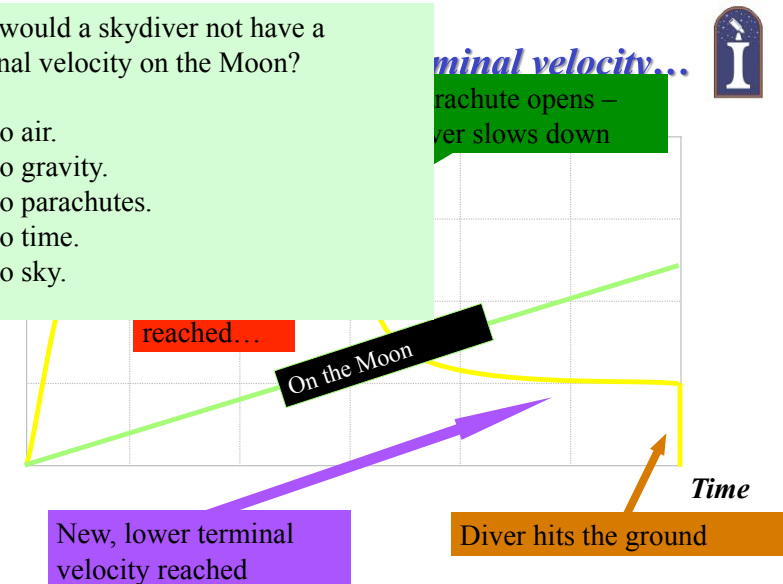


## Velocity-time graph for terminal velocity...



Why would a skydiver not have a terminal velocity on the Moon?

- A. No air.
- B. No gravity.
- C. No parachutes.
- D. No time.
- E. No sky.



## *Question*



A hammer and a feather are dropped in the lecture hall, which one hits the ground first?

- a) Hammer
- b) Feather
- c) Hit at the same time
- d) The feather floats up and never hits the ground.  
At least during our lifetime.