

Part A: Concepts and Patterns

Explain your reasoning. No calculator needed for problems 1 and 2.

- Earth pulls down on Priya with a gravitational force of 600 N.
 - How hard does Priya pull up on Earth? Explain.
 - Priya sits 1 m from her friend in class. Why can't she feel the gravitational pull between them, even though every two masses attract?

a. 600 N. The two forces are a Newton's third law pair, so the pull is the same size on both objects, even though Earth is much bigger.

b. G is incredibly small, so the force between two everyday masses is tiny (about 10^{-7} N, far too small to feel). Gravity only becomes noticeable when at least one of the masses is enormous, like a planet.
- An astronaut weighs 1200 N on Earth's surface, one Earth radius ($1 R$) from Earth's center. Fill in the table to show the gravitational force on the astronaut at each distance from Earth's center. The last row is a different astronaut with twice the mass.

Distance from Earth's center	Gravitational force
1 R	1200 N
2 R	300 N
3 R	133 N
4 R	75 N
3 R , astronaut with twice the mass	267 N

Gravity is an inverse square law: force = $1200 \text{ N} \div (\text{distance in } R)^2$.

2 R : $1200 \div 4 = \mathbf{300 \text{ N}}$. **3 R :** $1200 \div 9 = \mathbf{133 \text{ N}}$. **4 R :** $1200 \div 16 = \mathbf{75 \text{ N}}$.

Twice the mass at 3 R : force is proportional to mass, so $2 \times 133 \text{ N} = \mathbf{267 \text{ N}}$.

Part B: Using the Law of Gravitation

Use $F_g = Gm_1m_2/d^2$ with $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$. Show knowns, equation, substitution, and answer with units.

- Two boulders on a hillside have masses of $1.2 \times 10^3 \text{ kg}$ and $1.5 \times 10^3 \text{ kg}$. Their centers are 5.0 m apart. What is the gravitational force between them?

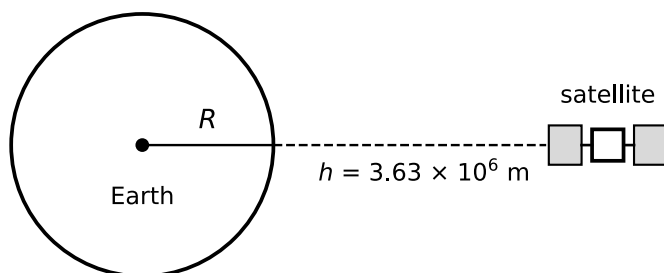
Knowns: $m_1 = 1.2 \times 10^3 \text{ kg}$, $m_2 = 1.5 \times 10^3 \text{ kg}$, $d = 5.0 \text{ m}$, $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$

Equation: $F_g = Gm_1m_2/d^2$

Top: $(6.67 \times 10^{-11})(1.2 \times 10^3)(1.5 \times 10^3) = 1.20 \times 10^{-4}$. **Bottom:** $(5.0 \text{ m})^2 = 25 \text{ m}^2$

Answer: $F_g = 1.20 \times 10^{-4} \div 25 = \mathbf{4.8 \times 10^{-6} \text{ N}}$ (attractive, like all gravity)

4. A 2.0×10^3 kg weather satellite orbits 3.63×10^6 m above Earth's surface. Earth's mass is 5.97×10^{24} kg and its radius is $R = 6.37 \times 10^6$ m.



- a. What is the distance d from Earth's center to the satellite?
 b. What is the gravitational force between Earth and the satellite?

a. d is measured center to center: $d = R + h = 6.37 \times 10^6$ m + 3.63×10^6 m = **1.00×10^7 m**

b. Knowns: $m_1 = 5.97 \times 10^{24}$ kg, $m_2 = 2.0 \times 10^3$ kg, $d = 1.00 \times 10^7$ m

Top: $(6.67 \times 10^{-11})(5.97 \times 10^{24})(2.0 \times 10^3) = 7.96 \times 10^{17}$. **Bottom:** $(1.00 \times 10^7 \text{ m})^2 = 1.00 \times 10^{14} \text{ m}^2$

Answer: $F_g = 7.96 \times 10^{17} \div 1.00 \times 10^{14} = \mathbf{7.96 \times 10^3 \text{ N}}$ (about 8.0×10^3 N)

Using only $h = 3.63 \times 10^6$ m for d is a common mistake and gives a force more than 7 times too big.

5. In a lab, a 20.0 kg lead sphere and a 30.0 kg lead sphere attract each other with a force of 1.00×10^{-8} N. How far apart are their centers?

Knowns: $m_1 = 20.0$ kg, $m_2 = 30.0$ kg, $F_g = 1.00 \times 10^{-8}$ N, $G = 6.67 \times 10^{-11} \text{ N}\cdot\text{m}^2/\text{kg}^2$

Rearrange: $d^2 = Gm_1m_2/F_g$

Substitute: $d^2 = (6.67 \times 10^{-11})(20.0)(30.0) / 1.00 \times 10^{-8} = 4.00 \times 10^{-8} / 1.00 \times 10^{-8} = 4.00 \text{ m}^2$

Answer: $d = \sqrt{(4.00 \text{ m}^2)} = \mathbf{2.00 \text{ m}}$

6. A 75 kg astronaut lands on a planet with a radius of 3.4×10^6 m. On the planet's surface, the planet pulls on her with a force of 277 N. What is the mass of the planet?

Knowns: $m_2 = 75$ kg, $d = R = 3.4 \times 10^6$ m (she is on the surface), $F_g = 277$ N

Rearrange: $m_1 = F_g d^2 / (Gm_2)$

Top: $(277 \text{ N})(3.4 \times 10^6 \text{ m})^2 = 3.20 \times 10^{15}$. **Bottom:** $(6.67 \times 10^{-11})(75 \text{ kg}) = 5.00 \times 10^{-9}$

Answer: $m_1 = 3.20 \times 10^{15} \div 5.00 \times 10^{-9} = \mathbf{6.4 \times 10^{23} \text{ kg}}$ (this is Mars)