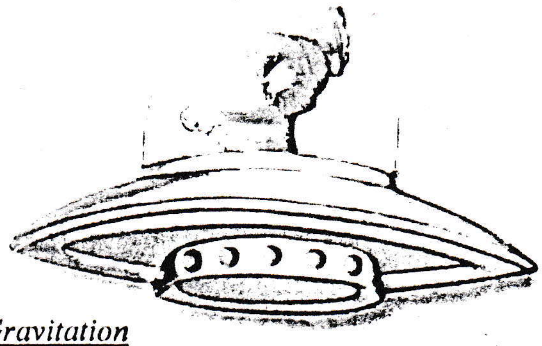
Centripetal Force meets **Gravitational Force**

When objects are in orbit, the centripetal force that holds them there is supplied by gravity.



G= $6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$

Using Universal Gravitation

1. Calculate the gravitational force of attraction between two objects of masses 900 kg and 400 kg, placed with their centres 30 m apart. (*Do this one accurate to two significant digits.)

2. Marvin The Martian (see above) is hovering in his 83 kg space scooter 36 m away from the centre of the mother ship, which has a mass of 3.7×10^{11} kg. If his instruments register a 2.0 N gravitational force pulling him towards the mother ship, what is Marvin's mass?

Centripetal Force

3. A 95 kg snowboarder carves a turn that would be part of a circle that has a radius of 3.0 m at a speed of 9.0 m/s.
   (a) What force is he subjected to during the turn?
   (b) How many times greater than his weight is the force in (a)?
   **This would be the 'g' value ie. 2g, 3g etc.*

4. An athlete needs a force of 153 N to spin a shot-put at a frequency of 0.90 c/s with a radius of spin of 1.2 m.
   Use this information to calculate the mass of the shot put.

Putting Them Together

5. An astronomer observes the planet Jupiter and finds that the period of its moon Io is 1.5×10^5 s. This moon has an average radius of orbit around Jupiter of 4.2×10^8 m. Using this data, calculate the mass of Jupiter.

6. A lunar lander is to be placed in orbit around the moon at a mean altitude of 100 km. What will the period be of the lunar lander?

7. An asteroid has a mean radius of orbit of 4.8×10^{11} m. What will its orbital period around the Sun be?

8. A spy satellite is located one Earth radii above the surface of the Earth. What is its period of revolution? *(Hint: Use the data about the moon on the chart to help solve this one.)*

9. Mars has two moons, Phobos and Deimos (Fear and Panic, the companions of Mars, the god of war). Deimos has a period of 30 h and 18 minutes and a mean distance from the centre of Mars of 2.3×10^4 km. If the period of Phobos is 7 h and 39 minutes, what mean distance is it from the centre of Mars?

10. Use the data from the table about the Earth's orbit to calculate:
    (a) the speed of the Earth b) the mass of the Sun

Centripetal Force meets Gravitational

#1. $F_g = \frac{GmM}{r^2}$ $\qquad$ $G = 6.67 \times 10^{-11} \frac{Nm^2}{kg^2}$

$m = 400kg$

$M = 900kg$

$r = 30m$

$F_g = 2.7 \times 10^{-8} N$

#2. $F_g = \frac{GmM}{r^2}$ $\qquad$ $m = \frac{F_g r^2}{GM}$ $\qquad$ $F_g = 2.0N$

$r = 36m$

$M = 3.7 \times 10^{11} kg$

$m = 105kg$

$\therefore$ Marvins mass $= 105kg - 83kg$

$= 22kg.$

#3 $F_c = \frac{mv^2}{r}$ $\qquad$ $m = 95.kg$ $\qquad$ $r = 3.0m$ $\qquad$ $v = 9.0 m/s$

$F_c = 2565 N$ $\qquad$ $F_g = mg = 931 N$

$\therefore F_c = 2.7$ x's F_g.

#4. $F_c = \frac{mv^2}{r} = 4\pi^2 r f^2 m$ $\qquad$ $r = 1.2m$

$f = 0.90 Hz.$

$F_c = 153N.$

$\therefore m = F_c / (4\pi^2 r f^2)$

$= 4.0 kg.$

#5. $M = \frac{4\pi^2 r^3}{GT^2} = 1.94 \times 10^{27} kg.$ $\qquad$ $T = 1.5 \times 10^5 s$

$r = 4.2 \times 10^8 m$

#6. $M = \frac{4\pi^2 r^3}{GT^2}$ $\qquad$ $T = \sqrt{\frac{4\pi^2 r^3}{GM}} = 7087s$ ≈ 2 hours

$M_{moon} = 7.34 \times 10^{22} kg.$

$r_{moon} = 1.74 \times 10^6 m$

$r_{orbit} = 1.84 \times 10^6 m$

7. $M_{Sun} = 1.98 \times 10^{30}\,kg$.

$r_{Sat} = 4.8 \times 10^{11}\,m$

$$M = \frac{4\pi^2 r^3}{G\,T^2}$$

$$\to T = \sqrt{\frac{4\pi^2 r^3}{MG}}$$

$$= 1.8 \times 10^{8}\,s.$$

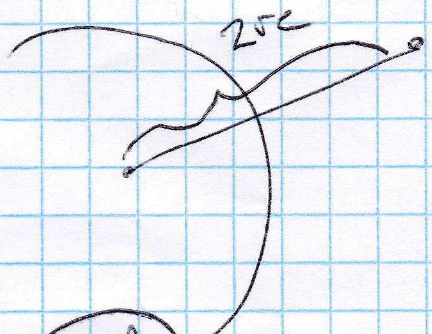
8. moon $r_{orbit} = 3.84 \times 10^{8}\,m$

$T_{orbit} = 27.3$ days.

$$\therefore M_e = \frac{4\pi^2 r^3}{G\,T^2} = 6.02 \times 10^{24}\,kg.$$

satellite.

$r_{orbit} = 2 \times 6.378 \times 10^{6}\,m = 1.276 \times 10^{7}\,m$



$$M_e = \frac{4\pi^2 r^3}{G\,T^2}$$

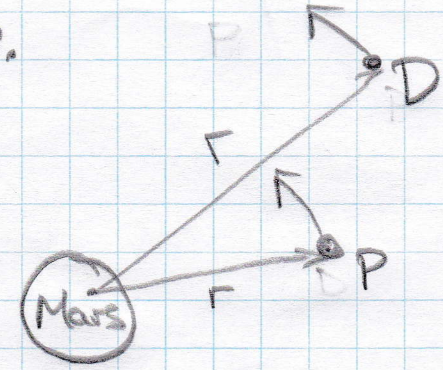
$$T = \sqrt{\frac{4\pi^2 r^3}{MG}} = 1.43 \times 10^{4}\,s.$$

method #2

using Keplers constant $\dfrac{r^3}{T^2}$

$$\underset{\text{moon}}{\frac{r^3}{T^2}} = \underset{\text{satellite}}{\frac{r^3}{T^2}} \quad \therefore \quad T_{Sat} = \sqrt{\frac{r^3_{sat} \times T^2_{moon}}{r^3_{moon}}} = 1.43 \times 10^{4}\,s.$$

#9.



D → $T = 109080\,s$
$r = 23\,000\,km$

use this to find mass Mars

$$M = \frac{4\pi^2 r^3}{G\,T^2}$$

$= 6.05 \times 10^{23}\,kg$

P → $T = 27540\,s$
$r = ?$

$$M = \frac{4\pi^2 r^3}{G T^2} \rightarrow r = \sqrt[3]{\frac{M G T^2}{4\pi^2}}$$

$= 9.19 \times 10^6\,m$

$= 9200\,km$

method #2.
using Kepler's constant

Deimos Phobos

$$\frac{r^3}{T^2} = \frac{r^3}{T^2}$$

$$r_{Phobos} = \sqrt[3]{\frac{T^2_{Phobos} \times r^3_{Deimos}}{T^2_{Deimos}}}$$

$= 9.19 \times 10^6\,m$

Same.

10. earth $r_{orbit} = 1.49 \times 10^{11}$ m

$T = 365.2$ days
$= 3.16 \times 10^{7}$ s.

$$V = \frac{2\pi r}{T} = 2.96 \times 10^{4} \text{ m/s}$$
$$\simeq 107\,000 \text{ km/hr.}$$

$$M_{sun} = \frac{4\pi^2 r^3}{G T^2}$$
$$= 1.95 \times 10^{30} \text{ kg.}$$