Gravitational Potential

To be able to explain what gravitational potential is and be able to calculate it
To know how gravitational potential is linked to potential energy and be able to calculate it
To be able to sketch graphs of potential and field strength over distance from surface

Gravitational Potential, V

The gravitational potential at a point r from a planet or mass is defined as:

The work done per unit mass against the field to move a point mass from infinity to that point

The gravitational potential at a distance r from a mass M is given by: $$V = -\frac{GM}{r}$$

The value is negative because the potential at infinity is zero and as we move to the mass we lose potential or energy. Gravitational potential is a scalar quantity.

The gravitational field is attractive so work is done **by** the field in moving the mass, meaning energy is given out.

Gravitational Potential is measured in Joules per kilogram, J kg^{-1}

Gravitational Potential Energy *(Also seen in AS Unit 2)*

In Unit 2 we calculated the gravitational potential energy of an object of mass m at a height of h with:

$$E_P = mgh$$

This is only true when the gravitational field strength does not change (or is constant) such as in a uniform field.

For radial fields the gravitational field strength is given by $g = -\frac{GM}{r^2}$

We can use this to help us calculate the gravitational potential energy in a radial field at a height r.

$$E_P = mgh \quad \rightarrow \quad E_P = m\frac{GM}{r^2}r \quad \rightarrow \quad E_P = m\frac{GM}{r}$$

(We have dropped the negative sign because energy is a scalar quantity)

If we look at the top equation for gravitational potential we can see that the gravitational potential energy can be calculated using: $$E_P = mV$$

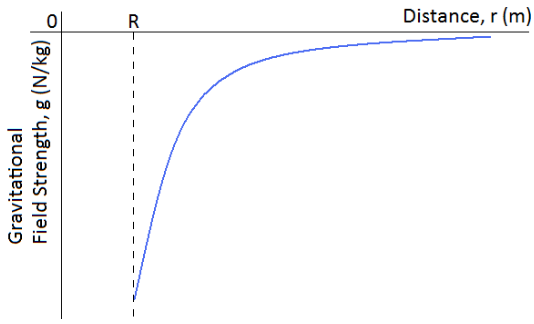
The work done to move an object from potential V_1 to potential V_2 is given by:

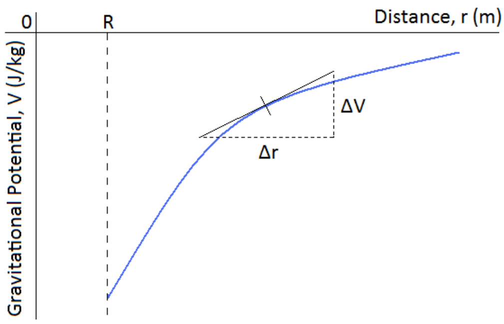
$\Delta W = m(V_2 - V_1)$ which can be written as $$\Delta W = m\Delta V$$

Gravitational Potential Energy is measured in Joules, J

Graphs

Here are the graphs of how gravitational field strength and gravitational potential vary with distance from the centre of a mass (eg planet). In both cases R is the radius of the mass (planet).





The gradient of the gravitational potential graph gives us the gravitational field strength at that point. To find the gradient at a point on a curve we must draw a tangent to the line then calculate the gradient of the tangent:

$$gradient = \frac{\Delta y}{\Delta x} \quad \rightarrow \quad \boxed{g = \frac{\Delta V}{\Delta r}}$$

If we rearrange the equation we can see where we get the top equation for gravitational potential.

$g = \frac{\Delta V}{\Delta r}$ → $g\Delta r = \Delta V$ sub in the equation for g → $-\frac{GM}{r^2}\Delta r = \Delta V$ → $-\frac{GM}{r^2}r = V$ → $-\frac{GM}{r} = V$