Homework 2 & recently graded observatory/planetarium reports are available for pickup.

Total eclipse of the Moon Feb. 20

Totality begins 10:00 PM, ends 10:51 PM

View with unaided eye or with binoculars

Just about any location is good.

Graphic from US Naval Observatory; more info
Next Brooks Observatory session next week

Monday, February 25 through Thursday, February 28

Begins 7:00 PM, runs through 8:45 PM or later, weather permitting.

Not required if you have already been to Brooks this semester, & written report

If you attend this time, report due Wednesday, March 12 (after spring break)
Quiz 3, Wed. Feb. 20

The usual routine, 20 multiple-choice questions, last 20 minutes of class.

Will cover

- Kepler’s Laws (chapter 3)
- Motion concepts, Newton’s Laws (chapter 4)
- Energy (chapter 4)
- Solar system overview (chapter 6)

Homework 3 will be distributed, due Feb. 27
This evening’s topics

Density and bulk composition of planets

Angular momentum

Review of motion, Newton’s Laws

Clues to the origin of the solar system

Theory of formation of the solar system (as time permits)
<table>
<thead>
<tr>
<th>Planets</th>
<th>Density*</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury, Venus, Earth</td>
<td>5</td>
<td>Terrestrial</td>
</tr>
<tr>
<td>(Moon)</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Mars</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>...asteroid belt...</td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Jupiter, Saturn, Uranus</td>
<td>1</td>
<td>Jovian</td>
</tr>
<tr>
<td>Neptune</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Pluto</td>
<td>2</td>
<td>Unclassified</td>
</tr>
</tbody>
</table>

*Grams per cubic centimeter (c. c.)
## Classification as terrestrial vs. jovian

<table>
<thead>
<tr>
<th></th>
<th>Terrestrial (inner)</th>
<th>Jovian (giant, outer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (Earth = 1)</td>
<td>0.4–1</td>
<td>4–11</td>
</tr>
<tr>
<td>Surface</td>
<td>Solid</td>
<td>None*</td>
</tr>
<tr>
<td>Density (grams per c.c.)</td>
<td>3 – 5</td>
<td>1–2</td>
</tr>
<tr>
<td>Location / asteroid belt</td>
<td>Interior</td>
<td>Exterior</td>
</tr>
</tbody>
</table>

*Thick massive, atmosphere; small, solid core

See Fig. 8.1
Using a planet’s bulk density as a clue to its composition: start with objects whose composition and density we know

- Earth
  - Density of crustal rock: 2 to 3 grams per cubic centimeter
  - Most abundant elements in crustal rock (combine to form minerals)
    * oxygen
    * silicon
    * aluminum
    * iron

Same combination applies to Earth as a whole
Some density values for common planetary materials

<table>
<thead>
<tr>
<th>Substance</th>
<th>Density (grams per cubic centimeter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.0</td>
</tr>
<tr>
<td>Terrestrial crustal rock</td>
<td>2.4</td>
</tr>
<tr>
<td>Terrestrial mantle rock</td>
<td>3.3</td>
</tr>
<tr>
<td>Earth, average</td>
<td>5.5</td>
</tr>
<tr>
<td>Iron</td>
<td>8</td>
</tr>
</tbody>
</table>
Density and composition

- In a solid, *higher-mass atoms take up about the same space as lower-mass ones*
- Same number of atoms in a given volume
- But if the atoms are heavier, *higher density*
Likely significance of the bulk density of a planet for its composition

- Density near 1 gram per c. c. suggests light elements (hydrogen, helium, carbon, nitrogen, oxygen) abundant
- Density near 3 grams per c. c. suggests rocky composition, medium mass elements
- Density near 5 grams per c. c. suggests mixture of rock and iron (iron is the most abundant heavy element)
What about small, solid *planetary bodies* with densities between 2 and 3? (too low for a purely rocky composition)

- Probably include solidified compounds of hydrogen, carbon, nitrogen, oxygen
- These elements are the most abundant ones (except for helium, which will not condense into a solid or form any compounds)
- Examples of compounds: water, carbon dioxide, methane, ammonia
- Such compounds are called *ices* when solid
More about motion: angular momentum

The *angular momentum* of a rotating object is determined by its rotation rate, its total mass, and how its mass is distributed.

More spread out $\implies$ more angular momentum (all else equal)

If an object is *isolated* from its surroundings, its angular momentum always remains constant (physical law).

So if the object expands/contracts, its spin rate decreases/increases to compensate.

This is how *figure skaters*, for example, slow down and speed up their spins.
More about motion: sample questions
Clues to origin

Features of the solar system that can’t be explained by present-day conditions or physical laws

1. Orderly motions suggest that the solar system formed out of a *single, large, rotating object*, whose *angular momentum* is preserved.

- All the planets and the Kuiper Belt objects orbit the Sun in the same plane, traveling in the same direction.
- The Sun and most of the planets rotate on their axes in this same direction.
2. There are two basic types of planets: terrestrial and jovian

- The inner (terrestrial) planets are smaller and denser than the outer (jovian) planets.
- Moreover, among the terrestrial planets, the densities are greater, the closer the planet is to the Sun.
- Exception: the Earth and the Moon are at essentially the same distance from the Sun, but have quite different densities (5.5 vs. 3.3)
3. The solar system includes many thousands of small bodies.

- Asteroids: rocky composition
- Comets: icy composition

These clues suggest a theory for the origin of the solar system.

A successful theory must explain them and also explain exceptions.

- The large size of the Moon in relation to Earth
- Uranus’s rotation axis is tipped “on its side”
- Venus’s rotation is retrograde, opposite to the general direction in the solar system
Multiple-choice questions. Mark in completely the ONE BEST answer on your answer sheet.

1. If a brick is transported to the Moon, its mass will be ______ on Earth
   (a) the same as (d) (meaningless)
   (b) smaller than (e) (none of the above)
   (c) larger than

2. You are in an elevator, and the elevator’s supporting cable has just been cut. Until the elevator hits the bottom of its shaft, you will experience
   (a) a sensation of increased weight
   (b) the same sensation of weight as before
   (c) half as much weight as before
   (d) weightlessness, or free fall

3. Jupiter experiences ____ acceleration by the Sun’s gravity than the Earth.
   (a) more (c) less
   (b) the same (d) none of the above

4. According to the scientific definition of velocity (given in class), which of the following is moving at constant velocity?
   (a) a satellite in orbit around the Earth
   (b) a car going around a circle at constant speed
   (c) the Moon
   (d) an apple falling from a tree
   (e) none of these

5. According to Newton’s laws, a force is acting whenever
   (a) time passes
   (b) an object moves at some speed
   (c) the direction of an object’s motion changes
   (d) an object moves in a straight line at constant speed

6. The fictitious planet Zorg has the same diameter as the Earth but 50% less mass. On Zorg, you would weigh ______ on Earth.
   (a) less than (c) (the same)
   (b) more than (d) (nothing)

7. The force by which every object in the universe attracts every other object is called
   (a) friction (d) geology
   (b) elasticity (e) geometry
   (c) gravity

8. Which compounds an atom is best able to form (its chemical properties) is most closely related to the atom’s
   (a) atomic number (d) speed
   (b) atomic mass (e) acceleration
   (c) velocity

9. Whether a given substance is mostly in the solid, the liquid, or the gas phase depends on
   (a) temperature only
   (b) pressure only
   (c) temperature and pressure
   (d) neither temperature nor pressure

10. The thermal energy of an object consists of
    (a) The total kinetic energy of all the moving particles of which it is made
    (b) Its chemical potential energy plus its gravitational potential energy
    (c) Light reflected from its surface
    (d) Its kinetic energy; if it is at rest, it has no thermal energy
    (e) Its gravitational potential energy plus its kinetic energy

11. In science, the term, “accelerated motion,” means
    (a) increasing speed
    (b) either increasing or decreasing speed
    (c) any change in position
    (d) changing speed or direction of motion
    (e) being at rest

12. A marble held stationary in my hand four feet above the floor possesses
    (a) kinetic energy
    (b) chemical potential energy
    (c) electrical potential energy
    (d) gravitational potential energy
13. The temperature of a material (solid, liquid, or gas) is most closely related to what characteristic of the atoms or molecules that make up the material?
   (a) average speed  (c) number of protons
   (b) mass         (d) number of electrons

14. In order to describe the velocity of a moving object at a particular time, one must specify
   (a) the acceleration and the speed of the object
   (b) the speed and direction of the object
   (c) the mass, speed, and position of the object
   (d) the speed of the object only
   (e) the direction of the motion only

15. All ordinary matter is made of
   (a) atoms         (d) electrons only
   (b) protons only  (e) plasma
   (c) neutrons only

16. The gravitational acceleration of a falling body near the Earth’s surface (ignoring the effect of air resistance)
   (a) is proportional to the mass of that object
   (b) is due to friction
   (c) brings moving objects on horizontal, frictionless surfaces to rest
   (d) does not depend on the falling body’s mass
   (e) is unknown

17. Chemically bound groups of atoms are called
   (a) protons       (d) droplets
   (b) molecules     (e) electrons
   (c) nuclei

18. Can the direction of the acceleration of a car ever be opposite to the direction in which the car is moving?
   (a) No, this is impossible.
   (b) Yes, if the car is speeding up.
   (c) Yes, if the car is slowing down.

19. Forces
   (a) slow down planets
   (b) cause a change in mass
   (c) tend to cause a change in velocity
   (d) cause motion; in the absence of a force, a body is always at rest
   (e) speed up an object but cannot slow it down

20. A satellite in a circular orbit around the Earth
   (a) does not undergo any acceleration
   (b) throughout its motion, is accelerated toward the center of the Earth
   (c) moves at an unchanging velocity
   (d) moves in a straight line

21. An object’s mass is the same thing as its
   (a) weight       (d) volume
   (b) density      (e) inertia
   (c) size

22. If an object experiences no acceleration, the reason must be that
   (a) no forces act on it
   (b) Newton’s laws of motion do not apply
   (c) if any forces act on it, they must be equal in magnitude to each other and opposite in direction, so that their net effect is zero
   (d) the object is massless
   (e) the object has no electrical charge

23. Suppose an object moves in a circular path. At any instant, the object’s velocity is directed
   (a) toward the center of the circle
   (b) away from the center of the circle
   (c) perpendicular to the plane of the circle
   (d) tangent to the circle

24. “If no force acts on an object, the object’s velocity does not change,” is a statement of
   (a) Kepler’s first law
   (b) Kepler’s second law
   (c) Newton’s first law
   (d) a fact sometimes observed
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25. An astronaut on the Moon drops a lead weight and a feather. What happens?
   (a) The two objects fall with the same acceleration.
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II. - Total Eclipse of the Moon  2008 February 21

UT of geocentric opposition in RA: February 21$^{d}$ 3$^{h}$ 48$^{m}$ 24.795
Umbral magnitude of the eclipse: 1.111

Areas of visibility of the eclipse at different stages