Design a Helicopter for Mars

Student worksheet — *Answer key*

Directions: Complete the sections below in preparation for your design challenge.

1. The following statements are false. Correct the statement(s) assigned to your group and explain why the statement is incorrect.

    a. Gravity pushes Earth away from the Sun.

    Correction: Gravity pulls the Earth toward the Sun.

    Explanation: The gravitational force never pushes. It is always attractive, so it can only pull objects closer together.

    The gravitational pull of the Sun makes the solar system planets (e.g. Earth) continuously "fall" toward the Sun, but the planets move just fast enough so their fall has a curvature that creates an almost circular orbit around the Sun. If the planets were to move at a higher velocity, they would move away from the Sun. If they were to move at a lower velocity, they would fall into the Sun.

    (See figures on the next page. These figures are also included in slides 3 and 4 of the slideshow.)

    b. Gravity pulls harder on objects that are farther away.

    Correction: Gravity pulls harder on objects that are closer together.

    Explanation: The gravitational pull lessens as you move farther away. Students might know that spacecraft need to overcome Earth's gravity when flying into space, and they might know that the gravitational pull on satellites is less than the gravitational pull on Earth's surface.

    For a more complex example, Venus and Earth have roughly the same mass, but the gravitational pull of the Sun on Venus is greater than the gravitational pull of the Sun on Earth because Venus is much closer to the Sun. For that reason, Venus needs to move faster (231 Earth days/revolution) to stay in orbit compared to Earth (365.24 Earth days/revolution).

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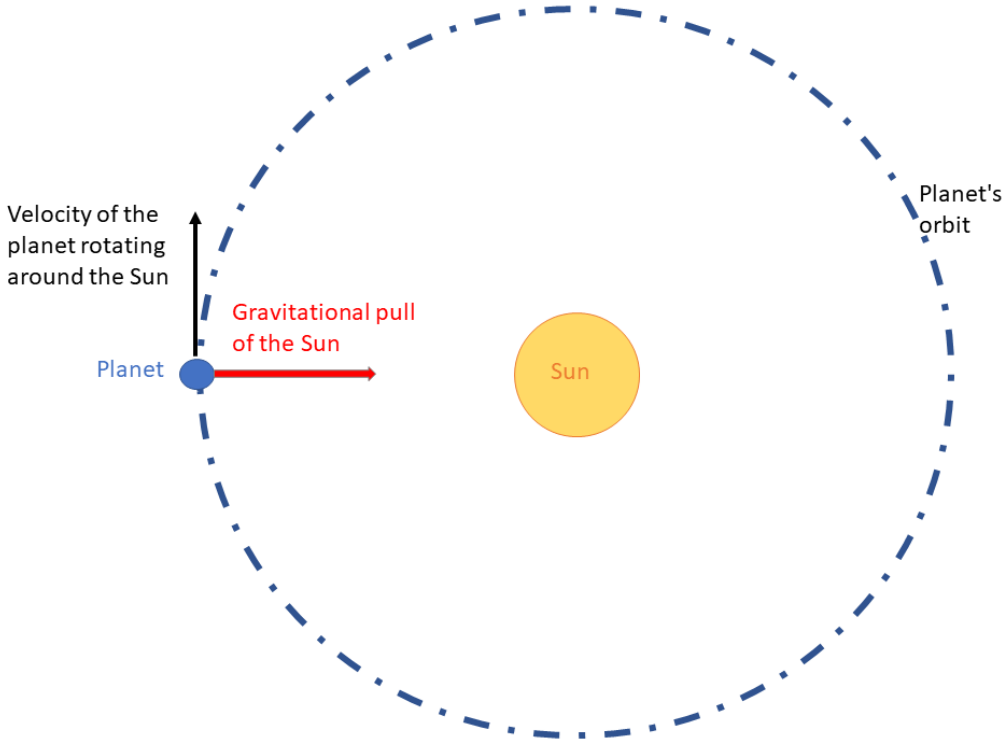
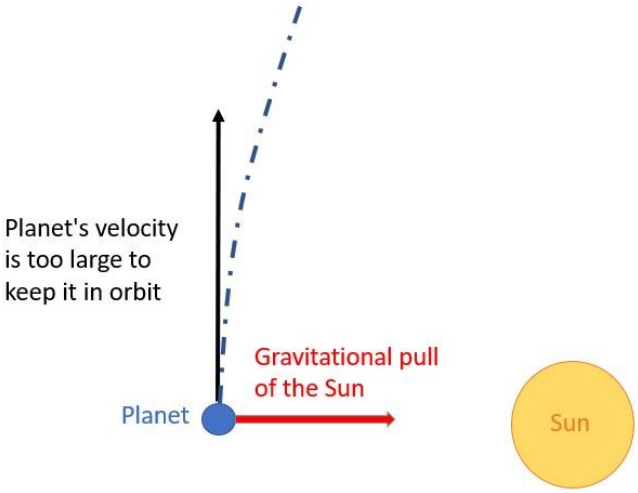
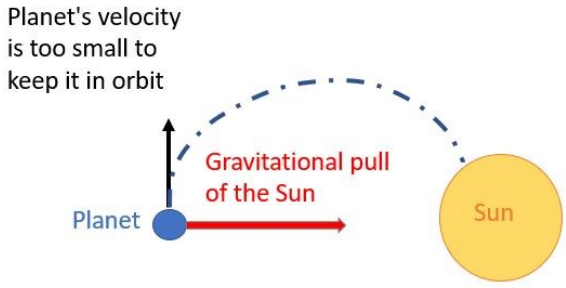






c. On Earth, the gravitational pull of the Sun does not act on us.

Correction: On Earth, the Sun's gravitational pull acts on us, but because our mass is so small, we do not notice it.

Explanation: No matter where you are in the solar system, the gravitational pull of the Sun is acting on you. Our mass is too small to notice the pull of the Sun on us; with this small mass, we would need to be much closer to the Sun to notice it. We know the gravitational pull of the Sun is there, however, because it pulls Earth into orbit.

d. Fact: Earth is 10 times more massive than Mars, and its diameter is smaller than that of Earth. Statement: Because of these differences, the mass of a helicopter on the surface of Mars is less than the mass of the same helicopter on the surface of Earth.

Correction: Earth is 10 times more massive than Mars, and its diameter is smaller than that of Earth. Because of these differences, the weight of a helicopter on the surface of Mars is less than the weight of the same helicopter on the surface of Earth.

(See sample explanation and figure on the next page.)

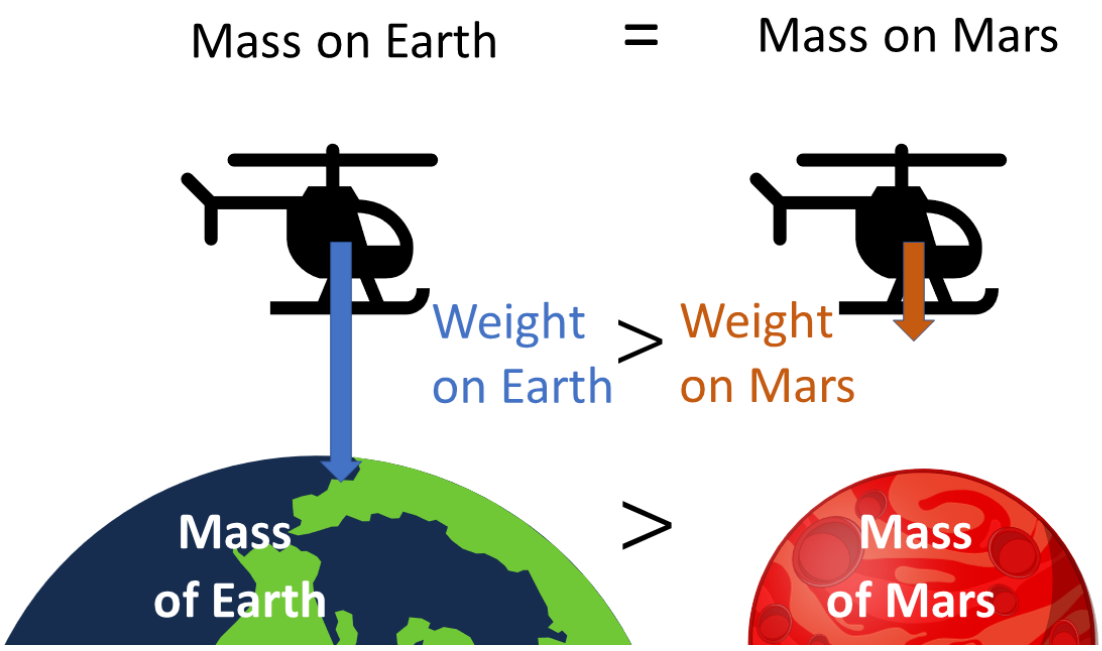
e. Fact: Helicopter blades use air to create lift (the force that pushes upward on the helicopter blades). Statement: Mars has a thinner atmosphere than Earth, so it is easier

Correction: Helicopter blades use air to create lift (the force that pushes upward on the helicopter blades). Mars has a thinner atmosphere than Earth, so it is harder to create lift on Mars compared to Earth.

Explanation: Rotating helicopter blades (or rotors) push air down, creating a net upward push, called lift. In general, the denser the air (i.e., the more particles like oxygen, water, etc. packed into a cubic centimeter of air), the harder the air can press on surfaces. The Martian atmosphere is 100 times less dense than Earth's atmosphere, so rotating blades on Mars cannot create as much lift compared to the same blades rotating on Earth.

Explanation of statement 1.d: The mass is a measure of how much material is in the object. It does not change when you place an object in a new environment. However, the weight of an object, or how much gravity pulls on the object, depends on its location.

Because Earth is 10 times more massive than Mars, it exerts a much stronger gravitational pull on objects in its vicinity compared to Mars. Note that Mars is also smaller, so objects on its surface are closer to its center. Because of this difference, the weight of objects on Mars is not 10 times less than the same object on Earth, but about 62% less.



2. In your own words, write a definition of gravity:

   Example: Gravity is the force by which a planet or other large mass draws objects with mass toward itself.

   Students should have the following facts included in their definition:
   - Gravity is a **force.**
   - Gravity pulls **masses** toward each other; it is always attractive.
   - Gravity is a very **small force**, except when one or both of the masses is very large.

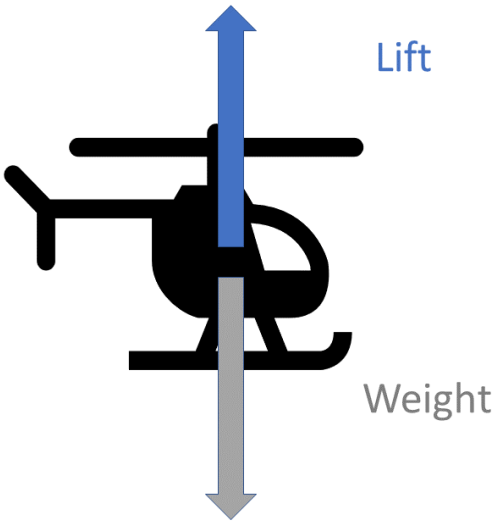
Directions: Complete the sections below to work through the engineering design process.

The Problem:

Helicopters built to fly on Earth do not fly on Mars. Your goal is to find design solutions for a helicopter that can fly on Mars.

Do background research.

3. What are the two main vertical forces that act on a helicopter? Think of what pulls the helicopter down and what keeps it in the air. Draw a helicopter (or paper helicopter) and indicate these forces with arrows.



4. Briefly write down how these forces are different on Mars compared to on Earth?
    - The helicopter weighs less on Mars compared to on Earth.
    - The air is thinner on Mars, so it is much harder to create lift.
    - Overall, it is harder to fly a helicopter on Mars than it is to fly a helicopter on Earth.

5. From that knowledge, what should be your goal for the weight and the lift when engineering a helicopter that needs to fly on Mars?
    - Lightweight
    - Rotors that can create a lot of lift

Make a prototype.

6. Use the template to make a paper helicopter. This paper helicopter is your initial design.

Brainstorm

7. In your group, brainstorm ideas to improve the design of the paper helicopter so it is better-suited to fly on Mars.

Evaluate, choose solutions, and test.

8. How will you measure improvement in your design? If you decide to use quantitative data (e.g., a time or number of frames in a video), take a measurement for your initial design and write down the result.

    A helicopter that falls more slowly on Earth will fly better on Mars as well, so we can use the time it takes to fall from a fixed height as a measure of improvement. A slower fall indicates a better performance.

9. Decide which design solution(s) you want to test. Make a prototype, and then test it. Record your findings in the Prototype 1 line of Table 1.

Answer Key

Make design changes based on the results.

10. Draw conclusions from your tests and use the data to redesign your prototype. Record at least 2 iterations in Table 1. Label your prototypes and keep them, as you might want to use them to communicate your findings later.

Table 1: Test results

Description or drawing of the main design features	Improvement? Yes/No If available: Quantitative data	What did we learn from this design iteration?
Prototype 1		
Iteration		
Iteration		

Answer Key

Communicate results.

11. Look back at the data you collected. What design advice would you give to the NASA design team tasked with designing a helicopter for Mars (what to do, as well as what not to do)? Provide at least two suggestions.

12. Choose the best-performing design and describe its main features?

13. Prepare to present your advice and best-performing model in a clear, concise, and convincing way. Use the data you collected to support your claims.