

The Virial Theorem

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The basics

If a body in space orbits around another, two different types of energy exist in the moving body. The Virial Theorem expresses the ratio of these two energies to each other.

- Kinetic Energy
- Potential Energy

Kinetic energy is the energy of the moving body and is defined by its mass and speed around another body.

Potential energy is the energy of a moving body if it were to give in to gravitational forces and fall on the other body.

These two energies are always in the ration of 1:2. Hence, the potential energy is always twice as big as the kinetic energy. The German physicist R. Clausius discovered this correlation. The ratio of 1:2 is explained as follows: If potential energy is *lost*, the difference between former and current potential energy is always transformed into friction (heat) and acceleration.

Formulas

Kinetic energy:

$$W_{kin} = m \frac{1}{2} v^2$$

Potential energy:

$$W_{pot} = mgh \quad \text{and} \quad g = yM \frac{1}{r^2} \quad \Rightarrow \quad W_{pot} = mMyh \frac{1}{r^2}$$

Example

In the system sun – earth the energies are calculated as follows:

$$W_{kin} = m \frac{1}{2} v^2$$

$$m = 5.97 \times 10^{24} \text{ kg}$$

$$v = 29,788 \frac{\text{m}}{\text{s}}$$

$$W_{kin} = 5.97 \times 10^{24} \text{ kg} \times \left(29,788 \frac{\text{m}}{\text{s}}\right)^2 \times \frac{1}{2}$$

$$W_{kin} = 2.65 \times 10^{33} \text{ J}$$

$$W_{pot} = mMyh \frac{1}{r^2}$$

$$M = 1.9903 \times 10^{30} kg$$

$$r = h = 1.49 \times 10^{11} m$$

$$y = 6.673 \times 10^{-11} \frac{m^3}{kg s^2}$$

$$W_{pot} = 5.97 \times 10^{24} kg \times 1.9903 \times 10^{30} kg \times 6.67 \times 10^{-11} \frac{m^3}{kg s^2} \times \frac{1}{1.49 \times 10^{11} m}$$

$$W_{pot} = 5.29 \times 10^{33} J$$

The ratio between the two energies is:

$$W_{kin} : W_{pot} = 2.6 \times 10^{33} : 5.3 \times 10^{33}$$

$$W_{kin} : W_{pot} = 1 : 2$$

Result

The example shows that the ratio applies.