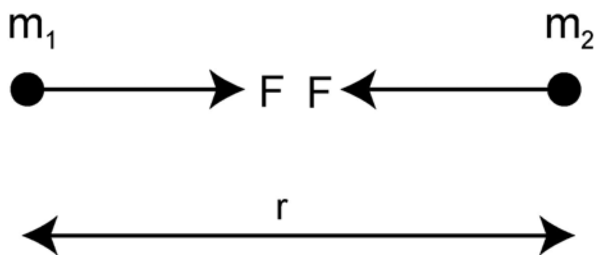
B2. BASICS OF GRAVITY EXPLORATION

B2.1 Newtonian gravitation



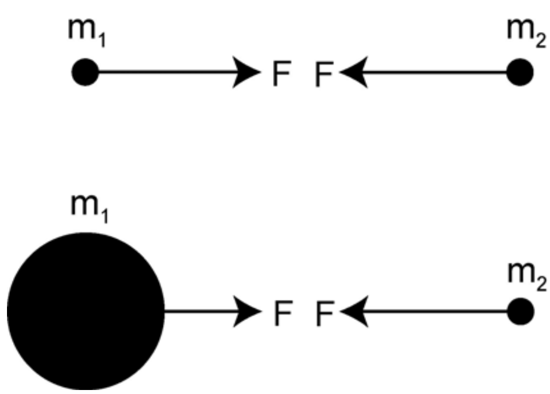
Consider two point masses that are a distance r apart. **Newton's theory of gravitation** predicts that they will **attract** each other with a force F that is given by:

$$F = \frac{G m_1 m_2}{r^2}$$

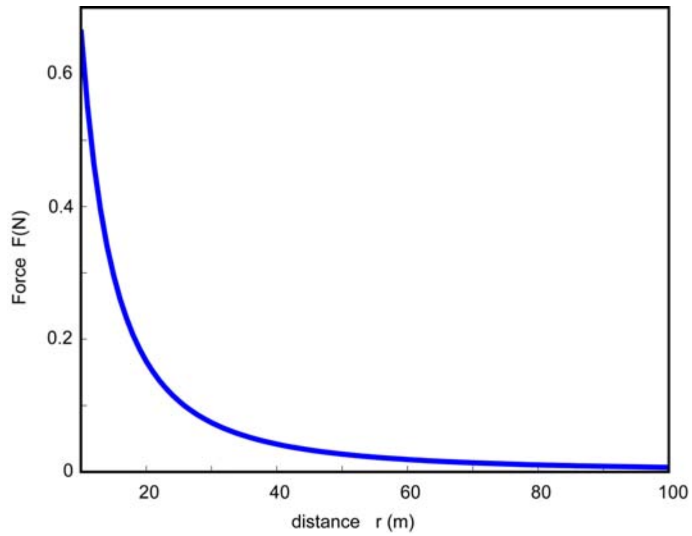
The quantity G is called the **gravitational constant** (or "big G") but is actually a small number. Newton deduced this equation from observing the motion of planets and moons in the solar system. The units are as follows:

F Newton (N)
m kg
r metres (m)
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

It can be shown that if one of the masses is finite in size (*e.g.* a planet or the sun), then F due to will be the same as if all the mass were concentrated at the centre.



If $m_1 = m_2 =$ 1,000,000 kg (1000 tonnes) then the variation of F as r increases will show the "*inverse square law*".



Consider the mass m_2. **Newton's Third Law of Motion** predicts that this mass will accelerate with an acceleration a, where:

$$F = m_2 a$$

Rearranging this equation gives

$$a = \frac{F}{m_2}$$

Now we know the value of F from the first equation so

$$a = g = \frac{Gm_1 m_2}{r^2}\frac{1}{m_2} = \frac{Gm_1}{r^2}$$

where g is called the **gravitational acceleration**.

Let us now consider that m_1 is the Earth and m_2 is a small object that we are going to drop. This equation tells us that the **acceleration does not depend on the mass of the object being dropped**.

This was proved by Galileo who allegedly dropped masses from the leaning tower of Pisa in Italy. This result says that a small mass and a large mass will fall with the same acceleration.

B2.2 Density of rocks and minerals

The Greek letter rho (ρ) is used to represent density. Rocks and minerals found on Earth have densities that range from 1000-7000 kg m^{-3}. Often densities are quoted in g cm^{-3}.

To convert, remember that 1 g cm^{-3} = 1000 kg m^{-3}.

Pure minerals can exhibit a high density since the atoms are closely packed together.

Magnetite	ρ = 4.90-5.20 *g cm*$^{-3}$
Pyrite	ρ = 4.90-5.20 *g cm*$^{-3}$
Galena	ρ = 7.40-7.60 *g cm*$^{-3}$

Sedimentary rocks generally have lower densities since the atoms are not as closely packed together and pore space is filled with lower density materials.

Water	ρ = 1.00-1.05 *g cm*$^{-3}$
Alluvium	ρ = 1.96-2.00 *g cm*$^{-3}$
Shale	ρ = 2.00-2.70 *g cm*$^{-3}$
Limestone	ρ = 2.60-2.80 *g cm*$^{-3}$
Dolomite	ρ = 2.28-2.90 *g cm*$^{-3}$

The **range** of density values reflects the degree of weathering and the porosity. Why?

The composition is secondary, but explains why dolomite is more dense than limestone.

Most sedimentary rocks increase in density with depth, owing to increased compaction. This reduces the pore space available for low density materials such as air, water and hydrocarbons.

Igneous rocks are generally more dense owing to minimal porosity.

Granite	ρ = 2.50-2.70 *g cm*$^{-3}$
Basalt	ρ = 2.70-3.20 *g cm*$^{-3}$

The density depends primarily on the rock composition. Mafic rocks are generally more dense than felsic rocks owing to increased proportion of heavier elements such as Fe and Mg.

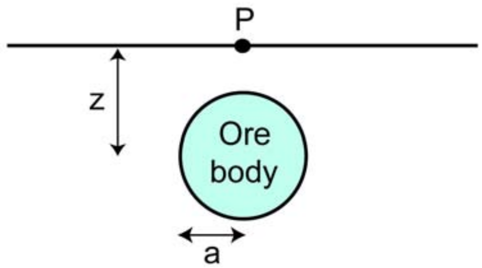
B2.3 Units for gravity measurements (milligals)

The gravitational acceleration at the Earths surface is 9.8 ms^{-2}. Subsurface variations in rock density produce very small changes in this value, so it is more convenient to use a smaller unit.

9.8 ms^{-2} = 980 cm s^{-2}
= 980 gal (after Galileo)
= 980,000 milligals

1 milligal = 10^{-5} ms^{-2}

B2.4 Approximate calculation to estimate the size of gravity anomalies



Consider a **spherical ore body** with density ρ and radius a that is buried at a depth z below the surface. The extra pull of gravity will be greatest at a point P directly above the ore body.

Remember that the pull of gravity (**g**) for a sphere is the same as if all the mass were concentrated at the centre.

Total mass of ore body = volume *x* density = $\frac{4}{3}\pi a^3 \rho$

Excess mass , m_E = mass of ore body – mass of rock that was already there

$$= \frac{4}{3}\pi a^3 \rho - \frac{4}{3}\pi a^3 \rho_0$$

$$= \frac{4}{3}\pi a^3 (\rho - \rho_0)$$

Above ore body, the change in gravity due to the ore body (gravity anomaly) is given by

$$\Delta g = \frac{G m_E}{z^2} = \frac{4G\pi a^3 (\rho - \rho_0)}{3z^2}$$

Now guess some values

a = 30 m
z = 40 m
ρ = 4000 kg m^{-3}
ρ_0 = 2000 kg m^{-3}

Careful use of a calculator gives Δg = 0.94 mgal

Perspective

This can be compared to value of g = 980,000 mgals

Fractional change = 9.6 10^{-7}

e.g. An 80 kg person would feel 0.08 g lighter!!!!!