Worksheet 4.1
Gravitational Force

1. A piece of space debris has a mass of 4 kg. It is located 2000 m from an asteroid. If the force of gravity is 0.6 N between them, what is the mass of the asteroid?

$.6 = \frac{(6.7\times10^{-11})(4\text{kg})(M)}{2000^2}$ $M = 9\times10^{15}\text{ kg}$

2. A $6\text{x}10^{12}$ kg moon in a distant galaxy experiences a 1 N force of attraction between it and a $10\text{x}10^{30}$ kg planet. How far apart are they?

$1 = \frac{(6.7\times10^{-11})(6\times10^{12})(10\times10^{30})}{r^2}$ $r = 6\times10^{16}\text{m}$

3. What is the force of gravity between earth and the moon? The earth's mass is 5.98×10^{24} kg, the distance from the earth to the moon is 3.90×10^{8} m. The mass of the moon is 7.30×10^{22} kg.

$F_g = \frac{(6.7\times10^{-11})(5.98\times10^{24})(7.3\times10^{22})}{(3.9\times10^{8})^2} = 1.9\times10^{20}\text{N}$

4. You weigh 458 N on earth, but you are on Mars. Here's some data on Mars: radius = 3.38×10^{6} m, mass = 6.42×10^{23} kg. (a) What is the acceleration of gravity on Mars? (b) How much do you weigh on Mars? (c) If you drop a 3.50 kg rock from the surface of Mars and it falls a distance of 1.20 m, how fast will it be going just before it hits the surface?

mass $= \frac{458\text{N}}{10\text{m/kg}} = 45.8\text{kg}$

$g_{mars} = \frac{(6.7\times10^{-11})(6.42\times10^{23})}{(3.38\times10^{6})^2} = 3.76\text{ m/s}^2$

$F_{g\,mars} = (45.8)(3.76) = 172.4\text{N}$

c) $0 = \frac{1}{2}(-3.76)t^2 + 0t + 1.2$

$t =$

$0 = -1.88t^2 + 1.2$

$t = .8\text{ s}$

$V_y = -3.76(.8) + 0$

$= -3\text{ m/s}$

5. If the mass of Mercury is $3.3\text{x}10^{23}$ kg and its radius of 2.4×10^{6} m, estimate the gravitational acceleration (g) at the surface of Mercury.

$g = \frac{(6.7\times10^{-11})(3.3\times10^{23})}{(2.4\times10^{6})^2} = 3.84\text{ m/s}^2$

6. An object of mass 0.5 kg is transported to the surface of Planet X where the object's weight is measured to be 20 N. The radius of the planet is 4×10^{6} m. (a) What is the mass of the planet? (b) What free fall acceleration will the 0.5 kg object experience when transported to a distance of 2.0×10^{6} m from the surface of the planet? (no longer on the surface)

$20\text{N} = g(.5)$ $g = 40\text{ m/s}^2$

$40 = \frac{(6.67\times10^{-11})(M)}{(4\times10^{6})^2}$

$m = 9.6\times10^{24}\text{kg}$

$g = \frac{(6.67\times10^{-11})(9.6\times10^{24})}{(4\times10^{6}+2\times10^{6})^2} = 17.8\text{ m/s}^2$

7. Saturn has many moons that orbit it. Saturn has a mass of 5.68 x 10^{26} kg.

a. The closest moon to Saturn, Mimas, has an orbital radius of 185,000,000 m from Saturn's core. What is the tangential velocity of Mimas as it orbits?

$F_g = F_c = \frac{mv^2}{r}$ $\quad \frac{GmM}{r^2} = \frac{mv^2}{r}$ $\quad \frac{(6.67\times10^{-11})(5.68\times10^{26})}{(185\times10^6)} = v^2$

$v = 14310$ m/s

b. What centripetal force does Mimas (mass = 3.8x10^9 kg) experience due to Saturn's gravitational pull?

$F_c = \frac{(3.8\times10^9)(14310)^2}{185\times10^6} = 4.2\times10^9$ N

c. Titan has a tangential velocity of 5,580 m/s. What is its orbital radius?

$5{,}580 = \sqrt{\frac{GM}{r}}$ $\quad 5580 = \sqrt{\frac{(6.7\times10^{-11})(5.68\times10^{26})}{r}}$ $\quad r = 1.2\times10^7$ m

d. Dione has a mass of 11x10^{20} kg and a diameter of 1,123,000 m. What is the acceleration due to gravity on the moon's surface?

$g = \frac{(6.7\times10^{-11})(11\times10^{20})}{(1123000/2)^2} = .23$ m/s^2

e. Dione is located 377,000,000 m from Saturn. What is the force of gravity between Dione and Saturn?

$F_g = \frac{(6.7\times10^{-11})(11\times10^{20})(5.68\times10^{24})}{377{,}000{,}000^2} = 2.9\times10^{18}$ N

f. Rhea has an orbital radius of 527,000,000 m and experiences a gravitational force of 3.1x10^{20} N. What is the mass of Rhea?

$3.1\times10^{20}\text{ N} = \frac{(6.7\times10^{-11})(5.68\times10^{24})(m)}{527{,}000{,}000^2}$ $\quad m = 2.3\times10^{23}$ kg

8. Fill in the missing information from the table below.

	Saturn	Titan	Prometheus
Force gravity from Saturn	X	3.4×10^{22} N	3.1×10^{17} N
Gravitational Constant (g)	12.8 m/s^2	1.352 m/s^2	
Radius	5.44 x 10^7 m	2.57 x 10^6 m	4.3 x 10^4 m
Distance from Saturn	X	1.2×10^9 m	1.4x10^8 m
Mass	5.6846 x 10^{26} kg	1.3 x 10^{24} kg	1.6 x 10^{17} kg
Period about Saturn	X	16 days	53410 seconds

$T = \frac{2\pi r}{v_c} = \frac{2\pi(1.4\times10^8)}{16469.7}$

$\frac{mv^2}{r} = 3.1\times10^{17}$ N

$\frac{1.6\times10^{17}v^2}{1.4\times10^8} = \nearrow$

$v = 16469.7$ m/s