Astronomy 1141 Quiz 2 Review

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Copernican Heliocentric Model: Tycho, Kepler, Galileo

Who was the first major proponent of the heliocentric model? What were the key facets of his model?

• 1. Copernicus.
• 2. His model had a central Sun with the planets orbiting it in circular orbits.

Who corrected this model? How? Using whose data?

• 1. Johannes Kepler solved this by incorporating elliptical orbits rather than perfectly circular ones, compiled from Tycho Brahe's data.

Which of Galileo's observations supported the heliocentric model?

• 1. Phases of Venus.
• 2. Satellites of Jupiter (something else in the Solar System has objects orbiting it besides the Earth).

Define:

• Perihelion - the closest a body comes to the Sun in its orbit.
• Aphelion - the furthest a body goes from the Sun in its orbit.
• Eccentricity - a measure of how an orbit deviates from being a perfect circle. Is 0 for a circle, 1 for a straight line. For elliptical orbits, is determined by the ratio of the distance from the center of the ellipse to one focus and the semimajor axis.

Explain Kepler's 3 Laws.

• 1. 1st Law - All the planets are on elliptical orbits, with the Sun at one of the foci.
• 2. 2nd Law - In their orbits around the Sun, every planet sweeps out equal area in equal time. Equivalently, planets move more slowly when further away from the Sun. • 3. 3rd Law - The square of the period, P, of any orbit is proportional to the semimajor axis, a, of said orbit to the third power, or P^2 / ai^3.

Gravity, Galileo, and Newton

What are some things Galileo observed through his telescope?

• 1. The phases of Venus.
• 2. Sunspots.
• 3. Lunar mountains and craters.
• 4. The largest and brightest moons of Jupiter.
• 5. That the Milky Way is made up of many individual stars.

Galileo also studied gravity. How did he do so, and what did he discover?

• 1. He studied the acceleration due to gravity and found that it was the same for any object regardless of mass.

What are Newton's 3 Laws?

• 1. Law of Inertia: A body stays at rest or in motion in a straight line unless acted upon by an external force. Mass is a measure of this inertia.
• 2. Law of Acceleration: For a given mass, its acceleration is proportional to the force applied. $F = ma$. More massive objects are more resistant to acceleration. • 3. Law of Action equals Reaction: For every action there is an equal and opposite reaction - momentum is conserved.

What is meant by conservation of momentum”?

• 1. The momentum (mass times velocity) of an object or system is the same, or conserved, before and after an event.

• 2. Example: If you and a friend stand facing each other on roller skates and you push them, you travel backwards in the opposite direction as your friend does.

What is Newton’s Law of Gravity?

• 1. The gravitational force between two objects is proportional to the product of their masses, and inversely proportional to the square of the distance between their centers; F = Gm1m2/r^2, where G is a constant.

What point do two objects orbiting each other revolve around? Where does it lie?

• 1. The barycenter, or their mutual center of mass.

• 2. An orbiting object’s distance from the barycenter is inversely proportional to its mass: more massive objects lie closer to the barycenter.

• 3. For example, in the Earth-Moon system, the barycenter is below Earth’s surface, but is not at the center of the Earth.

What is the energy associated with your position with respect to a source of gravity called? Energy associted with motion?

• 1. Gravitational potential energy.

• 2. Kinetic energy.

Light

1. What is light?
   - Light is electromagnetic energy
   - It is both a particle (photon) and a wave
2. How is light created and what can light interact with?
   - Light is created by moving electric charges, like electrons
   - Light can only interact with particles that have an electric charge, like electrons
3. How is the wavelength of light related to its frequency?
   - $c = \lambda f$, where c is the speed of light ($c = 300,000,000$ m/s), λ is the wavelength, and f is the frequency
4. What are the units for frequency and wavelength?
   - Frequency is measured in hertz (Hz), which are inverse seconds $1/s$
   - Wavelength is measured in many units of distance depending on how big it is, from angstroms (Å, 1 Å = 10^{-10} m) to nanometers (nm, 1 nm = 10^{-9} m) to millimeters, centimeters, or even meters or kilometers for very long waves. Mostly we’re interested in light with wavelengths the size of a few thousand angstroms, like visible light.
5. What is the speed of light? Can anything move faster than light?
   - Roughlly $c = 300,000,000$ m/s. Nothing can travel faster than light.
   - This means when we see the Sun’s light, since the Sun’s light takes 8 miutes to make it to Earth, we see the sun as it was 8 minutes ago, not as it is now.
6. List the electromagnetic spectrum from highest energy to lowest energy. Note that this is also the list from shortest wavelength to longest wavelength.

- Gamma rays, X-rays, ultraviolet, visible, infrared, microwaves, radio waves

7. What wavelength range is visible light?

    - 4000 Å(blue) to 7000 Å(red) is visible, but the human eye is most sensitive in the somewhat reduced range of 5000 Åto 6000 Å

8. How does the energy of a photon relate to other properties of light?

    - $E = hf = hc/\lambda$, where E is the energy of a photon, f is its frequency, λ is its wavelength, c is the speed of light, and h is Planck's constant
    - Since the speed of light is constant, this means that knowing a photon's energy, wavelength, or frequency is equivalent to knowing the other two.
    - A higher energy corresponds to a shorter wavelength and a larger frequency. A longer wavelength is a lower energy and smaller frequency.

Atoms and Spectroscopy

1. What subatomic particles make up the atom?

    - Protons and neutrons in the nucleus, electrons in "orbits" around them

2. How many protons, electrons, and neutrons does a hydrogen atom have?

    - One proton and one electron, no neutrons. A neutral atom (an atom without any charge) always has equal numbers of protons and electrons.
    - The number of protons in the nucleus, known as the "atomic number", separates distinct atoms. Hydrogen has one proton. Helium, the second element, has 2 protons.

3. Can electrons be anywhere around the nucleus?

    - No. Electrons must be in specific orbits around the nucleus with specific amounts of energy.
    - Electrons orbit around the nucleus because they are negatively charged, whereas the nucleus is made of positively charged protons.

4. What happens when an atom emits light? What is the energy of that light?

    - An atom can emit light when one of its electrons is in a large, high-energy orbit around the nucleus, and then the electron moves to a smaller, lower-energy orbit. The energy of the photon that is emitted is equal to the energy difference between the two orbits that the electron moved between.

5. What happens when an atom absorbs light? Can an atom absorb light of any energy?

    - An atom can absorb light by moving one of the electrons to a higher-energy orbit than it was originally in. The energy difference between the two electron orbits must be equal to the energy of the light, so an atom can't absorb every energy of light. It can only absorb light with the correct energy that matches the energy difference between electron orbits.
    - Since any absorption and emission must be equal to the energy required for an electron to move up or down orbital states, the emission lines of a gas occure at the exact same wavelengths as its absorption lines. Each gas, however, is unique in what its energy levels are, so based on a group of absorption and emission lines, you can determine what a gas is made of from its spectrum alone.

6. What does an emission spectrum look like, in general, for a single element?

- An emission spectrum will be mostly dark with bright emission lines at the specific energies where the atom can emit light. These energies are equal to energy differences between different electron orbits in the atom. An emission spectrum occurs when a gas is heated (thus exciting the electrons to higher orbits) and tries to cool itself down by emitting photons (as the electrons drop to lower energy orbits).

7. What does an absorption spectrum look like, in general, for a single element?

   - An absorption spectrum is mostly bright, with dark absorption lines where light is missing at the specific energies where the atom can absorb light. These energies are equal to the energy differences between different electron orbits in the atom. Here, the incoming light excites the gas by providing light at the proper energies to bump electrons to higher orbits.

8. What are some of the most well-known emission and absorption series of lines of hydrogen, and what part of the electromagnetic spectrum are they in?

   - The Lyman series: the electron transitions from higher-energy orbits to the lowest-energy orbit, seen in ultraviolet light
   - The Balmer series: the electron transitions from higher-energy orbits to the second lowest-energy orbit, seen in visible light
   - The Paschen series: the electron transitions from higher-energy orbits to the third lowest-energy orbit, seen in infrared light

9. What can you learn from looking at the spectrum of a star?

   - You can learn its temperature based on the wavelength where it emits the most energy
   - You can learn what elements make up its photosphere based on the absorption lines present, since each element has its own distinct pattern of emission and absorption
   - You can learn how fast it's moving toward or away from us (Doppler effect: see section below)

10. What is a blackbody?

    - A blackbody is a perfect absorber and emitter of radiation. It emits exactly as much radiation as it absorbs, and this causes it to have a certain temperature.
    - A blackbody has a very distinct emission. From its spectrum, you can directly determine its tempearture based on the wavelength of peak emission.

Doppler Effect

1. What causes the Doppler effect?

   - Wavelengths get "squished" when the object emitting them is moving toward you, because the object starts to "catch up" with the wave while it continues to emit. "Squished" here means they get a shorter wavelength/higher frequency. For sound, this means higher pitch. For light, it gets bluer.
   - Wavelengths get "stretched" when the object emitting them is moving away from you, because the object is moving away from the wave while it continues to emit. "Stretched??? here means they get a longer wavelength/lower frequency. For sound, this means lower pitch. For light, it gets redder.

2. What kinds of waves exhibit the Doppler effect?

- All kinds! We observe the Doppler effect in light and sound. In everyday life, it's much easier to observe in sound (think police car siren zooming by you) because sound travels MUCH slower than light. This makes it easier for the object to "catch up" or "leave behind" its sound wave. Objects moving very fast, like stars, have detectable Doppler shifts in the light they emit. Technically even slow-moving objects, like a person walking toward or away from you, exhibit Doppler shifts in the light coming from them, but it's such a small change because walking speed is such a small fraction of the speed of light that you can't detect it with your eye.

3. If a star has an emission line at a particular wavelength λ, will the observed wavelength be longer or shorter if the star moving away from us? What color will this emission line be shifted toward?

   - The wavelength of the star's emitted light will be longer if it's moving away from us. Since red light has longer wavelengths than blue light, this light is shifted toward red, and we say that it is "redshifted."
   - If the star was moving toward us, the light would be "blueshifted" and have a shorter wavelength than usual.

Our Universe

1. Is the universe expanding, contracting, or staying the same? How do we know this?

   - The universe is expanding. We know this because the further away an object is from us, the redder it appears to be. Because of the Doppler Effect, we know this means it must be moving away from us, and objects further from us are moving away faster.

2. What is Hubble's Law?

   - $v = H_0 d$, where v is the velocity of a galaxy (which we can determine from the redshift), d is the distance to that galaxy, and H_0 is Hubble's constant.

3. Using Hubble's law, how can we determine the age of the universe?

   - Since the universe is expanding and must have had a beginning, then $1/H_0$ is the time it took for galaxies to get where they are now, that is the Age of the Universe approximately 13.8 billion years.

4. What is the Cosmic Microwave Background?

   - The CMB is radiation left over from the Big Bang. It's a blackbody with a uniform temperature of 2.73 Kelvin pretty much everywhere, except it has some small variations due to the presence of matter right after the Big Bang.

Telescopes

1. Why do we use telescopes?

   - The apparent brightness of distant objects decreases with the square of the distance to them, so distant objects are extremely faint.
   - If we can build something that stares at something for a long time and can collect as much light as possible from that thing, then maybe we can see it.

2. What is the difference between a refracting and a reflecting telescope?

   - Refracting: light is bent and focused by passing through glass lenses.

- Reflecting: light is bent and focused by bouncing off of mirrors.

3. What happens when light passes through a lens?

   - Light travels slower in glass than in air, so the path of light gets bent at the interface between glass and air.
   - Red light doesn't get bent as much as blue light, so there can be **chromatic aberrations** where the image separates into a red image and blue image.
   - chromatic aberations can be eliminated by using a reflecting telescope.
   - This "bending" of light by altering its speed is used to focus a wide area of light down to a pinpoint.

4. Where is the best place to put a telescope?

   - Space! Then we don't have to deal with the Earth's atmosphere.
   - If we can't put a telescope in space, then any place where the atmosphere doesn't cause as many problems: dry, high, dark places.

5. How does the power of a telescope scale with its diameter?

   - Power $= \pi(D/2)^2$, where D is the diameter. So doubling the diameter will quadruple ($2^2 = 4$) the power.

6. What is the purpose of a telescope's eyepiece?

   - To magnify the focused image. The telescope itself does not magnify anything.

7. List a few of the important telescopes in use today.

   - Keck: Largest optical telescope with a 10 meter diameter, in Hawaii.
   - Large Binocular Telescope (LBT): Owned by OSU, has two 8 meter mirrors, in Arizona.
   - Hubble Space Telescope (HST): 2.4 meter, but huge advantage because it's in space and doesn't have to see through the atmosphere.