

Gravity and Orbits — Lab and Discussion Questions

Name: _____ Class: _____ Date: _____

Open the free **Gravity and Orbits** simulation by PhET (eolclassroom-online.com/classroom-simulations/ or phet.colorado.edu) and choose the **Model** screen. Select the scene with the **Sun and Earth** (top row of the panel). Turn on **Gravity Force**, **Velocity** and **Path**.

Part A — What keeps Earth in orbit?

1. Press play. Describe the shape of Earth's path. About how many Earth days does one orbit take?

2. Look at the gravity force arrows (blue). Which way do they point on Earth? On the Sun?

3. Compare the size of the force arrow on the Sun with the force arrow on Earth. What do you notice? Which law of motion does this show?

4. Look at the velocity arrow (green) and the force arrow on Earth. What angle is between them during the orbit?

5. Predict, then test: what will Earth do if you switch **Gravity off** in the middle of an orbit? Prediction: _____

What happened? Which law of motion explains it?

Part B — Change the masses

Press the reset button for the scene before each test (the round arrow next to the scene).

Change	Prediction	What happened to Earth's orbit?
Star mass → 2.0		
Star mass → 0.5		
Planet mass → 2.0		
Planet mass → 0.5		

6. Increasing the star's mass changed the orbit a lot. Explain why using the idea of force.

7. Changing the planet's mass made the force arrows bigger or smaller but hardly changed the orbit. Explain why (hint: $a = F \div m$).

Part C — Change the speed

Pause the simulation and drag the tip of Earth's velocity arrow to make it longer or shorter. Press play each time.

8. What happens when Earth starts **slower** than normal?

9. What happens when Earth starts **faster** than normal? What happens if it is much faster?

10. On a stretched (elliptical) orbit, where is Earth moving fastest: near the Sun or far from it?

Part D — Other systems

11. Choose the **Earth and Moon** scene. How many Earth days does one orbit of the Moon take?

12. Choose the **Earth and satellite** scene. How long does one orbit take? Why is it so much shorter than the Moon's orbit?

13. Switch to the **To Scale** screen. Why are the Sun, Earth and Moon drawn so much larger on the Model screen?

Part E — Discuss

14. Newton said the Moon is constantly "falling" toward Earth. Explain what he meant, using what you saw in Part A.

15. The gravitational force is $F = G \times m_1 \times m_2 \div r^2$. If the distance between two objects doubles, what happens to the force? If one mass doubles?

Answer Key (Teacher Copy)

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Part A

1. Nearly circular (a slight ellipse). One orbit takes about 365 Earth days.
2. On Earth, the force points toward the Sun. On the Sun, it points toward Earth.
3. The two arrows are the same size and point in opposite directions. This is Newton's third law: the Sun pulls on Earth exactly as hard as Earth pulls on the Sun.
4. About 90°: the force is perpendicular to the velocity in a circular orbit. The force changes Earth's direction, not its speed.
5. Earth moves off in a straight line at constant speed, along the direction it was moving at that moment (tangent to the orbit). Newton's first law: an object keeps moving in a straight line unless a force acts on it.

Part B

Change	What happened
Star mass → 2.0	The pull is stronger; Earth curves in more tightly, so its orbit becomes smaller and more elliptical (it may come very close to the star).
Star mass → 0.5	The pull is weaker; Earth swings out into a much larger orbit or escapes. (With half the star's mass, Earth's normal speed is exactly the escape speed.)
Planet mass → 2.0	Force arrows get bigger, but the orbit is almost unchanged.
Planet mass → 0.5	Force arrows get smaller, but the orbit is almost unchanged.

6. A more massive star exerts a stronger gravitational force on Earth. With the same starting speed, the stronger force bends Earth's path more, pulling it inward.
7. Doubling Earth's mass doubles the force on it, but also doubles the mass that has to be accelerated. Since $a = F \div m$, Earth's acceleration (and therefore its path) stays the same. This is the same reason heavy and light objects fall at the same rate.

Part C

8. Earth falls inward into a smaller, elliptical orbit. If it is much too slow, it can crash into the Sun.
9. Earth moves out into a larger, elliptical orbit. If it is fast enough, it escapes the Sun completely and does not return.
10. Fastest near the Sun, slowest far from it (Kepler's second law).

Part D

11. About 27 Earth days.
12. Roughly 90 minutes (shown in Earth minutes). The satellite is much closer to Earth, where gravity is stronger, so it must move faster and has a much shorter path to complete.
13. In real proportions the bodies are tiny compared with the distances between them, so they would be almost invisible. The Model screen enlarges them so we can see them.

Part E

14. The Moon is always accelerating toward Earth because of gravity. It is also moving sideways so fast that, as it falls, Earth's surface curves away beneath it, so it keeps falling *around* Earth instead of into it.
15. Doubling the distance makes the force one quarter as large (inverse square law). Doubling one mass doubles the force.