Section 10: Astronomy and Astrophysics

1. Scale Comparison

How many times farther is the Sun from Earth compared to the Moon from Earth? (Sun-Earth distance $\approx 150 \times 10^6$ km; Moon-Earth distance $\approx$ 384,000 km).

2. Angular Size

Calculate the angular size (in degrees) of the Sun and the Moon as seen from Earth. Sun's diameter $\approx 1.39 \times 10^6$ km; Moon's diameter $\approx$ 3,474 km. Why do they appear to be roughly the same size?

3. Rotational Velocity

Calculate the linear speed (in km/s) of a point on the Earth's equator due to its rotation. Earth's radius $\approx$ 6378 km.

4. Orbital Mechanics

Calculate the orbital speed of the International Space Station (ISS), which orbits at an altitude of approximately 400 km above the Earth's surface. (Earth's mass $M_E \approx 5.97 \times 10^{24}$ kg).

5. Microgravity

What is the acceleration due to gravity (g) at the altitude of the ISS (400 km)? Why do astronauts experience a state of "weightlessness" despite this gravity?

6. Geostationary Orbit

Satellites in geostationary orbit remain above the same point on Earth. What must their orbital period be? Calculate the altitude of a geostation-ary orbit above the Earth's surface.

7. Escape Velocity

What is the escape velocity from the surface of the Moon? (Moon's mass $M_M \approx 7.35 \times 10^{22}$ kg; Moon's radius $R_M \approx$ 1,737 km).

8. Solar Gravity

Calculate the acceleration due to gravity on the surface of the Sun. By what factor would your weight increase if you could stand on its surface? (Sun's mass $M_S \approx 2 \times 10^{30}$ kg; Sun's radius $R_S \approx 6.96 \times 10^8$ m).

9. Stellar Density

A white dwarf star has a mass roughly equal to the Sun's mass but a radius similar to the Earth's radius (~6371 km). What is the average density of such a white dwarf?

10. Megastructures

A "Dyson Sphere" is a hypothetical megastructure that completely encompasses a star to capture its energy output. If the mass of Mercury (3.3×10^{23} kg) were used to build a solar panel sphere with a surface density of 10 kg/m^2, what would be the radius of the sphere?