



A tidal force is a difference in the strength of gravity between two points. The gravitational field of the moon produces a tidal force across the diameter of Earth, which causes the Earth to deform. It also raises tides of several meters in the solid Earth, and larger tides in the liquid oceans.

If the tidal force is stronger than a body's cohesiveness, the body will be disrupted. The minimum distance that a satellite comes to a planet before it is shattered this way is called its Roche Distance. The artistic image to the left shows what tidal disruption could be like for an unlucky moon.

A human falling into a black hole will also experience tidal forces. In most cases these will be lethal! The difference in acceleration between the head and feet could be many thousands of Earth Gravities. A person would literally be pulled apart! Some physicists have termed this process spaghettification!

$$a = \frac{2GMd}{R^3}$$

Problem 1 - The equation lets us calculate the tidal acceleration, **a**, across a body with a length of **d**. The acceleration of gravity on Earth's surface is 979 cm/sec^2 . The tidal acceleration between your head and feet is given by the above formula. For **M** = the mass of Earth (5.9×10^{27} grams), **R** = the radius of Earth (6.4×10^8 cm) and the constant of gravity whose value is $G = 6.67 \times 10^{-8} \text{ dynes cm}^2/\text{gm}^2$ calculate the tidal acceleration, **a**, if **d** = 2 meters.

Problem 2 - What is the tidal acceleration across the full diameter of Earth?

Problem 3 - A stellar-mass black hole has the mass of the sun (1.9×10^{33} grams), and a radius of 2.9 kilometers. A) What would be the tidal acceleration across a human at a distance of 100 kilometers? B) Would a human be spaghettified?

Problem 4 - A supermassive black hole has 100 million times the mass of the sun (1.9×10^{33} grams), and a radius of 295 million kilometers. What would be the tidal acceleration across a human at a distance of 100 kilometers from the event horizon of the supermassive black hole?

Problem 5 - Which black hole could a human enter without being spaghettified?

Answer Key:

Problem 1 - The equation lets us calculate the tidal acceleration, **a**, across a body with a length of **d**. The acceleration of gravity on Earth's surface is 979 cm/sec^2 . The tidal acceleration between your head and feet is given by the above formula. For M = the mass of Earth (5.9×10^{27} grams), R = the radius of Earth (6.4×10^8 cm) and the constant of gravity whose value is $G = 6.67 \times 10^{-8} \text{ dynes cm}^2/\text{gm}^2$ calculate the tidal acceleration, **a**, if $d = 2$ meters.

$$\begin{aligned} \text{Answer: } a &= 2 \times (6.67 \times 10^{-8}) \times (5.9 \times 10^{27}) \times 200 / (6.4 \times 10^8)^3 \\ &= 0.000003 \times (200) \\ &= 0.0006 \text{ cm/sec}^2 \end{aligned}$$

Problem 2 - What is the tidal acceleration across the full diameter of Earth?

$$\text{Answer: } d = 1.28 \times 10^9 \text{ cm, so } a = 0.000003 \times 1.28 \times 10^9 = 3,840 \text{ cm/sec}^2$$

Problem 3 - A stellar-mass black hole has the mass of the sun (1.9×10^{33} grams), and a radius of 2.9 kilometers. A) What would be the tidal acceleration across a human at a distance of 100 kilometers? B) Would a human be spaghettified?

$$\begin{aligned} \text{Answer: } a &= 2 \times (6.67 \times 10^{-8}) \times (1.9 \times 10^{33}) \times 200 / (1.0 \times 10^7)^3 \\ &= 50,700,000 \text{ cm/sec}^2 \\ &\text{Yes, this is equal to } 50,700,000/979 = 51,700 \text{ times the acceleration of} \\ &\text{gravity, and a human would be pulled apart and 'spaghettified'} \end{aligned}$$

Problem 4 - A supermassive black hole has 100 million times the mass of the sun (1.9×10^{33} grams), and an event horizon radius of 295 million kilometers. What would be the tidal acceleration across a $d=2$ meter human at a distance of 100 kilometers from the event horizon of the supermassive black hole?

$$\begin{aligned} \text{Answer: } a &= 2 \times (6.67 \times 10^{-8}) \times (1.9 \times 10^{41}) \times 200 / (2.95 \times 10^{13})^3 \\ &= 0.00020 \text{ cm/sec}^2 \end{aligned}$$

Note that $R + 2$ meters is essentially R if $R = 295$ million kilometers.

Problem 5 - Which black hole could a human enter without being spaghettified?

Answer: The supermassive black hole, because the tidal force is far less than what a human normally experiences on the surface of Earth. That raises the question that as a space traveler, you could find yourself trapped by a supermassive black hole unless you knew exactly what its size was before hand. You would have no physical sensation of having crossed over the black hole's Event Horizon before it was too late.