Second of the Three Astronomy Exams

May 21, 2021

Newton's Laws (Chapter 5)

1. Newton's Third Law of Motion

A 180-pound skater pushes on a 90-pound skater with 20 Newtons of force. Thanks to Newton's Third Law, we know that the 90-pound skater is pushing back on the 180-pound skater with _______ Newtons of force?

2. Newton's Universal Law of Gravitation, Proportional Reasoning

The formula for Newton's Universal Law of Gravitation is:

$$F = \frac{Gm_1 m_2}{r^2}$$

Suppose the Earth's gravity pulls on an astronomy textbook with 6 Newtons of force at the surface of the Earth. The distance from the surface of the Earth to its center is r_E. Imagine a platform that is r_E above the surface of the Earth. At this height, the Earth's gravity pulls on the textbook with ________ Newtons of force. HINT: The distance from the platform to the center of the Earth is $2\,r_E$. In other words, r has been doubled. Everything else in the formula for F is unchanged!

Making Sense of the Variety of Objects in the Solar System (Chapters 6, 7, and 8, and Section 9.1)

The definition of density is mass over volume: $\rho \equiv \frac{M}{V}$. The volume of a sphere $V = \frac{4}{3}\pi R^3$.

3. Masses and Densities of the Planets

The least dense planet is _______ and its density is ______ than water (1000 kg/m^3).

HINT/HELP: You did a whole worksheet on this, and I don't expect you to have the results memorized. To help you narrow down what to put in the blanks, I will say that it is one of these four combinations: (A) Mercury / greater (B) Mars / less (C) Jupiter / greater (D) Saturn / less.

4. An Imaginary New Planet, Proportional Reasoning

The four innermost planets, including Earth, are mostly rock, and they all have densities that are around 5000 kg / m^3. The four outermost planets are compressed gas, and have densities that are very roughly 1000 kg / m^3.

Imagine a new planet is found that has 5 times the radius of the Earth and 25 times the mass.

What is the density of this new planet? ______________

Is it probably mostly rock or mostly compressed gas? _________________

HINT: You don't need a calculator. You just need proportional reasoning and the formulas for ρ and V. You might need that $5^3 = 125$ or that 25/125 = 1/5.

5. Kuiper Belt Objects

Neptune's semi-major axis is about 30 AU. The Kuiper Belt Objects (KBOs) are mostly beyond Neptune and they go out to about 50AU. An object larger than Pluto that is currently 97AU from the Sun was first sighted in 2003 and confirmed in 2005. What explanation did Pasachoff and Filippenko give to explain why this object, now called Eris, is in such a highly tilted orbit relative to the ecliptic?

____

6. Meteoroids vs. Meteorites

Meteoroids are small chunks from the size of a grain of sand to a boulder (about 1m). Anything larger than that is usually called an asteroid. What is the distinction between a meteoroid and a meteorite?

____

Observing the Sun and Other Stars (Chapters 10, and 11)

7. Parallax

The pie-crust formula in degrees is:

$$\frac{s}{R} = \frac{\theta}{57.3^\circ}$$

If you put one arc-second in for θ, and 1 A.U. in for s, and solve for R, *then by definition* you get (circle one):

(A) 1 A.U.
(B) 1 light-year
(C) 1 parsec

8. Parallax (changing the baseline)

The orbital distance from the Earth to the Sun is 150,000,000 km. The pie-crust formula with that and all the conversions to arcseconds put in is:

$$\frac{150{,}000{,}000\ \text{km}}{R} = \frac{\theta}{57.3 \times 60 \times 60\ \text{arcseconds}}$$

Suppose astronomers put a telescope on Mars, which has an orbital radius of 225,000,000 km (that's 1.5 A.U.). If we measured a parallax angle of 0.2 arcseconds here on Earth for some star, then the telescope on Mars would observe a parallax angle of ____________________.

HINT/HELP: If you don't see what changing 150,000,000 km to 225,000,000 km does to the above formula, it could conceivably help to draw a parallax angle diagram and note what is changing if the baseline increases from 150,000,000km to 225,000,000km.

9. Parallax (the nearest star)

In round numbers, the nearest star, Alpha Centauri has a parallax angle of 3/4 of an arcsecond. This star is therefore about:

(A) 3/4 of a parsec away
(B) 4/3 of a parsec away
(C) 3/4 of a light-year away
(D) 4/3 of a light-year away

10. Inverse Square Law for Light

The formula for intensity or brightness (called the inverse square law for light) is:

$$b = \frac{L}{4\pi R^2}$$

Suppose two stars have the same luminosity, *L*. Suppose Star 1 is three times as far away from Earth as Star 2. Then the brightness of Star 1 we would measure is:

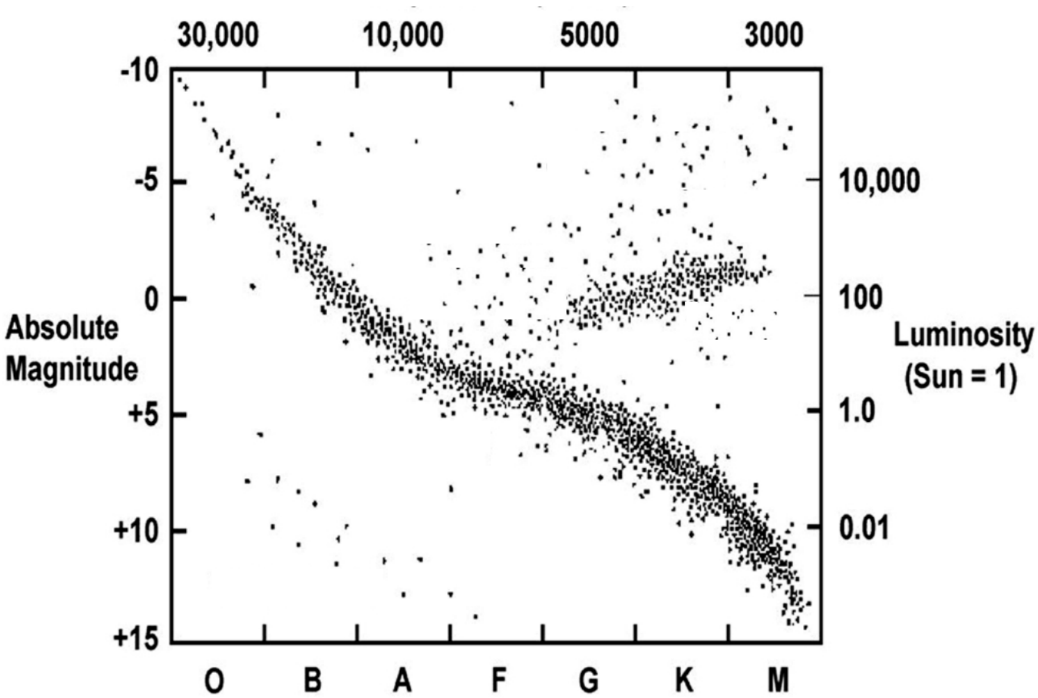
(A) 9 times the intensity of Star 2
(B) 3 times the intensity of Star 2
(C) 1/3 the intensity of Star 2
(D) 1/9 the intensity of Star 2

11. Inverse Square Law and Absolute Magnitude

Imagine moving a star from 100 parsecs away from us to the standard distance of 10 parsecs (the distance we use to determine absolute magnitude). After this imaginary movement, the star would appear:

______ times brighter/dimmer (circle one) and this is a change of _______ magnitudes. After this imaginary movement to the standard distance a star of magnitude 6 would then appear as a star of whose absolute magnitude is ______?

12. HR Diagrams



From the Hertzsprung-Russell diagram above which shows many stars, if you see a B-Type star that is 20,000K, then *most likely* it has absolute magnitude:

(A) -7
(B) -1.5
(C) +4
(D) +9.5

13. HR Diagrams

90% of all stars on the HR diagram fall into a region called:

(A) the main sequence
(B) the red giant region
(C) the white dwarf region

Within this region, the stars that are largest, heaviest, and brightest (circle all that are correct):

(W) last the longest because they have the most hydrogen to convert to helium
(X) burn out the soonest because they convert their hydrogen disproportionately quickly
(Y) are the O and B stars
(Z) are the K and M stars

Energy, Power, Intensity, and Fusion (Chapter 12)

14. Ivy Mike Fusion Bomb and $E = mc^2$

The process that powers the Sun was unleashed on the Earth when the Ivy Mike H-Bomb was exploded in 1952. It produced about 4.5×10^{16} Joules.

Using the the $E = m c^2$ formula, how much mass disappeared in this explosion?

(A) 0.5 kg (B) 0.5 g (C) 1.5×10^8 kg (D) 1.5×10^8 g

HINT/RECALL: If you use MKS units (Newtons, Watts, Joules, meters, and seconds) then your answers come out in kg.

15. The Amount of Hydrogen in the Sun

The Sun’s mass is 1.99×10^{30} kg. The mass of a hydrogen atom is 1.67×10^{-27} kg. Let’s just be sloppy and round those two numbers to 2×10^{30} kg and 2×10^{-27} kg. Pretending that the entire Sun is hydrogen and not any other elements, how many hydrogen atoms are there in the Sun?

(A) 4×10^{57} (B) 10^{57} (C) 10^{-57} (D) 4×10^{-57}

16. Nuclear Fusion in the Sun (I added a 16th problem so that if you miss one, you still have a chance of getting 15/15 :))

The net effect of the basic reaction in the Sun is four Hydrogens becomes one Helium. In this reaction, 0.02862 atomic mass units becomes energy. An atomic mass unit is 1.67×10^{-27}kg. From the $E = m c^2$ formula find the energy that the reaction must release.

So that you can do this without a calculator, round 0.02862 to 0.03, and write 1.67×10^{-27}kg as $\frac{5}{3} \times 10^{-27}$ kg. The only other thing that you need is the speed of light which is $3 \text{x} 10^8$ m/s. You are also going to have to remember the difference between a Joule and a Watt (of course if you read some of the prior problems carefully, you will have refreshed your memory)!

(A) 0.45×10^{-11} Joules
(B) 0.45×10^{-11} Watts
(C) 0.045×10^{-27} Joules
(D) 0.045×10^{-27} Watts