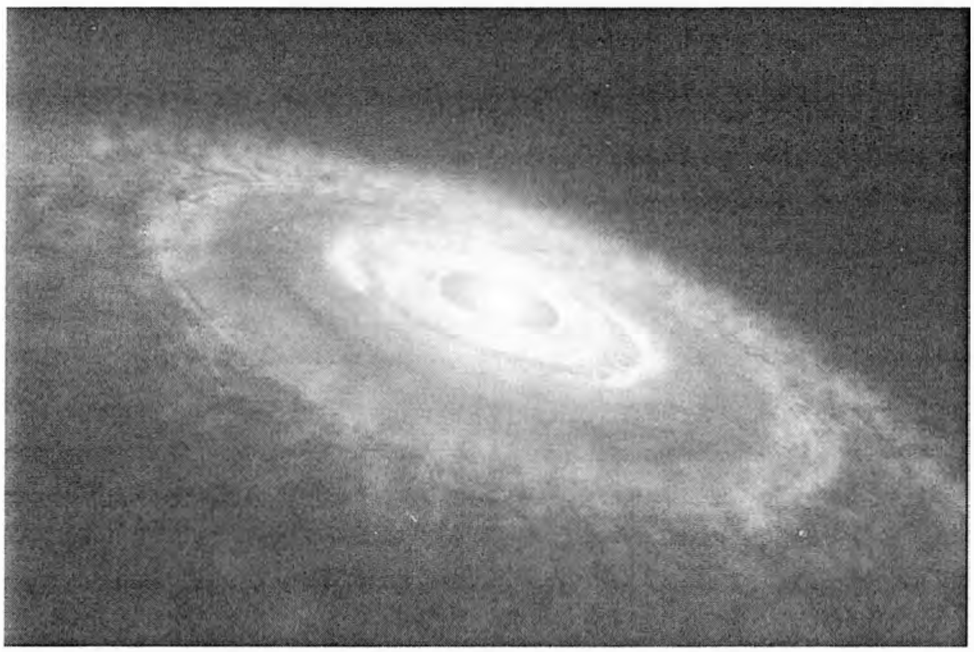
Formation of Planets



[M1U4]

Formation of the Earth - Conservation of Momentum

Linear Momentum

Activity 1: Can you "feel" momentum?

- Get in group of 3: facilitator, recorder, reporter.
- Recorder: get a piece of paper, a golf ball, and a baseball.
- Reporter: Measure the mass of a golf ball, a ball of paper (crumple up 1 sheet of paper into a ball), and a baseball. Recorder record the mass.
- Everyone takes turn to drop each ball from 2 m above the ground
- Everyone: take turn to catch each of the ball just before it hit the ground.

Reflection: (facilitator lead this reflection using CM math & science discussion cards)

- Reporter: list the balls in a data table from lightest to heaviest.
- Group: Each person in the group need to use 3 out of the 5 cards in the discussion.
  i) Explain and describe how it feel to catch the ball.
  ii) List 2 things that you all have in common?
  iii) Report out.

Formation of the Earth - Conservation of Momentum

Linear Momentum

Activity 2: How much momentum did you feel?
In the same group of 3.

- Recorder : get an electronic balance.
- Facilitator: facilitate the design and building of a "catcher" that represents your hand. This catcher will be placed on top of the electronic balance. The purpose of this catcher is to "catch" the ball in such a way that the ball will not bounce when it hit the catcher.
- Reporter: measure the mass of your catcher.
- Recorder: record the mass of the catcher, and draw the picture of your catcher (with dimension)
- Facilitator: discuss in your group why did you choose such design and choice of materials?
- Drop each ball on the catcher. Video tape the readings on the scale. Record the reading when the ball hit the catcher.

Reflection:

a. Recorder: record the scale reading when the ball hit the catcher
b. Group: Write a conclusion about momentum

Formation of the Earth - Conservation of Momentum

Linear Momentum

Calculation of momentum

1. **Linear Momentum:** mass in linear motion:
   - $p = mv$
     - m : linear mass
     - v : linear speed = how fast an object move in a straight line
2. Example 1: What is the momentum of a 70 kg person running at 2 m/s?
     - $p = mv = 70\ kg \times 2\ m/s = 140\ kg.m/s$

3. Example 2: A 3.1 g penny was dropped from 3 m. What is its momentum just before it hit the floor?
     - Given: m = 3.1 g   h = 3 m

     - Asking: momentum p = ?

     - Formula and concepts:
       1. **p = mv** (m was given, we need to find v just before the penny hits the floor)
       2. 2 ways to find v:
          a. By free fall:
             i. Time of free fall:
                1. $d = ½ gt^2$ ---> $t^2 = 6/g = 6/(9.8 m/s^2)$
                2. t = 0.782 s
             ii. Speed: $v = gt = (9.8\ m/s^2)(0.782\ s)$
                 a. = 7.67 m/s
          b. By conservation of energy:
             i. GPE at the top = KE at the bottom
             ii. $mgh = ½ mv^2$ --------> $v^2 = 2gh$
             iii. $v^2 = 2(9.8\ m/s^2)(3\ m) = 58.8\ m^2/s^2$
             iv. v = 7.67 m/s

     - Solve: p = mv = (3.1 g)(7.67 m/s) = **23.8 g.m/s**

4. Practice
     - Find the momentum of each ball in your experiment.

Formation of the Earth - Conservation of Momentum

Angular Momentum

1) **Activity 1:** Designing "Excalibur"?
    a) Get in your group.
    b) You will need a meter stick, tapes, and 500-g mass in designing your "Excalibur"
    c) Hold the meter stick at the zero cm end, and tape the 500-g mass at various positions on the meter stick.
    d) At each of the position (500-g mass), rotate the meter stick in a circular motion, keeping your hand (the one holding the meter stick) at the center of the circular motion.
    e) Record how it feel to rotate the meter stick with the mass at different locations.

2) **Reflection:**
    a) Discuss in your group the best location to put the mass so that your "Excalibur" would be maneuverable.
    b) Write and submit a summary of your finding, explain why your group choose that location for the mass on the meter stick.

3) **Angular Momentum:** mass in spinning motion:
    - L = I x $\boldsymbol{\omega}$
        - I : Rotational Inertia = angular mass (mass distribution): the farther the mass is from the center of rotation, the more rotational inertia you get. (resistant to the spin).
        - $\boldsymbol{\omega}$: Rotational speed = how fast an object spin

- Conservation of Momentum: Regardless of what kind of momentum it is, the momentum in a system is always conserved. In other words:
    - In a linear system: **(optional)**
        - $M_v = m_V$
        - Large mass, small speed = small mass, large speed.
        - Example 1:
            - A cargo ship fully loaded is being chased by a pirate ship. In order to escape the pirate ship, the cargo ship can dump its cargo, hence increase speed.
        - Example 2:
            - think-pair-share: share with your partner an example of conservation of linear momentum.
    - In a rotational system: (**mandatory)**

- I x ω = I x ω
- Small rotational inertia, large rotational speed = large rotational inertia, small rotational speed.
- Demo: Spinning chair with arms extended and pull arms in.
- Think-pair-share: share with your partners an example of conservation of angular momentum.

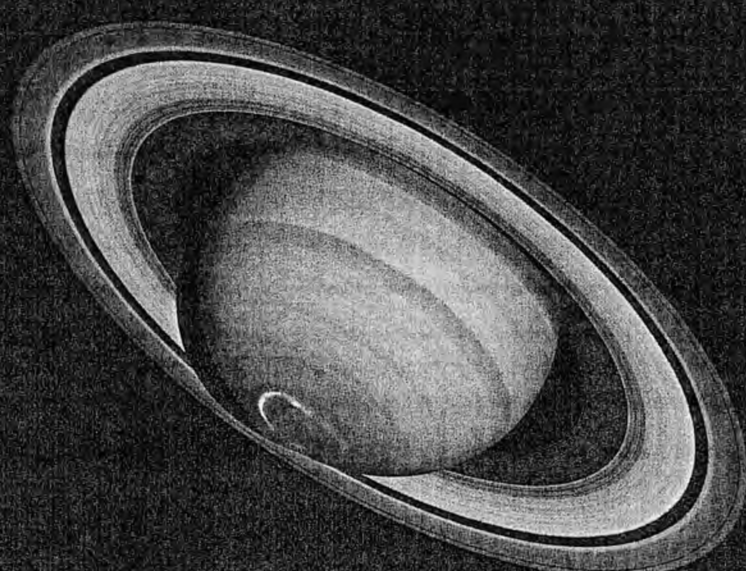
4) Ticket out the door: In a sheet of paper, write:

- 3 things you learned in this lesson
- 2 questions you have about this lesson
- 1 positive thing about the lesson (what you remember the most)

Today's Goal

- Derive the velocity and period of a satellite in a circular orbit

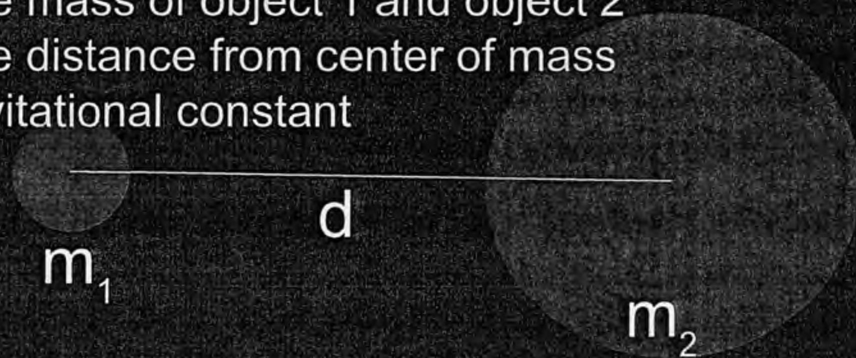
Newton's Universal Law of Gravity



Newton's Universal Law of Gravity

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

F: The force of gravity between m_1 and m_2
m: The mass of object 1 and object 2
d: The distance from center of mass
G: gravitational constant



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

Determine Force of gravity between…

The Earth and you. ~600 N
You and a friend 1 meter apart. $\sim 4 \times 10^{-7}$ N

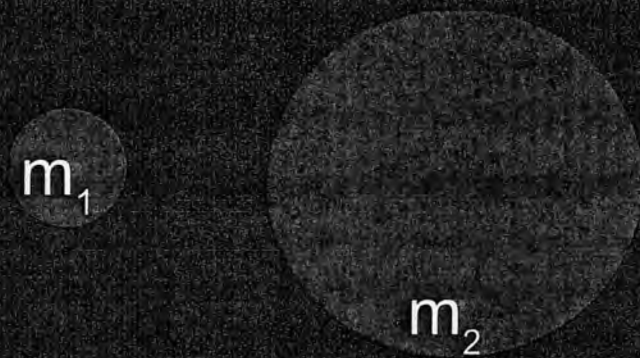
Mass of the Earth…………….5.98×10^{24} kg

Radius of the Earth………….6.37×10^{6} m

Orbital Velocity and Period

These derivations require that

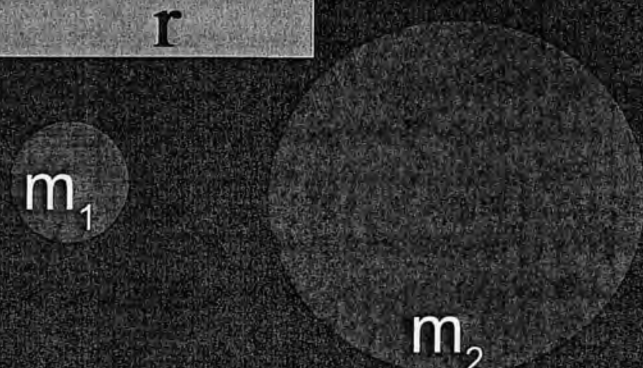
1. The satellite has much less mass than the body
2. The orbit is circular



Average Orbital Velocity

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

$$F_c = \frac{m_1 v^2}{r}$$



Average Orbital Velocity

$$F_c = F$$

$$\frac{m_1 v^2}{r} = G\frac{m_1 m_2}{r^2}$$

$$\frac{v^2}{r} = G\frac{m_2}{r^2}$$

$$v^2 = G\frac{m_2}{r}$$

$$v = \sqrt{G\frac{m_2}{r}}$$

m_2

Average Orbital Velocity

$$v = \sqrt{G\frac{m_2}{r}}$$

$$v = \frac{\text{dis tan ce}}{\text{time}}$$

$$v = \frac{2\pi r}{T}$$

$$\frac{2\pi r}{T} = \sqrt{G\frac{m_2}{r}}$$

$$\frac{T}{2\pi r} = \sqrt{\frac{r}{Gm}}$$

$$T = 2\pi r\sqrt{\frac{r}{Gm}}$$

m

Average Orbital Velocity

$$T = 2\pi r\sqrt{\frac{r}{Gm}}$$

$$T = 2\pi\sqrt{\frac{r^2 r}{Gm}}$$

$$T = 2\pi\sqrt{\frac{r^3}{Gm}}$$

m_2

Summary

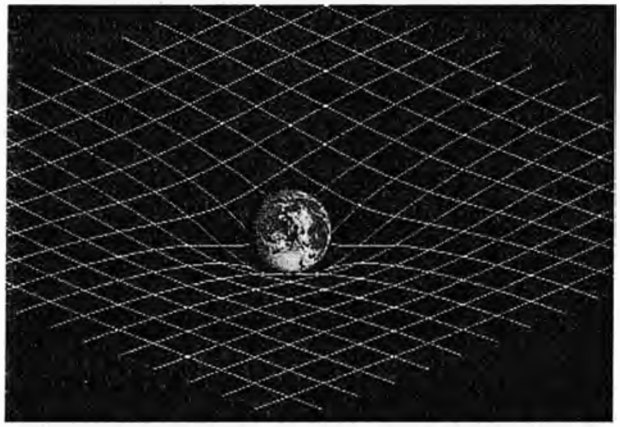
$$v = \sqrt{G\frac{m_2}{r}}$$

$$T = 2\pi\sqrt{\frac{r^3}{Gm}}$$

These equations are valid only when

1. The satellite has much less mass than the body
2. The orbit is circular

Module 1, Unit 4: Formation of the Earth
Lesson 2: Universal Gravitation

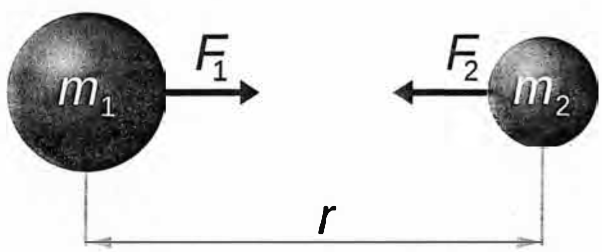


HS-PS2-4: Use mathematical representation of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

Goals: In this unit, students will be able to describe and explain the attractive forces between bodies of mass in their discussion and calculations.

Part A: Direct Instruction

1) **Newton's Law of Universal Gravitation:**
   All bodies with mass attract all other bodies with mass.



$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

m_1 = mass of body 1
m_2 = mass of body 2

F_1 = force of body 1
F_2 = force of body 2

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r = distance between the two bodies G = Universal Gravitational Constant.

2) Math work:

a) **Example 1:** (I do) A 75 kg man stands 2-m away from a 45-kg woman. What is the attraction force between them?

|<---- 2 m ----->|

Solution:

- Given: m_1 = 75-kg
  m_2 = 45-kg
  d = 2-m
  $G = 6.67 \times 10^{-11}\ m^3kg^{-1}s^{-2}$

- Formula: $F = G(m_1m_2)/d^2$
  $= 6.67 \times 10^{-11}\ m^3kg^{-1}s^{-2}\ (75\text{-kg})(45\text{-kg})/(2\text{-m})^2$
  $= 2.25 \times 10^{-7}\ m^3kgs^{-2}/4\ m^2$
  $= 5.63 \times 10^{-8}$ N

b) **Example 2:** (we do) What is the attraction force between the Earth and a 70-kg person standing on Earth? (Students look up the mass and the radius of the Earth)

Solution:

- Given: m_1 = 70-kg
  m_2 = mass of the Earth = $M_E = 6 \times 10^{24}$ kg
  d = radius of the Earth = $R_E = 6.37 \times 10^6$ m

- Formula: $F = G(m_1M_E)/d^2$
  $= 6.67 \times 10^{-11}\ m^3kg^{-1}s^{-2}\ (70\ kg)(6 \times 10^{24}\ kg)/(6.37 \times 10^6\ m)^2$
  $= 3 \times 10^{16}\ m^3kgs^{-2}/\ 40.6 \times 10^{12}\ m^2$
  = 738.9 N

****Extension:**** Since the mass of a person is so insignificant compare to the mass of the Earth, it can be ignore. The Universal Gravitation Equation for Earth would be:

$F = GM_E/R_E$
$= (6.67 \times 10^{-11}\ m^3kg^{-1}s^{-2})(6 \times 10^{24}\ kg)/(6.37 \times 10^6\ m)^2$
= 9.8 N

Note: This is the acceleration due to gravity of the Earth: 9.8 m/s^2

c) **Example 3:** (you do)

i) What is the gravity on the moon?
ii) What is the gravity on Mars?
iii) What is the gravity on Saturn?

iv) What is the attraction force between the sun and the Earth?

Part B: Activities

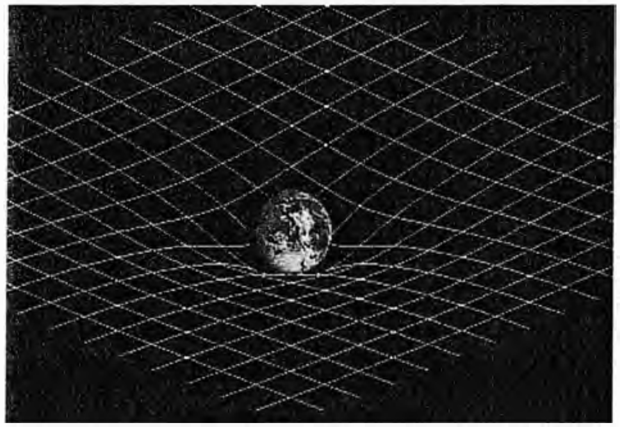
1) **Phet time:**
   a) Universal Gravitation Simulation.
   b) What happened to the forces when you:
      i) double mass 1?
      ii) double mass 2?
      iii) double both masses?
      iv) double the distance?
      v) triple the distance?

   c) Summary: what are the effect of masses and distance on gravitational force?

2) **Can you say "inverse square"?**
   Design an experiment using photocells, ammeter and a light source to show that light has the same "inverse square" property as gravity. Submit your procedure, data table, any calculations, and conclusion.

3) **Ticket out the door:** In a sheet of paper, write:
   - 3 things you learned in this lesson
   - 2 questions you have about this lesson
   - 1 positive thing about the lesson (what you remember the most)

Module 1, Unit 4: Formation of the Earth
Consensus Lesson: Coulomb's Law



HS-PS2-4: Use mathematical representation of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

Goals: In this unit, students will be able to describe and explain the attractive forces between charges. *[What happens to the force as the distance changes?]*

Part A: Direct Instruction

1) **Coulomb's Law:**
   All charged particles attract or repel all other charged particles.

$$F = \frac{kq_1q_2}{r^2}$$

q_1 = charge of body 1
q_2 = charge of body 2
r = distance between the two charges

F = force between 2 charges.
k = Coulomb Constant.

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2) **Compare and Contrast:**

Coulomb's Law looks VERY similar to Newton's Universal Law of Gravitation

$$F = G\frac{m_1 m_2}{d^2} \qquad F = k\frac{q_1 q_2}{d^2}$$

Differences:

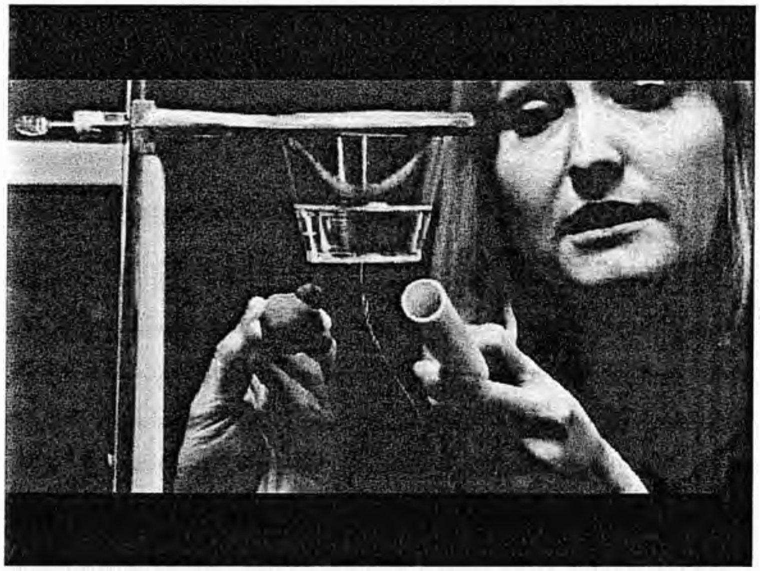
1. **Gravitational Force is based on MASS.**
   Coulomb's law is based on CHARGE.
2. **Gravity is ALWAYS an attractive force.**
   The Electric Force can attract and repel.
3. **"G" is a tiny number, therefore gravity force is a relatively small force.**
   "k" is a huge number, therefore electric force is a relatively large force.

Similarity: Both have the same inverse square relationship.

Part B: Inverse Square Activity

1) Materials:
   a) Ring stand and ring
   b) Plastic cup
   c) ¾ x 6 PVC pipe
   d) Water
   e) Protractor and ruler.
2) Procedure:

- Drill a hole in the bottom of the plastic cup (melt a small hole with a soldering pencil if the drill shatters the plastic)
- Place the cup in the ring on the ring stand (see pic)
- Pour water in the cup
- Rub the PVC pipe on your hair (work better if you have long hair)
- Bring the charged PVC pipe to a distance of 1 cm from the stream of water.
- Measure record the deflection of water: use a protractor
- Increase the distance between the PVC pipe and the stream of water to 2-cm and 3-cm
- Measure and record the deflection each time.



a) Analysis: What happened to the forces when you:
   i) double the distance?
   ii) triple the distance?

What happens to the water stream if you *increase* the distance?

a. Stream of water will bend less
b. Stream of water will show no effect
c. Stream of water will bend more
d. Stream of water will bend in the opposite direction

If you did not rub the object against hair or fabric, then there will be no charge, the result would be ______

a. Increased deflection of the stream
b. No deflection of the stream
c. Slight repulsion of the stream
d. Increased repulsion of the stream

What happens to the force as the distance is *decreased*?

a. Force will not be affected
b. Force will decrease
c. Force will increase
d. Force will be in the opposite direction

b) Summary: what are the effect of distance on electrostatic forces? CER?
[Summary is student work for evaluation, students will put their summaries into Illuminate for scoring]

Claim - I claim that the stream of water will change as I get closer.
Evidence -
Reasoning -
Score using rubric -
Add score to Illuminate for data
Exemplar -

2) **Ticket out the door:** In a sheet of paper, write:
   - 3 things you learned in this lesson
   - 2 questions you have about this lesson
   - 1 positive thing about the lesson (what you remember the most)

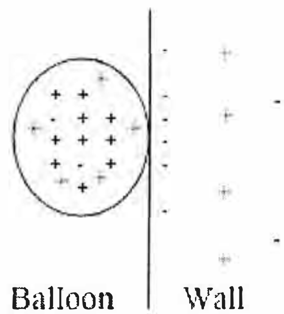
Points Awarded	2	1	0
Claim	Answers the question and is accurate based on data.	Answers the question, but is inaccurate based on data.	No claim, or does not answer the question.
Evidence	Cites data and patterns within the data and uses labels accurately.	Cites data from the data source, but not within the context of the prompt.	No evidence, or cites changes, but does not use data from the data source.
Reasoning	Cites the scientifically accurate reason, using correct vocabulary, and connects this to the claim. Shows accurate understanding of the concept.	Cites a reason, but it is inaccurate or does not support the claim. Reasoning does not use scientific terminology or uses it inaccurately.	No reasoning, or restates the claim but offers no reasoning.

Unit 4 - Formation of the Earth

Formation of Stars and Planets

<u>Part A:</u> The Nebula

1) **Activity 1: Attractive to others?**
    a) Group: 3-4 students each with assigned role.
    b) Materials: magnet, 1 balloon.
    c) Bring the magnet closer to a small stream of water from a faucet. Observe, discuss and record what happened to the stream of water.
    d) Blow up the balloon, rub the balloon against your hair, then touch the balloon to the wall. Let go of your hands. Observe, discuss, and record what happened to the balloon.



Unit 4 - Formation of the Earth

Formation of Stars and Planets

2) **Activity 2: Float or sink?**
   a) Get in group of 3: facilitator, recorder, reporter.
   b) Recorder: get a beaker of bean, a ping pong ball, and a 300 g mass.
   c) Reporter: Measure the mass of the ping pong ball. Recorder record the mass.
   d) Fill the plastic beaker half way with bean, place the 300 g mass and the ping pong ball on top of the bean. Then pour in the rest of the bean. (the mass and the ping pong ball should be completely covered in the bean).
   e) Gently move the beaker of bean back and forth, and observe what happened. Recorder: record the observation.

   f) **Reflection:** (facilitator lead this reflection using CM math & science discussion cards)
      i) Reporter: list the balls in a data table from lightest to heaviest.
      ii) Group: Each person in the group need to use 3 out of the 5 cards in the discussion.
      iii) Explain and describe what happened?
      iv) List 2 things that you all have in common?
      v) Report out.

Unit 4 - Formation of the Earth

Formation of Stars and Planets

3) **Activity 3: To the center.**
   a) In the same group of 3.
   b) Reporter: get a lazy-susan, a ping pong ball, and a 300 g mass..
   c) Recorder : record the mass of the ball.
   d) Facilitator: facilitate the experiment
      i) Make sure that the surface of the lazy-susan is smooth. Put the ping pong ball and the 300 g mass midway between the center and the edge of the lazy-susan.
      ii) Spin the lazy-susan
      iii) Observe and record what happened. (the group can use smartphone to record)
   e) **<u>Reflection:</u>**
      i) Facilitator: discuss in your group what happened, and why?
      ii) Group: conclusion from what you observed. (academic language)

Part B: The Model

1) A Star is Born !!!
   a) A Star is Born (video)
   b) Students do a Three Reads activity on an article from The Big History Project.
   c) Students then construct a timeline of the creation of Earth.
   d) Facilitator: facilitate a model for the formation of a star based on concepts of universal gravitation, conservation of momentum, accretion, and the three reads. (your group can build a 3D model on the computer, or a poster, or a narrative)
   e) What evidence do your group need to look for to give validity to your model?
   f) When finished, put your model up on the wall for a gallery walk

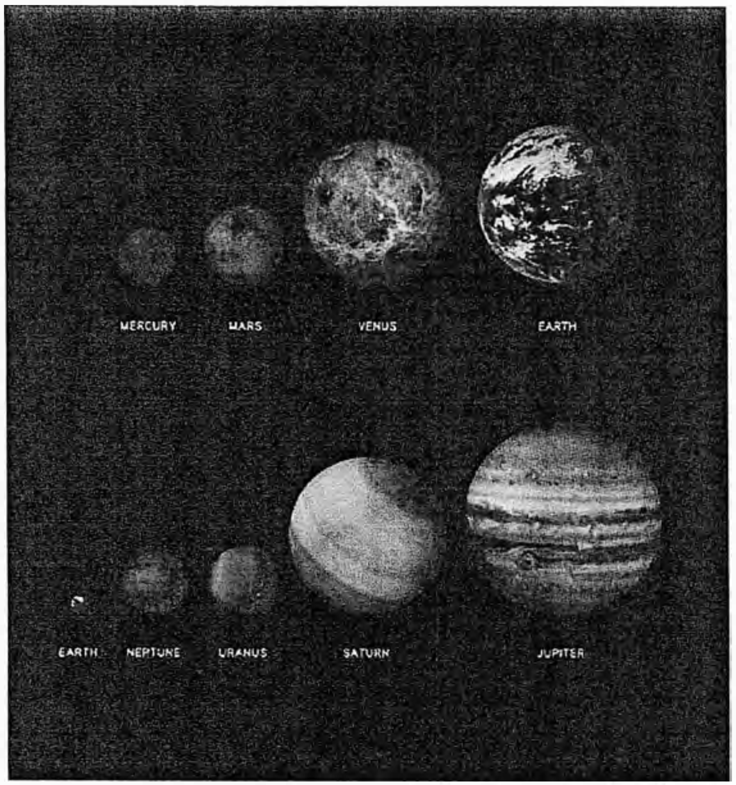
2) Formation of Earth model:
   a) Facilitator: facilitate a model for the formation of the Earth using concepts of universal gravitation, conservation of momentum, the reading, and accretion. (your group can build a 3D model on the computer, or a poster, or a narrative). What do you think ancient Earth look like?
   b) What evidence do your group need to look for to give validity to your model?
   c) When finished, put your model up on the wall for a gallery walk

3) **Gallery walk:**
   - Walk with your group around the room and observe other models.
   - What are 3 things that you have in common with other models?
   - What are 2 things that you have differently from other models?
   - What is 1 thing that you learn from other models?

4) **Ticket out the door:** In a sheet of paper, write:
   - 3 things you learned in this lesson
   - 2 questions you have about this lesson
   - 1 positive thing about the lesson (what you remember the most)

The Solar System that we live in consists of a medium-size star (the Sun) with eight planets orbiting it. The planets are of two different types. The four inner planets, those closest to the Sun, are Mercury, Venus, Earth, and Mars. They are smaller and composed mainly of metals and rocks. The four outer planets — Jupiter, Saturn, Uranus, and Neptune — are larger and composed mostly of gases.

What are planets? Where did they come from? Why would some be rocky and some gaseous? What is our planet like? This essay will try to answer these questions.



Each of the planets in our Solar System is unique. They vary in size and composition.

The birth of the Sun

Let's quickly review how our star came into being. Five billion years ago, a giant cloud floated in one of the spiral arms of the Milky Way galaxy. This cloud, called a nebula by astronomers, was made up of dust and gas, mostly hydrogen and helium, with a small percentage of heavier atoms. These heavier atoms had been formed earlier in the history of the Universe when other stars aged and died.

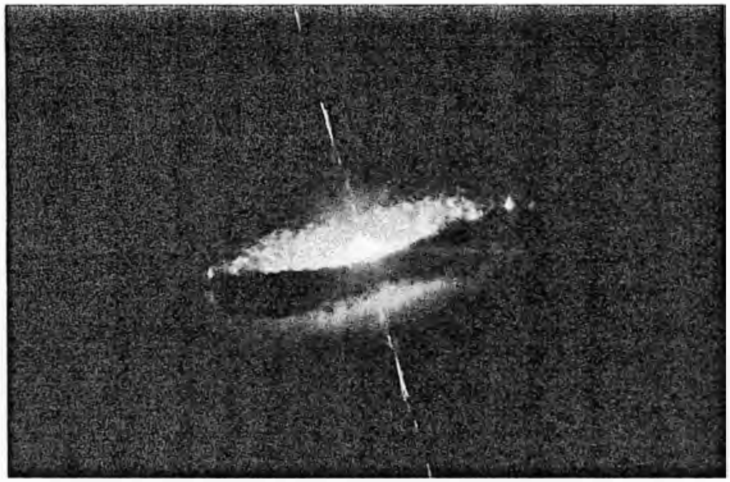
This cloud/nebula began to contract, collapsing in on itself. The atoms, once separated, began to jostle each other, generating heat. In the rising heat, the atoms collided more frequently and more violently. Eventually, they reached a temperature at which the protons at the centers of the atoms began to fuse, in a process called nuclear fusion. As they did, a tiny bit of matter transformed into a whole lot of energy, and a star was born. In this way, our Sun came into being.

The birth of the planets

The material in the nebula not absorbed into the Sun swirled around it into a flat disk of dust and gas, held in orbit by the Sun's gravity. This disk is called an accretion disk. Material in the disk accumulated by further accretion — from sticking together.

Each planet began as microscopic grains of dust in the accretion disk. The atoms and molecules began to stick together, or accrete, into larger particles. By gentle collisions, some grains built up into balls and then into objects a mile in diameter, called planetesimals. These objects were big enough to attract others by gravity rather than by chance.

If the collisions of planetesimals occurred at high speeds, they could shatter the objects. But when impacts were gentle enough, the objects combined and grew. For some 10 to 100 million years these protoplanets orbited the Sun, some in egg-shaped circuits that resulted in more frequent collisions.



This illustration shows the accretion disk of a star that, like our Sun, could go on to form planets from the dust and gas around it.

Worlds collided, combined, and evolved for a dramatic period of time. When it was over, there remained eight stable planets that had swept their orbits clean. A planet is defined as a body that orbits the Sun, is massive enough for its own gravity to make it spherical, and has cleaned its neighborhood of smaller objects.

In 2007, researchers at the University of California–Davis determined that our Solar System was fully formed at 4.568 billion years ago. They did this by determining the age of stony materials from the asteroid belt.

The Sun sent out energy and particles in a steady stream, called stellar winds. These winds proved so strong that they blew off the gases of the four planets closest to the Sun, leaving them smaller, with only their rocks and metals intact. That's why they are called rocky, or terrestrial, planets. The four outer planets were so far from the Sun that its winds could not blow away their ice and gases. They remained gaseous, with only a small rocky core. They were made of more gas (namely hydrogen and helium) than the others to begin with, the Sun's gravity having pulled closer the heavier materials in the original solar disk.

Between the inner and outer planets lies an area filled with millions of asteroids — small rocky, icy, and metallic bodies left over from the formation of the Solar System. No planet formed in this area. Astronomers theorize that Jupiter's gravity influenced this region so much that no large planet could take shape. Jupiter is 11 times the size (in diameter) of Earth and more than twice as big as all the other planets combined. It is almost large enough to have become a star.

Of the four rocky planets, Mercury is the smallest, about two-fifths the size of Earth. Earth and Venus are almost the same size, while Mars is about half their size. Astronomers speculate that a smaller object must have hit Mercury, vaporizing its crust and leaving only the larger-than-usual iron core.

Conditions on Earth

When the rocky planets first formed, they were largely melted (molten) rock. Over hundreds of millions of years, they slowly cooled. Eventually Mercury and Mars, because they are small, solidified and became rigid all the way to their centers.

Only on Earth, and possibly on Venus, have conditions remained in an in-between state. Earth has stayed partially molten. Its crust is solid rock, and its mantle is rigid in short-term time. But over geologic time the mantle flows slowly. And the center of Earth consists of a solid iron core rotating in hot liquid called magma.

Some scientists and Big Historians use the term "Goldilocks Conditions" to describe conditions on Earth. This comes from an Anglo-Saxon children's story, "Goldilocks and the Three Bears." In the story, a young girl named Goldilocks wanders into the home of three bears, who are away. She tries out their porridge, their chairs, and their beds, finding some too hot or too cold, too hard or too soft, too large or too small, but one of each just right. Likewise, Earth is not too hot or too cold, not too big or too little, not too near the Sun or too far away, but just right for life to flourish.

Earth's Moon

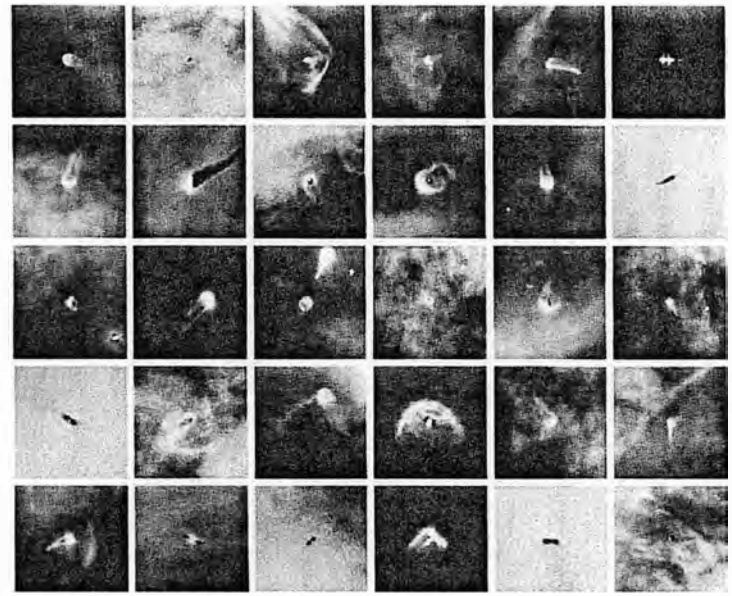
The rocky object nearest to us is the Moon. Where did it come from? Good question. The Moon orbits Earth, not the Sun, so it is not a planet. The Moon is about one-fourth the size of Earth. The origin of the Moon remains mysterious, but since astronauts walked on the Moon in 1969 and brought back rock and soil samples, we know more about it now than before.

The standard argument today holds that a small contending planet, about one-tenth the size of Earth, must have collided with Earth about 4.45 billion years ago. Earth was still red-hot beneath a possible thin new crust. Some of the material from the impact was absorbed into the liquefied Earth but some material ricocheted into space, where it settled into orbit and condensed as the Moon. At first the Moon orbited much closer to Earth. It is still moving away at a rate of almost two inches (four centimeters) per year.

The Moon significantly affects conditions on Earth. The impact that produced the Moon tilted Earth on its axis. This causes Earth's seasonal variations in temperature, since the side tilted toward the Sun for one-half the year's journey around the Sun receives more direct sunlight. Also, the Moon's gravity causes the oceans' tides, reduces the Earth's wobble (which helps stabilize climate), and slows the spin of the Earth. The Earth used to complete a rotation on its axis in 12 hours, but now it takes 24.

Pluto and beyond

Before 2006, students learned that our Solar System had nine planets, not eight. The one counted as the ninth, Pluto, orbits out beyond Neptune. However, in 2006, the International Astronomical Union declared that Pluto does not count as a planet. It is smaller than Earth's Moon. It orbits way out in a belt of asteroids beyond Neptune, and does not have enough gravity to clear the neighborhood around its path. Therefore, it was downgraded to a "dwarf planet," or a planetesimal.



Dust-and-gas clouds surround nascent stars in the Orion Nebula.

Astronomers feel confident that our Solar System formed by accretion because now they are able to glimpse a similar process occurring in part of the Orion Nebula. This planet-forming area is on the near side of a giant cloud complex that embraces much of the constellation Orion, 1,500 light-years from Earth. Since 1993, astronomers have discovered several hundred stars there in the process of formation, most of them surrounded by rings of dust in accretion disks, just like the one they believe produced the solar planets. These clouds of dust and gas around new stars in the Orion Nebula may develop into planetary systems similar to our own.

In 1995, astronomers in Switzerland found, for the first time, a planet beyond our Solar System orbiting an ordinary star. Such a planet is called an extrasolar planet, or an exoplanet. As of June 2012, more than 700 exoplanets had been discovered and confirmed. Most of them are giants, closer in size to Jupiter, as larger planets have proved easier to detect hundreds of light-years away. Most are detected not by direct imaging, but indirectly by measuring the effect of their gravity on their parent star or by observing how the light of the parent star dims as the planet passes in front of it.

In 2009, the National Aeronautics and Space Administration (NASA) sent a telescope into orbit around the Sun to hunt for habitable exoplanets in the region near the constellations Cygnus and Lyra. This telescope (actually a photometer), the centerpiece of what's known as the Kepler mission, will monitor 100,000 stars a few hundred to a few thousand light-years away. (One light-year equals 6 trillion miles.) The mission will last three and a half to six years; in the first two years, it has found 17 planets with conditions thought to allow for the development of life.

In summary, planets are bodies orbiting a star. Planets form from particles in a disk of gas and dust, colliding and sticking together as they orbit the star. The planets nearest to the star tend to be rockier because the star's wind blows away their gases and because they are made of heavier materials attracted by the star's gravity. In the Sun's system, Earth is one of four rocky planets, but a unique one, with rigid and molten layers.

Three Reads

Read 1: Getting the Gist (2-3 sentences)

Look at the title of the article, the bold headings, and the photo. What do you think this article might be about? Do you already know something about the topic?

Read 2: Summary (3-5 sentences)

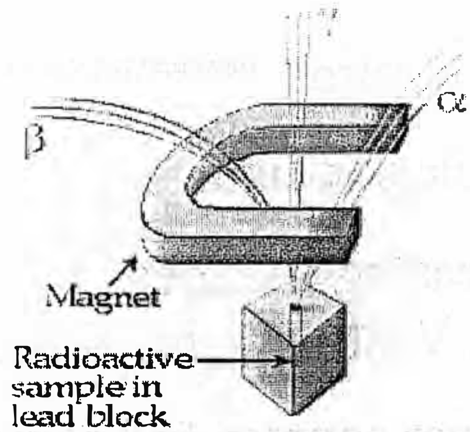
Now read the whole article. I suggest underlining what you think the main ideas and important details are. Below, write a paragraph that summarizes what the article was about, so that someone who didn't read it could still understand.

Read 3: Thinking Bigger (3-5 sentences)

This is where I care about your opinion/your reaction to the article. If you don't know what to write, think about: Were you surprised by any info? Does it make you curious about something else? Does it relate to something we learned in class or something you already know? How's it relate to Big History?

Radioactive Particles

Electric Charge = -1 0 +2



Pierre and Marie Curie discover 3 distinct types of accelerated particles from radioactive decay

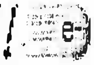
named after the first three letters of the Greek alphabet:
α(alpha), β(beta), and γ (gamma)

separated by a magnetic field
positive alpha particles bend one direction
negative beta particles bend opposite
neutral gamma rays do not bend at all

BACK NEXT

Curie's Discovery

Alpha particle: nucleus of helium (2 p, 2 n)  $^{4}He_{2}^{2}$

Beta particle: speedy electron Yeeeeeeehaaaaaaaa!! 

Gamma radiation: bullets of light 

Photons with increasing energies:

Radio Waves, Visible Light, X-Rays, Gamma rays

Experiment with Geiger counter and sources

alpha particles: stopped by a sheet of paper

beta particles: sheet of aluminum

gamma radiation: a block of lead.

penetrates far into a material

disrupts chemical bonds

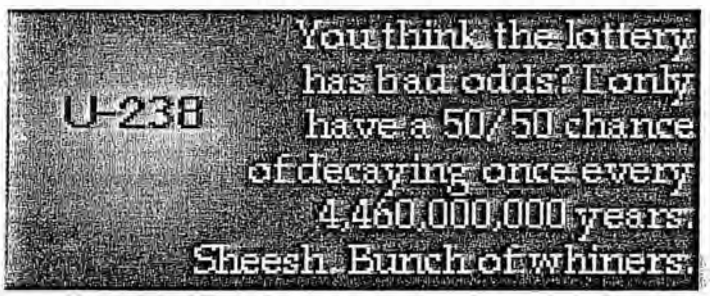
neutrons: discovered later, boiled off by a fissioning nucleus

Sadly, many years passed before scientists realized the perils of penetrating radiation

Half-Life... Radioactivity Decreases Exponentially with Time

- rate of decay measured by how long it takes for half to decay
- utterly random when a particular atom will decay
- half-life valid only for large number of nuclei

Why will an atom, just sitting there, decay according to some set probability?



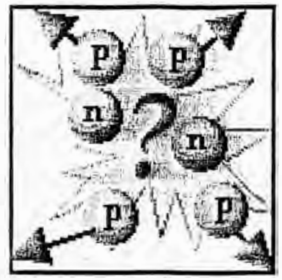
Many physicists very unhappy that chance rules physical properties

Einstein proclaimed, "God doesn't play dice!"

Einstein was wrong...measure half-life of radioactive Indium

BACK NEXT

Residual Strong Force
Holds the Nucleus Together



nucleus is held together by strong interaction

- should be blown apart by electrical repulsion between protons
- but its "glued" together by gluon particles
-

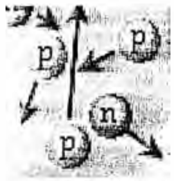
nucleus analogy

- tightly cocked spring (the electrical repulsion)
- held in place by very big rope (strong force)
- stored-up (mass) energy in spring can't be released to kinetic energy because rope is too strong

BACK NEXT

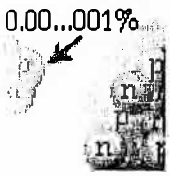
-

Alpha Decay: Quantum Mechanical Tunneling

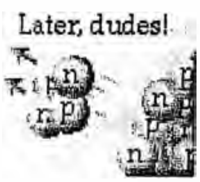


protons and neutrons bounce around inside a nucleus

probability that proton or neutron in any region



minuscule chance that 2 alpha particles together outside the nucleus greater chance in a large nucleus than in a small one



Outside range of strong force
like a suddenly released spring
the positive alpha particle will be repelled from nucleus

fundamental to quantum mechanics - branch of physics that explains particle behaviors in terms of probabilities

for heavy atoms, nucleus may - for shortest of instants - exist in a state that allows it to blow apart

Fission: Mass Conversion to Energy

any heavy elements...uranium, thorium, radium
decay into simpler elements

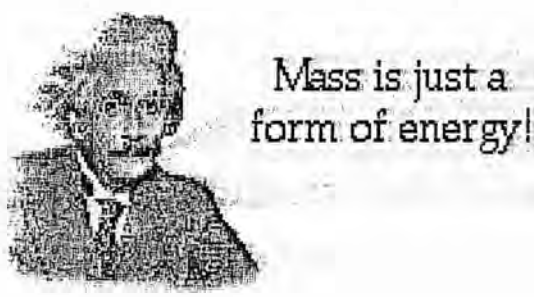
Uranium's mass =238.0508 atomic mass units (amu).

- decays into thorium (234.0436 amu) plus alpha particle (4.0026 amu)
  Uranium's mass minus mass of decay products

  .0046 amu

Where did this "missing" mass go?

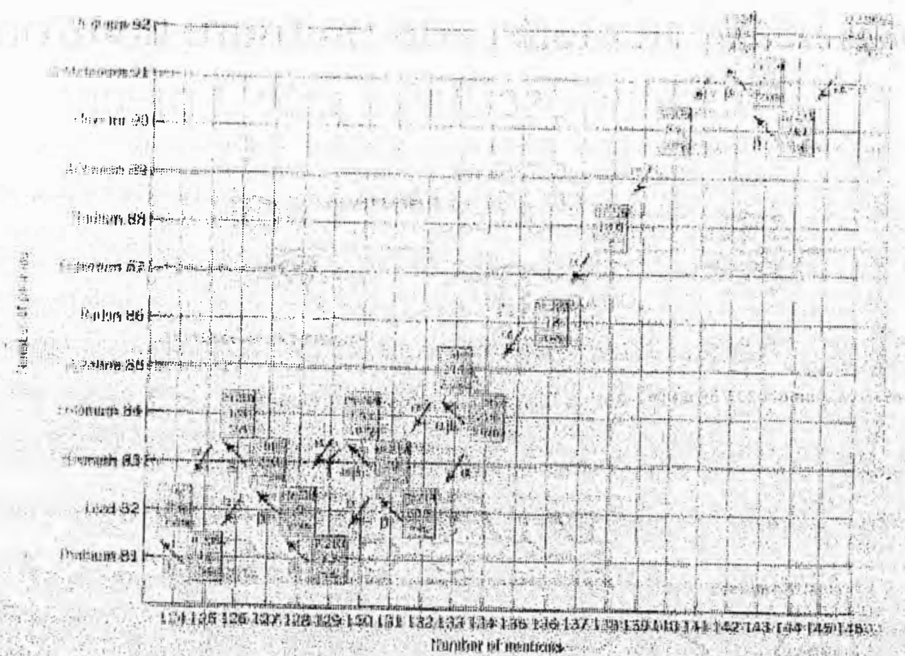
Einstein said:



lot of energy stored in strong force holding
uranium atom together...binding energy

potential energy stores as mass released
as kinetic energy (energy of motion)

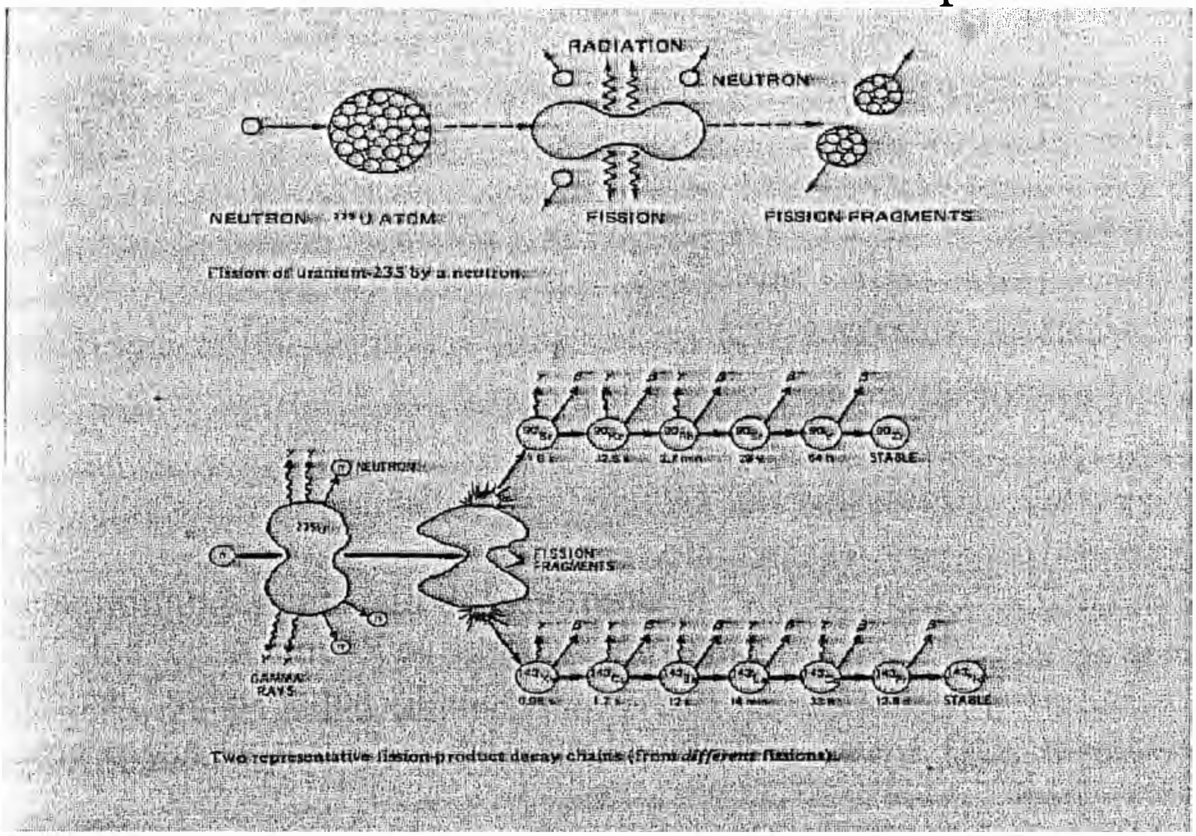
Radioactive Decay Chain



Uranium 238 lives for 4.5 billion years
...leaving radioactive Radon (4 day half life)
....eventually super stable Lead 206
double closed shells of neutrons and protons.

Liquid Drop Model of Nucleus

or a heavy nucleus, add on more neutron
nucleus oscillates into 2 pieces

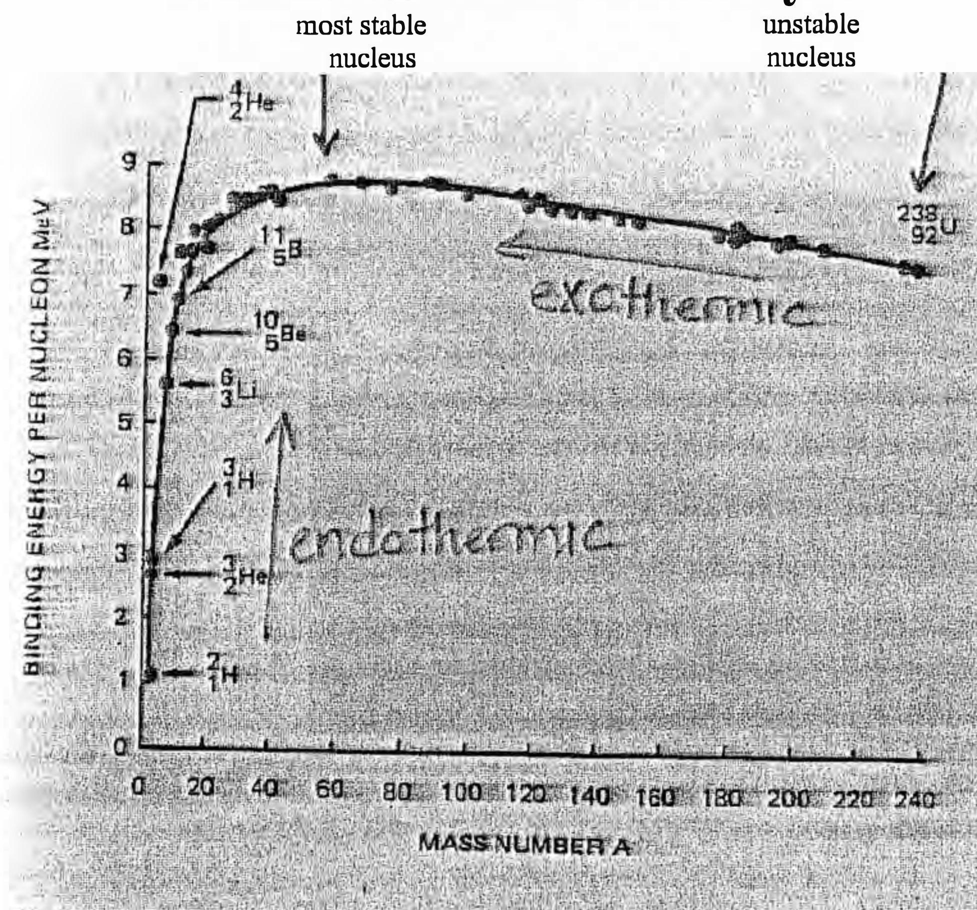


...each fragment decays sequentially to a stable daughter

...more neutrons out than in, producing chain reaction ...see mousetrap model of fission

BACK NEXT

Chart of Nuclear Stability



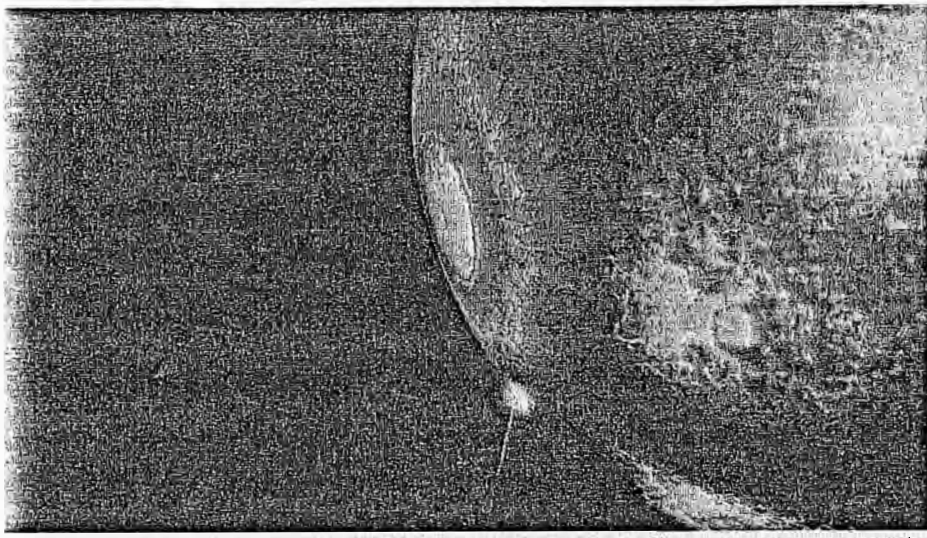
Binding energy per nucleon as a function of mass number.

...binding energy is greatest for iron
...nuclei lighter than iron produced by fusion in stars
...nuclei heavier than iron made in shockwave of supernova implosion

...we are all recycled star dust

The Earth forms

- Science
- The Earth
- Earth Timeline
- The Earth forms



The Earth is thought to have been formed about 4.6 billion years ago by collisions in the giant disc-shaped cloud of material that also formed the Sun. Gravity slowly gathered this gas and dust together into clumps that became asteroids and small early planets called planetesimals. These objects collided repeatedly and gradually got bigger, building up the planets in the Solar System, including the Earth.

The details of how the Earth formed are still being worked out. Scientists study meteorites and the oldest rocks on Earth to understand what happened in these earliest times in the Solar System. They also observe other solar systems in our galaxy, the Milky Way.

Image: Artwork showing the early Earth (credit: Walter Myers/SPL)

Introduction


The Earth forms

TV clips (3)


play Hot rocks

How did Lord Kelvin estimate the age of the Earth?

Lord Kelvin, the eminent 19th and early 20th century scientist, was determined to work out the age of the Earth. A simple experiment with molten rock gave him figures for his calculations. (This experiment should only be carried out under controlled conditions and with professional supervision.)


play The Earth's birth

Our planet develops its inner heat.

Dr Iain Stewart explains how the Earth developed its inner heat during a time known as the Hadean eon, about 4.5 billion years ago.


play First water

Volcanoes and comets bring water to the Earth.

Dr Iain Stewart explains the theory that steam from volcanoes and water from comets filled the Earth's oceans.

The Earth forms

Read more at Wikipedia

This entry is from *Wikipedia*, the user-contributed encyclopedia. If you find the content in the 'About' section factually incorrect, defamatory or highly offensive you can edit this article at Wikipedia.

Related Earth topics

Penetrating Power of Radioactive Particles

Procedure

Work with two partners to demonstrate the penetrating power of the three types of radiation.

Your group will need each of the following: a small marshmallow, a BB, a marble, 3 tissues, 2 sheets of paper and a 30 cm^2 piece of cardboard. Each member in your group must wear goggles during this activity.

- Have two group members hold the tissue upright between them so it is perpendicular to the lab table and there is no slack.
- Have the third group member throw the marshmallow at the tissue from a distance of about 70 cm.
- Repeat this process two more times with the marshmallow and a sheet of paper and the piece of cardboard.
- Record your results in the table.
- Repeat step 3 with the BB and the marble, respectively.

Radiation Type	Tissue (skin)	Paper (paper)	Cardboard (lead)
Marshmallow (α particle)			
BB (β particle)			
Marble (γ radiation)			

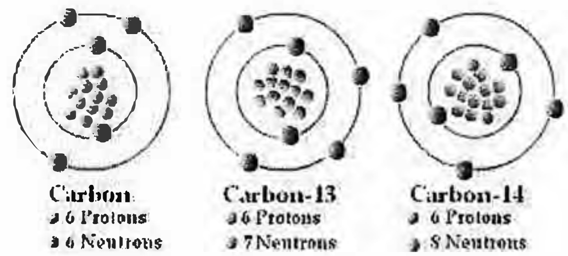
Write a summary describing the penetrating power of the three types of radioactive particles on skin, paper and lead based on your observations in this activity.

Half-Life

Background

Half-Life

If two nuclei have different masses, but the same atomic number, those nuclei are considered to be isotopes. Isotopes have the same chemical properties, but different physical properties. An example of isotopes is carbon, which has three main isotopes, carbon-12, carbon-13 and carbon-14. All three isotopes have the same atomic number of 6, but have different numbers of neutrons. Carbon-14 has 2 more neutrons than carbon-12 and 1 more than carbon-13, both of which are stable. Carbon-14 is radioactive and undergoes radioactive decay.



Radioactive materials contain some nuclei that are stable and other nuclei that are unstable. Not all of the atoms of a radioactive isotope (radioisotope) decay at the same time. Rather, the atoms decay at a rate that is characteristic to the isotope. The rate of decay is a fixed rate called a half-life.

The half-life of a radioactive isotope refers to the amount of time required for half of a quantity of a radioactive isotope to decay. Carbon-14 has a half-life of 5730 years, which means that if you take one gram of carbon-14, half of it will decay in 5730 years. Different isotopes have different half-lives.

The ratio of the amounts of carbon-12 to carbon-14 in a human is the same as in every other living thing. After death, the carbon-14 decays and is not replaced. The carbon-14 decays, with its half-life of 5,730 years, while the amount of carbon-12 remains constant in the sample. By looking at the ratio of carbon-12 to carbon-14 in the sample and comparing it to the ratio in a living organism, it is possible to determine the age of a formerly living thing. Radiocarbon dates do not tell archaeologists exactly how old an artifact is, but they can date the sample within a few hundred years of the age.

Finding Half-Life The basic equation for calculating the amount of radioactive material remaining is: $y = 1/2^{t\,1/2}$

Where,

y = the fraction of the original material remaining

$t_{1/2}$ = the number of half-lives

To find the age of an object using half-life, the following equations are used:

$$t_{age} = (\text{half-life}) * \log_2\left(\frac{1}{y}\right) = t_{age} = \left(\frac{\text{half-life}}{0.693}\right) * \ln(1/y) = t_{age} = \frac{(-1)}{K} * \ln\left(\frac{n_o}{n_t}\right)$$

Where,

$$K = \frac{0.693}{\text{half-life}} = \frac{\ln(2)}{\text{half-life}}$$

$$\text{and} \quad y = \left(\frac{n_o}{n_t}\right)$$

y = fraction of original material

n_o = amount of parent material left

n_t = total amount of material = parent + daughter

Suggested Activity -

Students can design their own experiment, using paper, M&M's®, Pennies, other 2 sided material or Licorice as a radioactive material undergoing decay to discover the nature of the half-life of that material.

Students can experiment with their graphing results to see if trends begin to form.

V

Half-Life

Paper

Table 1

Beginning Amount	1st Half-Life	2nd Half-Life	3rd Half-Life	4th Half-Life	5th Half-Life	6th Half-Life	7th Half-Life
% Decay							

Questions

1. Define the term half-life.
2. What does it mean when we say an atom has "**decayed**"?
3. For Table 1, at the end of each half-life, at approximately what percentage are the atoms decaying?
4. List two things that stayed the same during this activity and list two things that are different during this activity.
5. Do the number of atoms you start with affect the outcome? Explain.
6. How do scientists use radioactive decay to date fossils and artifacts?
7. The population of the earth is doubling every 40 years. If the population of the earth is now 6 billion people, how many people will be here when you are 95 years old?

v

Half-Life

M&M's® (or pennies or puzzle pieces)

Toss Results	Trail 0	Trail 1	Trail 2	Trail 3	Trail 4	Trail 5	Trail 6	Trail 7
ours	10							
Group 2	10							
Group 3	10							
Group 4	10							
Group 5	10							
Group 6	10							
Group 7	10							
Group 8	10							
Group 9	10							
Group 10	10							
Totals	100							

Questions

1. Define the term half-life.
2. What does it mean when we say an atom has "decayed"?
3. Do the number of atoms you start with affect the outcome? Explain.
4. Did each group get the same results?
5. Did any group still have candies remaining after Trial 7?
6. Why do the totals for the 10 groups better show what happens during half-life rather than any one group's results?
7. What happens to the total number of candies with each trial (half-life)?
8. Plot the total results on a graph with number of candies on the vertical axis and trial number on the horizontal axis. Is the result a straight or a curved line? What does the line indicate about the nature of decay of radionuclides?
9. How do scientists use radioactive decay to date fossils and artifacts?

Creation of Earth Timeline

v

You will be creating a timeline of the formation of Earth using the information from the Three Reads article. Your timeline will should include at least 6 events that lead to the creation of Earth. The events should be named, with a short description and a drawing to illustrate what is happening.

THE GEOLOGIC TIME SCALE

Table 1. The development of life through time.

Million years before present	Era, System, or Event	Relative to a calendar year (date time)
	Precambrian	
4600	**Earth formed from planetary nebula**	**1/1 0:00**
3900	Inferred origin of life (first cells)	2/25 13:02
3800	Oldest age-dated rocks on Earth	3/5 11:28
3600	Fossil algae and stromatolites (prokaryots)	3/21 8:20
3250	Fossil evidence of bacteria	4/18 2:52
2100	Fossil evidence of cells with a nucleus (eukaryots)	7/18 8:52
1500	First multi-celled organisms (seaweed and algae)	9/3 23:28
670	Oldest marine worms and jellyfish	11/8 20:05
600	Vendian period begins: Edicarian fossils	11/14 9:23
	Paleozoic	
544	**Cambrian system begins**	**11/18 20:02**
515	Burgess Shale animals. animals with a notochord	11/21 3:15
505	**Ordovician system begins**	**11/21 22:18**
505	First fish	11/21 22:18
470	First fossil evidence of land plants	11/24 16:57
438	**Silurian system begins**	**11/27 5:53**
430	First vascular land plants	11/27 21:07
414	Oldest lung fish fossils	11/29 3:36
408	**Devonian system begins**	**11/29 15:01**
408	Oldest fossil evidence of mosses	11/29 15:01
385	First insects (beetles), scorpions, and centipedes	12/1 10:49
380	First lobe-finned fish	12/1 20:20
375	First land animals (amphibians)	12/2 5:52
370	First sharks	12/2 15:23
365	First seed plants (ferns)	12/3 0:54
360	**Mississippian system begins**	**12/3 10:26**
330	First possible reptiles	12/5 19:33
320	**Pennsylvanian system (Kentucky coal)**	**12/6 14:36**
286	Permian system begins	12/9 7:21
260	Sail-backed reptiles (Dimetrodon)	12/11 8:52
245	End of Paleozoic. 96% of all life on Earth perishes	12/12 13:26
	Mesozoic, the "Age of Reptiles"	
245	**Triassic system begins**	**12/12 13:26**
240	First crocodiles	12/12 22:57
228	First dinosaurs (Eoraptor and Saltoposuchus)	12/13 21:48
221	First mammals (shrew-like)	12/14 11:08
210	First turtles	12/15 8:05
208	**Jurassic system begins**	**12/15 11:53**
195	Dilophosaurus. an early Jurassic dinosaur	12/16 12:39
155	First bird. Archeopteryx	12/19 16:49
152	Apatosaurus and Brachiosaurus (long-necked	12/19 22:32
150	Allosaurus, (meat-eating dinosaur)	12/20 2:20
148	Stegosaurus. (plate-backed dinosaur)	12/20 6:09
144	**Cretaceous system begins**	**12/20 13:46**
115	First flowering plants	12/22 21:00
82	Duck-billed dinosaurs (Maiasaurus)	12/25 11:50
80	Protoceratops (first dinosaur eggs discovered)	12/25 15:39
75	Triceratops	12/26 1:10
70	Tyrannosaurus rex and Velociraptor	12/26 10:41
65	End of Mesozoic, probably meteor or comet impact	12/26 20:13
	Cenozoic, the "Age of Mammals"	
65	**Tertiary system begins**	**12/26 20:13**
64	First ancestors of dogs and cats	12/26 22:07
60	Grasses become widespread	12/27 5:44
57	First ancestors of pigs and deer	12/27 11:27
55	First horses (Eohippus)	12/27 15:15
45	First ancestors of rabbits	12/28 10:18
39	First monkeys	12/28 21:43
4	Oldest human like ancestors (hominids)	12/31 17:20
2	**Quaternary system begins**	**12/31 20:57**
1	First of four ice ages	12/31 22:05
1	Oldest direct human-ancestor fossil, Homo habilis	12/31 23:02
0.1	First modern man. Homo sapiens	12/31 23:48
0.05	Mammoth and mastodon bones, Big Bone Lick, KY	12/31 23:54
235 years	Revolutionary War	12/31 23:59
70 years	World War II	1/1 0:00

The scale of geologic time is vast, currently estimated at nearly 4.6 billion years. During that time, life evolved into the familiar forms we see today. These materials are provided to assist in understanding time relationships and how life on Earth changed through time.

The dates shown were compiled from several available sources. Table 1 shows some important events in Earth history, presented in the order in which they occurred. The data are also shown on the scale of a calendar year. When geologic time is compressed to the scale of a calendar year, 1 second equals about 146 years. At this scale, World War II began about 0.4 second before midnight on December 31; because of rounding, this is shown as midnight of the new year.

On the back of this sheet is a chart showing the geologic eras, systems, and series; the oldest is at the bottom. On the chart, each dot, number, or letter represents 1 million years. The dots get "older" as you read down the chart, or to the right along a row. Thus, they represent millions of years before present ("mybp") and show the ages of the oldest known fossils of selected animals or the time of an event. Not all of the items shown in Table 1 are shown on the chart because of space limitations.

For more information on the geologic time scale, see:

- www.uky.edu/KGS/education/activities.html
- Dinosaurs: Fact & Fiction pubs.usgs.gov/gip/dinosaurs/
- Fossils, Rocks, and Time: pubs.usgs.gov/gip/fossils/
- Geologic Time: pubs.usgs.gov/gip/geotime/
- Teaching About Evolution and the Nature of Science: books.nap.edu/books/0309063647/html/index.html
- Learning from the Fossil Record www.ucmp.berkeley.edu/fosrec/fosrec.html
- Understanding Evolution: evolution.berkeley.edu/
- National Center for Science Education: www.natcenscied.org/

The dot scale of geologic time is adapted from an idea by Charly Zuppann of the Indiana Geological Survey, Bloomington, Indiana

The Kentucky Geological Survey is a research and public-service center of the University of Kentucky.

Kentucky Geological Survey
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Lexington, Kentucky 40506-0107
Phone: (859) 257-5500
On the Web: www.uky.edu/KGS

Scan this for more on geologic time

THE GEOLOGIC TIME SCALE

Era	System and Series		Began mybp	Relative Time (1 dot or character = 1 million years)
Cenozoic	Quaternary	Holocene	0.01	
		Pleistocene	1.8	X•
	Tertiary	Pliocene	5	•W•
		Miocene	23	••••••••••••••••••
		Oligocene	34	•••••••••••
		Eocene	57	•••V•••••••••••••••U•T
		Paleocene	65	••S•••RQ
Mesozoic	Cretaceous		144	•••P••••O•••••••N•••••••••••••••••••••••••••••••••••••••M••••••••••••••••••••••••••••••
	Jurassic		208	•••L•K•J••I•••
	Triassic		245	•H•••••••••G••••••F••••••••••••••••
Paleozoic	Permian		286	E••
	Carboniferous Systems	Pennsylvanian	320	••••••••••••••••••••••••••••••••••
		Mississippian	360	•••••••••D••••••••••••••••••••••••••••••
	Devonian		408	••••C••••B••••A•••••••••9•••••••••••••••••••••
	Silurian		438	••••••••••••••••••••••••••••••
	Ordovician		505	••••••••••••••••••••••••••••••8••••••••••••••••••••••••••••••••••7
	Cambrian		544	•••••••••••••••••••••••••••••••••••••••
Precambrian	Proterozoic Era		2,500	••••••••••••••••••••••6•••••••••••••••••••••••5••••••••••••••••••••••
	Archean Era		3,800	••••••••••••••••••••••4•••••••••••••3•••••••••••••••••••••••2
	Hadean Era		4,600	••••••••••••1•••••••••••••••••••••••••••••0

Events

0 Earth formed
1 Life originates
2 Oldest age-dated rocks
3 Blue-green algae
4 Bacteria
5 Cells with a nucleus
6 Multicellular life
7 Fish
8 Land plants
9 Insects
A Amphibians
B Sharks
C Plants with seeds (ferns)
D Reptiles
E End-Permian extinction
F Early dinosaurs (such as *Eoraptor*)
G Mammals (shrew-like)
H Turtles
I *Archeopteryx*
J *Apatosaurus*
K *Allosaurus*
L *Stegosaurus*
M Flowering plants
N Duck-billed dinosaurs
O *Tricerotops*
P *Tyrannosaurus rex*
Q End-Cretaceous extinction
R Dogs and cats
S Grasses widespread
T Pigs and deer
U Horses (*Eohippus*)
V Monkeys
W Hominids
X First of four ice ages

Geologic Time Scale

1. Based on our timeline, in which geologic time period is your birthday?

2. What are three events that happened in this geologic time period?

3. We keep track of time (minutes, hours, months, years…) in different ways based on the movement of the Earth around the sun, and the spinning of the Earth on its axis. This is not how the length of the different eras is determined. How was it decided that one time period ended and another began? Give examples.

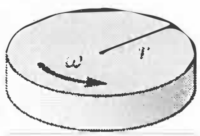
4. What evidence do scientists use to determine when a type of animal became extinct? How valid do you think their evidence is? Explain.

M1U4 Assessment: Formation of Earth

1. A ring and a solid disk of the same radius, and the same mass rolled down and incline. Which one

- ❑ the ring

- ❑ the disk

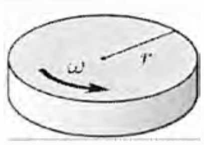


- ❑ It's a trick question. They both reach the ground at the same time.

2. A ring and a solid disk of the same radius, and the same mass. Which one has better mass distribution?

- ❑ the ring

- ❑ the disk



- ❑ It's a trick question. They both have the same mass.

3. Meter stick (A) has 500-g mass attached to the end (100 cm from the rotational axis). Meter stick (B) has 500-g mass attached to a point 20 cm from the rotational axis. Meter stick (C) has the 500-g mass attached to the 50 cm point. Which has the highest rotational inertia?

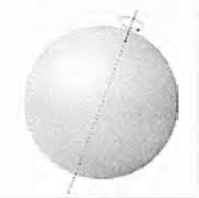
- ❑ meter stick A
- ❑ meter stick B
- ❑ meter stick C
- ❑ It's a trick question. They all have the same rotational inertia

4. In consideration of how fast an object rotate, the higher the object's rotational inertia, the __________ the object rotate.

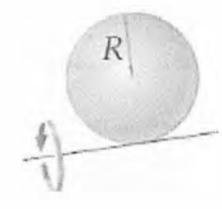
- ❑ faster
- ❑ slower
- ❑ It's a trick question Rotational inertia does not affect the rotating speed of the object.

5. Which of the following Earth model would have a higher rotational inertia?

- ❑ Earth with rotational axis in the middle.



- ❑ Earth with rotational axis outside the Earth.



- ❑ It's a trick question. They both have the same rotational inertia.

6. Explain what happen when a figure skater pulls her arms in.

7. Universal gravitation law states that
   - ❑ There is an attraction force between any 2 objects
   - ❑ The bigger the masses, the bigger the attraction force (direct proportion)
   - ❑ Also known as the inverse square law
   - ❑ The farther they are away, the weaker the attraction force is
   - ❑ All of the above

8. The attraction force of a star or a planet is also called
   - ❑ Attractive force
   - ❑ Repulsive force
   - ❑ Gravitational pull of the star or planet
   - ❑ None of the above.