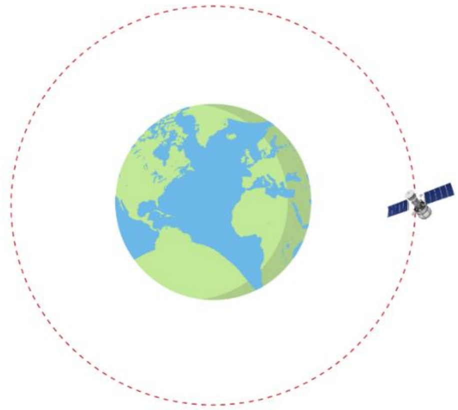
CONCEPT: Velocity of a Satellite

● For a satellite in circular orbit, the gravitational force keeps it in ______________________________.

- The orbital speed & distance are related by:

$v_{sat} =$ __________



- **M** = mass of planet
- **r** = orbital distance (not height!)
- For every value of **r**, there is an *exact* speed required to maintain circular orbit.

EXAMPLE: Calculate the height of the International Space Station, which orbits at 7,670 m/s in a nearly circular orbit.

EQUATIONS		CONSTANTS
$F_G = \frac{Gm_1m_2}{r^2}$	$r = R + h$	$G = 6.67\times10^{-11} \frac{m^3}{kg\cdot s^2}$
$g_{near} = \frac{GM}{R^2}$	$g_{far} = \frac{GM}{r^2}$	$M_E = 5.97\times10^{24}$ kg
$v_{sat} = \sqrt{\frac{GM}{r}}$		$R_E = 6.37\times10^{6}$ m

PRACTICE: Suppose that you used some geometry and kinematics to estimate that the Earth goes around the Sun with an orbital speed of approximately 30,000 m/s (60,000 mph), and that the Sun is approximately 150 million kilometers away from the Earth. Use this information to estimate the mass of the Sun.

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$F_G = \frac{Gm_1m_2}{r^2}$	$r = R + h$	$G = 6.67\times10^{-11}\ \frac{m^3}{kg\cdot s^2}$
$g = \frac{GM}{r^2}$	$g_{surf} = \frac{GM}{R^2}$	$M_E = 5.97\times10^{24}$ kg
$v_{sat} = \sqrt{\frac{GM}{r}}$		$R_E = 6.37\times10^6$ m

EXAMPLE: Two satellites are in circular orbits around a mysterious planet that is 8×10^7 m in diameter. The first satellite has mass 68kg, orbital radius 6×10^8 m, and orbital speed 3000 m/s, while the other has mass 84 kg, orbital radius 9×10^8 m/s. What is the orbital speed of this second satellite?

EQUATIONS		CONSTANTS
$F_G = \frac{Gm_1m_2}{r^2}$	$r = R + h$	$G = 6.67\times10^{-11}\ \frac{m^3}{kg\cdot s^2}$
$g = \frac{GM}{r^2}$	$g_{surf} = \frac{GM}{R^2}$	$M_E = 5.97\times10^{24}$ kg
$v_{sat} = \sqrt{\frac{GM}{r}}$		$R_E = 6.37\times10^6$ m

PRACTICE: You throw a baseball horizontally while on the surface of a small, spherical asteroid of mass 7×10^{16} kg and diameter of 22km. What is the minimum speed so that it just barely goes around the asteroid without hitting anything?

EQUATIONS		CONSTANTS
$F_G = \frac{Gm_1m_2}{r^2}$	$r = R + h$	$G = 6.67\times10^{-11}\ \frac{m^3}{kg\cdot s^2}$
$g = \frac{GM}{r^2}$	$g_{surf} = \frac{GM}{R^2}$	$M_E = 5.97\times10^{24}$ kg
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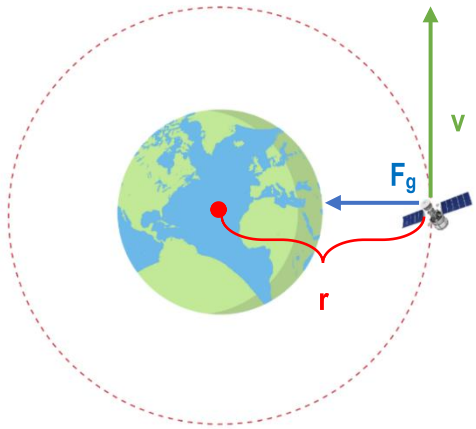
CONCEPT: Orbital Period of a Satellite

● We can also relate the orbital speed and orbital period **T**, the time it takes to complete 1 orbit, using circular motion.

SATELLITE MOTION
$v_{sat} = \sqrt{\frac{GM}{r}}$

$v_{sat} =$ ______

$T^2 =$ ______



- This equation is also called ________________.

- Orbital speed, period, distance all interdependent. As distance increases, **v** ____________, **T** ____________.

EXAMPLE: What is the orbital period and speed of the International Space Station orbiting 400km above Earth's surface?

SATELLITE MOTION	GRAV. CONSTANTS
$v_{sat} = \sqrt{\frac{GM}{r}}$ $v = \frac{2\pi r}{T}$ $T_{sat}^2 = \frac{4\pi^2 r^3}{GM}$	$G = 6.67\times10^{-11}$ $M_E = 5.97\times10^{24}$ kg $R_E = 6.37\times10^{6}$ m

PRACTICE: A satellite orbits at an orbital period of 2 hours around the Moon. What is the satellite's orbital altitude?

EQUATIONS		CONSTANTS
$F_G = \frac{Gm_1m_2}{r^2}$	$r = R + h$	$G = 6.67\times10^{-11}\ \frac{m^3}{kg\cdot s^2}$
$g_{near} = \frac{GM}{R^2}$	$g_{far} = \frac{GM}{r^2}$	$M_E = 5.97\times10^{24}$ kg $R_E = 6.37\times10^6$ m
$v_{sat} = \sqrt{\frac{GM}{r}}$	$v_{sat} = \frac{2\pi r}{T}$	$M_{Moon} = 7.35\times10^{22}$ kg $R_{Moon} = 1.74\times10^6$ m
$T_{sat}^2 = \frac{4\pi^2r^3}{GM}$		

EXAMPLE: A small moon orbits its planet with a speed of 7500 m/s. It takes 28 hours to complete 1 full orbit. What is the mass of this unknown planet?

EQUATIONS		CONSTANTS
$F_G = \frac{Gm_1m_2}{r^2}$	$r = R + h$	$G = 6.67\times10^{-11}\ \frac{m^3}{kg\cdot s^2}$
$g_{near} = \frac{GM}{R^2}$	$g_{far} = \frac{GM}{r^2}$	$M_E = 5.97\times10^{24}$ kg $R_E = 6.37\times10^6$ m
$v_{sat} = \sqrt{\frac{GM}{r}}$	$v_{sat} = \frac{2\pi r}{T}$	$M_{Moon} = 7.35\times10^{22}$ kg $R_{Moon} = 1.74\times10^6$ m
$T_{sat}^2 = \frac{4\pi^2r^3}{GM}$		

PRACTICE: A distant planet orbits a star 3 times the mass of our Sun. This planet of mass $8x10^{26}$ kg feels a gravitational force of $2x10^{26}$ N. What is this planet's orbital speed and how long does it take to orbit once?

EQUATIONS		CONSTANTS
$F_G = \frac{Gm_1m_2}{r^2}$	$r = R + h$	$G = 6.67\times10^{-11}\ \frac{m^3}{kg\cdot s^2}$
$g_{near} = \frac{GM}{R^2}$	$g_{far} = \frac{GM}{r^2}$	$M_E = 5.97\times10^{24}$ kg $R_E = 6.37\times10^6$ m
$v_{sat} = \sqrt{\frac{GM}{r}}$	$v_{sat} = \frac{2\pi r}{T}$	$M_{Moon} = 7.35\times10^{22}$ kg $R_{Moon} = 1.74\times10^6$ m $M_{Sun} = 2\times10^{30}$ kg
$T_{sat}^2 = \frac{4\pi^2r^3}{GM}$		