RLP-PHYB · RLP Physics B — Energy, Thermal Physics, Electromagnetism and Waves

Unit 5: Missouri Physics Supplement

Practice Workbook. The same problems, in the same order, as the Practice sections of the online lessons.

Name _____ Period _____

Lesson 5.1 — Stars, Elements and the Big Bang

FLUENCY

1. What is the net fusion reaction in the Sun's core, and where does the released energy come from?

2. A star above about 8 solar masses fuses its way up to which element, and why does fusion stop there?

3. Name the three main pieces of evidence for the Big Bang.

4. Why does a star more than 8 times the Sun's mass live a much shorter time than the Sun, even though it has more fuel?

APPLICATION

5. Use Wien's law, $\lambda_{max} = (2.898 \times 10^{-3}\ \text{m·K}) \div T$, to find the peak wavelength of the Sun's 5,772 K photosphere. In what part of the spectrum is it?

6. The Sun's luminosity is 3.828×10^{26} W and Earth is 1.496×10^{11} m away. Use the inverse-square law to find the power per square meter reaching Earth.

7. M87 has z = 0.004283. Find its recession speed (c = 299,792 km/s) and the wavelength at which its 656.28 nm hydrogen-alpha line arrives.

CHALLENGE

8. Helium fusion turns 3×4.00260 u into exactly 12.00000 u of carbon-12. Compare the fraction of mass released with hydrogen fusion's 0.712%, and use the comparison to explain why each later stage of a massive star's life is shorter.

9. The Sun fuses about 6.0×10^{11} kg of hydrogen per second. Over its 10-billion-year main sequence (1 year = 3.156×10^{7} s), what fraction of its 1.9884×10^{30} kg mass is fused, and what does this say about why its main-sequence life ends?

10. The early-universe light was emitted at about 2,973 K and is now measured at 2.7 K. By what factor has its wavelength been stretched, and how does this connect to galaxy redshifts?

REVIEW

11. (Unit 1) Energy is conserved. Where does the energy carried away by sunlight come from, in the terms of $E = mc^2$?

12. (Unit 4) A spectral line arrives at a shorter wavelength than it was emitted. Is the source approaching or receding, and is the photon energy higher or lower?

Lesson 5.2 — Earth's Crust and Earth's Story

FLUENCY

1. According to USGS, how does the age of ocean crust change with distance from a mid-ocean ridge?

2. Give the best age for Earth and the solar system, and name the material that gives it.

3. Label each process in the St. Francois Mountains' history as constructive or destructive: volcanic ash flows; weathering of the volcanic hills; Paleozoic seas laying down limestone; erosion after the Ozark uplift.

4. Why can carbon-14 not be used to date the St. Francois Mountains?

APPLICATION

5. A ridge spreads at 5.0 cm/yr (each side 2.5 cm/yr). How far from the ridge is crust that is 20 million years old?

6. A zircon contains 0.969 atoms of lead-206 from decay for every atom of uranium-238 left. Using $t = T \log_2(1 + D/P)$ with $T = 4.5$ billion years, how old is it?

7. A St. Francois rhyolite is 1.48 billion years old. What fraction of its original potassium-40 (half-life 1.25 billion years) remains?

CHALLENGE

8. The oldest sea floor is about 180 million years old and the Acasta Gneiss 4.03 billion. Explain the 22-fold difference using density, subduction and the fact that Earth's size has not changed.

9. Why does the Moon give older rock ages than almost anywhere on Earth, and how do Moon rocks and meteorites together constrain Earth's age?

10. MDC reports the St. Francois Mountains had more than 2,000 feet of relief after their volcanic era and less than 1,000 feet today. Convert both to meters and explain which processes, internal and surface, changed the relief.

REVIEW

11. (Physics A, motion) A plate moves 2.5 cm a year. How far does it travel in 1 million years, in kilometers?

12. (Unit 2, particles and density) Denser material sinks below less dense material. How does this idea explain subduction?

Lesson 5.3 — Earth's Energy and Feedbacks

FLUENCY

1. What evidence shows that Earth's outer core is liquid?

2. State the Stefan-Boltzmann law and the meaning of each symbol.

3. Is the ice-albedo feedback reinforcing (positive) or damping (negative)? Explain in one sentence.

4. What is slab pull, and which half of the mantle convection cycle does it represent?

APPLICATION

5. Find Earth's balance temperature for S = 1,361 W/m^2 and albedo 0.30, and compare it with 255.1 K for albedo 0.294.

6. Earth's surface averages 288 K. How much power per square meter does it radiate, and how does that compare with the 240 W/m^2 of sunlight Earth absorbs?

7. One square meter of Arctic surface receives the same sunlight whether it is covered by sea ice (albedo 0.5) or open ocean (albedo 0.06). How many times more energy does the ocean absorb?

CHALLENGE

8. Earth's interior heat flow averages 0.087 W/m^2 and absorbed sunlight 240 W/m^2. Explain which one drives plate tectonics and which one controls climate, using the ratio.

9. Before channelization a reach of the Missouri River was 1,200 ft wide; afterward 600 ft. Model a flood with the same discharge and the same speed in both channels. How must the depth change, and what does this predict about flood stages?

10. St. Louis warmed 3.5 °F (1.9 K) between the 1960s and 2016-2025. A 0.1% brighter Sun warms the model 0.06 K, and Milankovitch cycles act over tens of thousands of years. Which variation in energy flow best fits the St. Louis change, and what is one caution?

REVIEW

11. (Unit 2) Why does a dark roof get hotter in sunlight than a white one, and what is the Earth-scale version of the same idea?

12. (Unit 2) Thermal energy flows from hot to cold on its own. How does this drive mantle convection?