WORKSHEET 20 Math Skills

Gravitational Potential Energy

An automobile to be transported by ship is raised 7.0 m above the dock. If its gravitational potential energy is 6.6×10^4 J, what is the automobile's mass?

1. List the given and unknown values.

Given: *gravitational potential energy*, $PE = 6.6 \times 10^4$ J
height, $h = 7.0$ m
free-fall acceleration, $g = 9.8$ m/s^2

Unknown: *mass*, $m = ?$ kg

2. Use the gravitational potential energy equation, and rearrange it to solve for mass.

gravitational potential energy = *mass* × *free-fall acceleration* × *height*

$$PE = mgh$$

$$\frac{PE}{gh} = \frac{mgh}{gh} = m$$

3. Substitute gravitational potential energy, height, and free-fall acceleration values into the equation, and solve.

$$m = \frac{6.6 \times 10^4 \text{ J}}{9.8 \text{ m/s}^2 \times 7.0 \text{ m}} = \frac{6.6 \times 10^4 \text{ kg} \cdot \text{m}^2/\text{s}^2}{9.8 \text{ m/s}^2 \times 7.0 \text{ m}}$$

$$m = 9.6 \times 10^2 \text{ kg}$$

Practice

1. The world record for pole vaulting is 6.15 m. If the pole vaulter's gravitational potential is 4942 J, what is his mass?
2. One of the tallest radio towers is in Fargo, North Dakota. The tower is 629 m tall, or about 44 percent taller than the Sears Tower in Chicago. If a bird lands on top of the tower, so that the gravitational potential energy associated with the bird is 2033 J, what is its mass?
3. One of the largest planes ever to fly, and the largest to fly frequently, is the Ukrainian-built Antonov An-124 *Ruslan*. Its wingspan is 73.2 m and its length is 69.2 m. The gravitational potential energy associated with the plane at an altitude of 1.45 km is 3.36×10^9 J. What is the airplane's mass?

Sample Problem

The largest sea turtle found in the United States had a mass of 860 kg. If the gravitational potential energy associated with the turtle as it was being lifted onto a ship was 2.0×10^4 J, how high above the water was the turtle?

1. List the given and unknown values.

Given: *gravitational potential energy*, $PE = 2.0 \times 10^4$ J
mass, $m = 860$ kg
free-fall acceleration, $g = 9.8$ m/s^2

Unknown: *height*, $h = ?$ m

2. Use the gravitational potential energy equation, and rearrange it to solve for height.

gravitational potential energy = *mass* × *free-fall acceleration* × *height*

$$PE = mgh$$

$$\frac{PE}{mg} = \frac{mgh}{mg} = h$$

3. Substitute gravitational potential energy, mass, and free-fall acceleration values into the equation, and solve.

$$h = \frac{2.0 \times 10^4 \text{ J}}{860 \text{ kg} \times 9.8 \text{ m/s}^2} = \frac{2.0 \times 10^4 \text{ kg} \cdot \text{m}^2/\text{s}^2}{860 \text{ kg} \times 9.8 \text{ m/s}^2}$$

$$h = 2.4 \text{ m}$$

Practice

4. In 1993, Cuban athlete Javier Sotomayor set the world record for the high jump. The gravitational potential energy associated with Sotomayor's jump was 1970 J. Sotomayor's mass was 82.0 kg. How high did Sotomayor jump?

5. An 1750 kg weather satellite moves in a circular orbit with a gravitational potential energy of 1.69×10^{10} J. At its location, free-fall acceleration is only 6.44 m/s^2. How high above Earth's surface is the satellite?

6. The largest airplane ever built is the Hughes H-4 *Hercules* flying boat. Its 97.5 m wingspan is still 9.1 m longer than the next largest plane ever to be built. However, because it is made of birch (not spruce, as its popular nickname—the *Spruce Goose*—would suggest), the mass of the H-4 is 1.81×10^5 kg, considerably lighter than any other giant plane. The H-4 was flown only once, over a distance of about 1.6 km. If the maximum gravitational potential energy associated with the H-4 was 3.78×10^7 J, how high did it fly?

Sample Problem

What is the gravitational potential energy associated with a 75 kg tourist at the top floor of the Sears Tower in Chicago, with respect to the street 436 m below?

1. List the given and unknown values.

Given: *mass*, $m = 75$ kg
height, $h = 436$ m
free-fall acceleration, $g = 9.8$ m/s^2

Unknown: *gravitational potential energy*, $PE = ?$ J

2. Write out the equation for gravitational potential energy.

gravitational potential energy = *mass* × *free-fall acceleration* × *height*

$$PE = mgh$$

3. Substitute mass, height, and free-fall acceleration values into the gravitational potential energy equation, and solve.

$$PE = (75 \text{ kg}) \times (9.8 \text{ m/s}^2) \times (436 \text{ m}) = 3.2 \times 10^5 \text{ kg} \cdot \text{m}^2/\text{s}^2$$

$$PE = 3.2 \times 10^5 \text{ J}$$

Practice

7. With an elevation of 5334 m above sea level, the village of Aucanquilca, Chile is the highest inhabited town in the world. What would be the gravitational potential energy associated with a 64 kg person in Aucanquilca?

8. The peak of the extinct volcano Volcán Chimborazo in Ecuador is the farthest point on Earth from Earth's center. This is because Earth bulges outward due to its rotation, and this bulge is greatest at the Equator, which is only about 100 km north of Chimborazo. Volcán Chimborazo's summit is 6267 m above sea level. If a mountain climber with a mass of 85 kg (climbing equipment included) reaches the mountain's peak, what is the gravitational potential energy associated with the climber with respect to sea level?

Mixed Review

9. The Royal Gorge Bridge is situated 321 m above the Arkansas River in Colorado. If the gravitational potential energy associated with a tourist on the bridge is 1.73×10^5 J with respect to the river, what is the tourist's mass?

10. The most massive piece of equipment ever carried by a plane was a 1.24×10^5 kg generator built in Germany in 1993. How far above the ground was the generator when the potential energy associated with it was 9.17×10^8 J?