Science: Physics

Gravitational Acceleration

Objectives

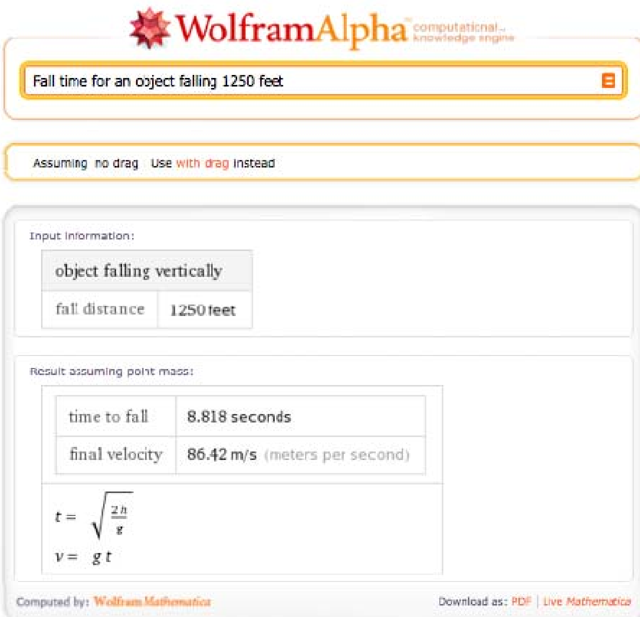
Students will be able to:

- Review the formulas for fall time and final velocity of a free-falling object.
- Derive the formula for acceleration due to gravity, *g*.
- Understand the independence of an object's weight and its acceleration due to gravity.
- Calculate quantifiable effects of air resistance on a falling object.

Warm-Up

Ask students to guess the final velocity of a brick dropped off the roof of the Empire State Building. Use W|A to look up the height of the building.

Then look up the fall time for the object.

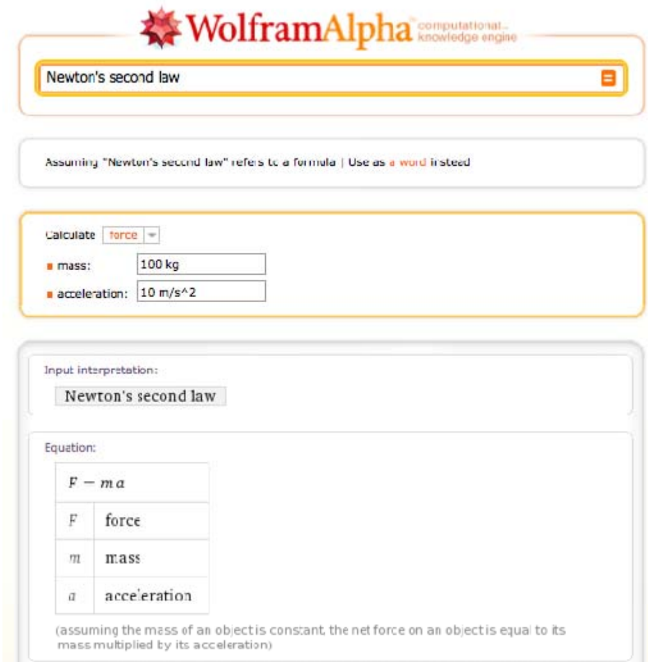


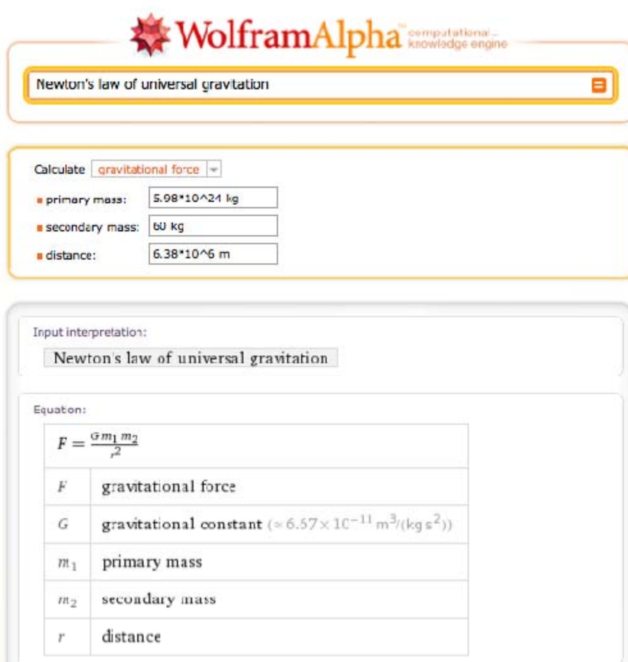
Now ask students: What would be the final velocity of a block of balsa wood dropped from the same height? Is there a difference? Was mass a variable in the equation used to answer the question?

Lesson

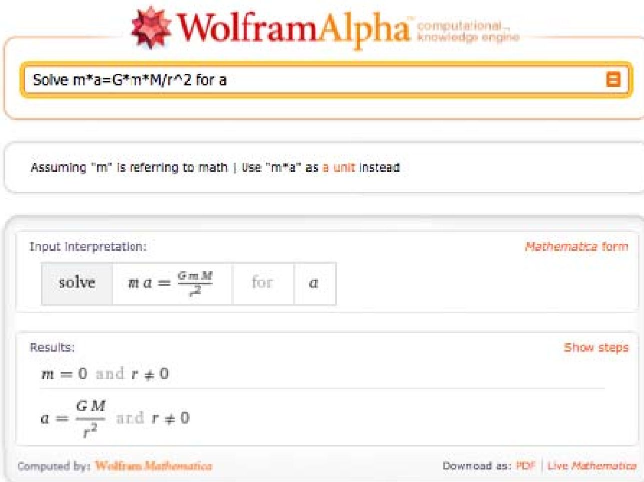
• Review Aristotle's statement that heavy objects fall faster than lightweight ones. Discuss how this statement was accepted as fact for thousands of years, and explain Galileo's overturning of this misconception and Newton's discovery of the mathematical basis for the independence of an object's mass and its gravitational acceleration.

• Ask students to derive for themselves the independence of an object's mass and its gravitational acceleration using Newton's second law and his law of universal gravitation. Check the formulas with W|A.





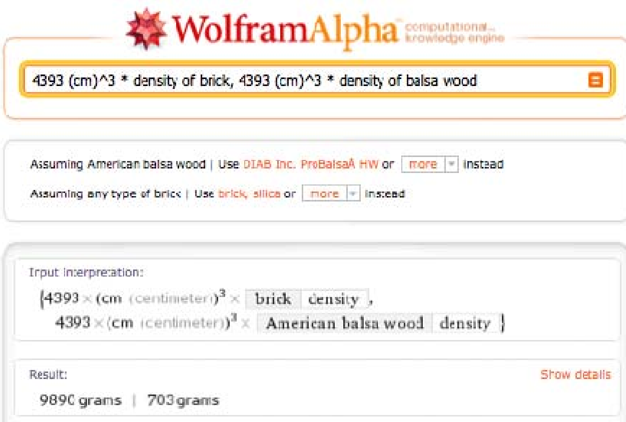
• Explain that in the case of gravitational acceleration, the term *a* in the second law is equal to gravitational acceleration *g*, so the force *F* must be the force of gravity and the two equations can be set equal to each other. Have students rename m_1 to m and m_2 to M in the formula for gravitational force and solve for *a* (check solution with W|A).



• Ask students why Aristotle's error was considered true for so long. Students should recognize that falling objects experience forces of air resistance that *do* depend in part upon mass.

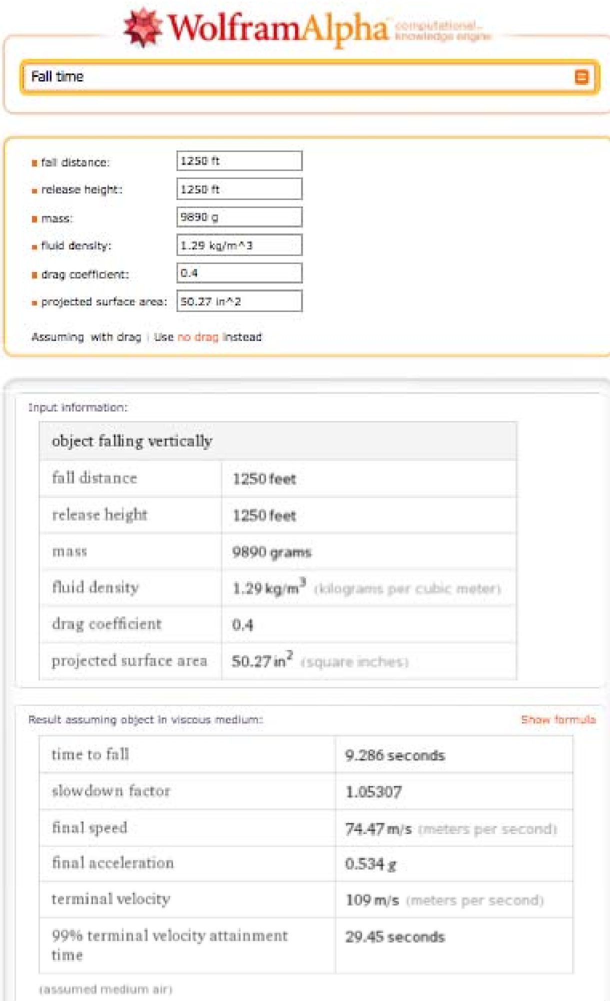
Closing

• Ask students to use W|A to predict the effects of air resistance (drag) on falling objects made of brick and balsa wood. For simplicity's sake, use spheres instead of bricks (W|A can tell you the average brick has dimensions 8x4x2.5, so instruct them to use 8 inches for the diameter of the sphere). Students will need to know the mass, drag coefficient, and projected area of each sphere. Instruct them to calculate the volume of both spheres and the mass of each, finding densities with W|A.



• Now ask students to assume the drag coefficient of both spheres to be 0.4, and to find their projected surface area (simply the area of a circle with radius 8 in).

• Now ask students to input this data in W|A's falling object calculator and find the fall times and final velocities of spheres made of brick and balsa wood.


WolframAlpha computational knowledge engine

Fall time

- fall distance: 1250 ft
- release height: 1250 ft
- mass: 9890 g
- fluid density: 1.29 kg/m^3
- drag coefficient: 0.4
- projected surface area: 50.27 in^2

Assuming with drag | Use no drag instead

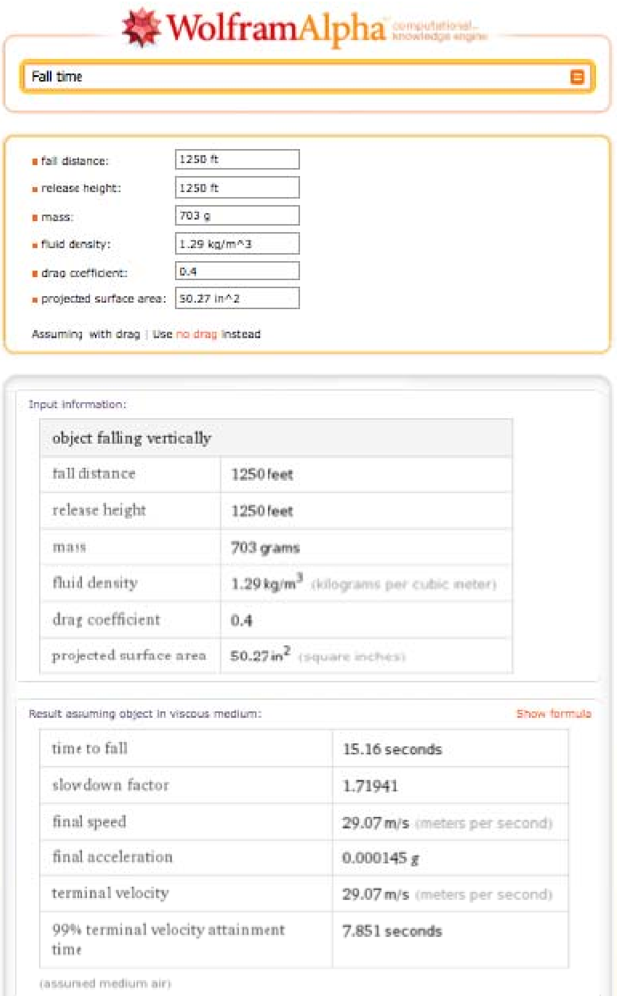
Input information:

object falling vertically	
fall distance	1250 feet
release height	1250 feet
mass	9890 grams
fluid density	1.29 kg/m^3 (kilograms per cubic meter)
drag coefficient	0.4
projected surface area	50.27 in^2 (square inches)

Result assuming object in viscous medium: Show formula

time to fall	9.286 seconds
slowdown factor	1.05307
final speed	74.47 m/s (meters per second)
final acceleration	0.534 g
terminal velocity	109 m/s (meters per second)
99% terminal velocity attainment time	29.45 seconds

(assumed medium air)



• Point out to students that the final speed of the brick sphere is more than twice that of a similarly shaped object made of balsa wood. Assign them to perform similar computations with objects of different sizes or compositions.

Demonstrations

Free Fall on the Solar System Planets and the Moon

Velocity of a Falling Object

Projectile with Air Drag