

## DEFINITIONS AND UNITS

No physics without precise definitions!

The only worldwide units for education, science and industry are those of the International System of Units (symbol **SI**), adopted by United States in 1964 and by United Kingdom in 1984.

This system is based on the metric system created during the French Revolution in 1790.

### What are the most common units in automobile?

- The unit of length and distance is the meter (symbol **m**); definition: one meter is the length of 40,000,000th of the circumference of the globe.

- The unit of area is the square meter (symbol **m<sup>2</sup>**), the unit of volume is the cubic meter (symbol **m<sup>3</sup>**).

- The unit of time is the second (symbol **s**); definition: one second is the 31,556,940th of the time it takes the Earth to make one complete revolution around the sun.

- The mass is the amount of physical matter; the unit of mass is the kilogram (symbol **kg**); definition: one kilogram is the mass of 1 liter of water.

- The weight refers to the gravitational force; a force is any cause capable to change the speed or trajectory of a body; weight and force have the same unit, the newton (symbol **N**); definition: 1 N is the force able to communicate an acceleration of  $1 \text{ m}\cdot\text{s}^{-2}$  to a mass of 1 kilogram.

- The torque is the product of a force by a lever arm; the torque unit is the Newton-meter (symbol **Nm**); definition: 1 Nm is the torque produced by a 1N force exerted on a 1 meter long lever arm.

- Pressure is the ratio between force and surface; the pressure unit is the Pascal (symbol **Pa**) or the bar (1 bar = 100,000 Pa); definition: 1 Pa is the pressure of a 1 N weight applied on a surface of  $1 \text{ m}^2$ .

- The absolute temperature unit is Kelvin (symbol **K**); definition:

0 K = - 273 degrees Celsius = - 460 °F;

273 K = 0 degree Celsius = + 32 °F = temperature of melting ice;

373 K = + 100 degrees Celsius = + 212 °F = temperature of boiling water.

- Energy means any manifestation of movement, heat, light, noise or radiation; the energy of movement is called kinetic energy; all forms of energy are equivalent and have

the same unit, the joule (symbol **J**); definition: 1 J is the kinetic energy of a mass of 2 kg moving at the speed of  $1 \text{ m.s}^{-1}$ .

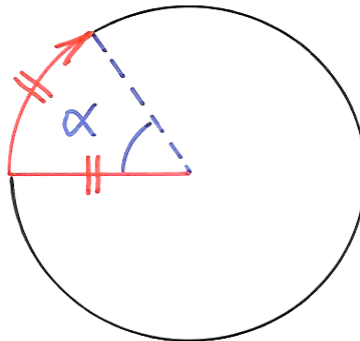
- The work refers to the energy required to move a force; work and energy have the same unit, the joule (symbol **J**); definition: 1 J is the work required to move a force of 1 N over a distance of 1 meter.

**Warning ! The confusion between mass, weight, force, work and energy is common!**

- The power is the ratio between energy and time; the power unit is the watt (symbol **W**); definition: 1 W is the power required to produce a 1 J work in 1 second.

- The velocity is the ratio between distance and time; the velocity unit is the meter per second (symbol  $\text{m.s}^{-1}$ ); definition:  $1 \text{ m.s}^{-1}$  is the velocity that allows to cover the distance of 1 meter in 1 second.

- The rotational speed is expressed in revolutions per minute (symbol **rpm**), in revolutions per second ( $\text{rev.s}^{-1}$  symbol), or in radians per second (symbol  $\text{rad.s}^{-1}$ ); definition: 1 radian is central angle that intercepts an arc length equal to the radius; 1 turn =  $360^\circ = 2\pi$  radians = 6.28 radians, where 1 radian = 57.3 degrees.



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The radian is central angle intercepting an arc of length equal to the radius.  
 $1 \text{ radian} = 360 \text{ degrees} / 2 \pi = 360 / 6.28 = 57.3 \text{ degrees}$ .

- The acceleration (or deceleration) is the rate of the change of the speed, that is the ratio between velocity and time; the unit of acceleration (or deceleration) is meters per second squared (symbol  $\text{m.s}^{-2}$ ); definition:  $1 \text{ m.s}^{-2}$  is an acceleration (or deceleration) which is reflected by a rate of change of  $1 \text{ m.s}^{-1}$  per second.

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## MULTIPLE AND SUBMULTIPLES

- *yotta* (symbole **Y**) means  $10^{24}$  units
- *zetta* (symbole **Z**) means  $10^{21}$  units,
- *exa* (symbole **E**) means  $10^{18}$  units,
- *peta* (symbole **P**) means  $10^{15}$  units,
- *tera* (symbole **T**) means  $10^{12}$  units,
- *giga* (symbole **G**) means  $10^9$  units,
- *mega* (symbole **M**) means  $10^6$  units,
- *kilo* (symbole **k**) means  $10^3$  units,
- *hecto* (symbole **h**) means  $10^2$  units,
- *deca* (symbole **da**) means  $10^1$  units,
  
- *deci* (symbole **d**) means  $10^{-1}$  units,
- *centi* (symbole **c**) means  $10^{-2}$  units,
- *milli* (symbole **m**) means  $10^{-3}$  units,
- *micro* (symbole  $\mu$ ) means  $10^{-6}$  units,
- *nano* (symbole **n**) means  $10^{-9}$  units,
- *pico* (symbole **p**) means  $10^{-12}$  units,
- *femto* (symbole **f**) means  $10^{-15}$  units,
- *atto* (symbole **a**) means  $10^{-18}$  units,
- *zepto* (symbole **z**) means  $10^{-21}$  units,
- *yocto* (symbole **y**) means  $10^{-24}$  units.

## SOME RELATIONSHIPS BETWEEN PHYSICAL QUANTITIES...

### Weight:

$$P = M \cdot g$$

**P**: weight, expressed in **N**

**M**: mass, expressed in **kg**

**g**: gravitational acceleration, expressed in **m.s<sup>-2</sup>**

(Earth:  $g = 9.8 \text{ m.s}^{-2}$ )

consistency of the units:  $P = \text{kg} \cdot \text{m.s}^{-2} = \text{N}$

Example: calculate the weight of a 1,000 kg mass car:

$$P = 1,000 \times 9.8 = 9,800 \text{ N}$$

### Force:

$$F = M \cdot Y$$

**F**: force, expressed in **N**

**M**: mass, expressed in **kg**

**Y**: acceleration or deceleration, expressed in **m.s<sup>-2</sup>**

consistency of the units:  $F = \text{kg} \cdot \text{m.s}^{-2} = \text{N}$

Example: calculate the force to communicate a  $4 \text{ m.s}^{-2}$  acceleration to a 1,000 kg mass car:

$$F = 1,000 \times 4 = 4,000 \text{ N}$$

### Torque:

$$T = F \cdot D$$

**T**: torque, expressed in **Nm**

**F**: force, expressed in **N**

**D**: lever arm, expressed in **m**

consistency of the units:  $T = \text{N} \cdot \text{m} = \text{Nm}$

Example: calculate the torque provided by a force of 20 N and a lever arm of 0.5 mètre:

$$T = 20 \times 0.5 = 10 \text{ Nm}$$

### Pressure:

$$Pr = F / S$$

**Pr**: pressure, expressed in **Pa**

**F**: force, expressed in **N**

**S**: surface, expressed in **m<sup>2</sup>**

consistency of the units:  $Pr = \text{kg} \cdot \text{m}^{-1} \cdot \text{s}^{-2} \cdot \text{m}^{-2} = \text{kg} \cdot \text{m}^{-1} \cdot \text{s}^{-2} = \text{Pa}$

Example: calculate the pressure of a mass of 1,000 kg car exerts on the ground, the contact area of the four tires is 500 square centimeters (0.05 m<sup>2</sup>):

$$Pr = 10,000 / 0.05 = 200,000 \text{ Pa} = 2 \text{ bars}$$

### Work:

$$E = F \cdot D$$

**E**: work, expressed in **J**

**F**: force, expressed in **N**

**D**: distance, expressed in **m**

consistency of the units:  $E = \text{kg} \cdot \text{m}^{-1} \cdot \text{s}^{-2} \cdot \text{m}^1 = \text{kg} \cdot \text{m}^2 \cdot \text{s}^{-2} = \text{J}$

Example: calculate the work of a 4,000 N force that moved one kilometer:

$$E = 4,000 \times 1,000 = 4,000,000 \text{ J}$$

### Kinetic energy:

$$E = \frac{1}{2} M \cdot V^2$$

**E**: kinetic energy, expressed in **J**

**M**: mass, expressed in **kg**

**V**: velocity, expressed in **m.s<sup>-1</sup>**

consistency of the units:  $E = \text{kg} \cdot (\text{m} \cdot \text{s}^{-1})^2 = \text{kg} \cdot \text{m}^2 \cdot \text{s}^{-2} = \text{J}$

Example: calculate the kinetic energy of a mass of 1,000 kg car moving at 25 m.s<sup>-1</sup> (55 mph):

$$E = \frac{1}{2} \times 1,000 \times 25^2 = 500 \times 625 = 312,500 \text{ J}$$

**Power:**

$$B = E / T$$

**B**: power, expressed in **W**

**E**: energy, expressed in **J**

**T**: duration, expressed in **s**

consistency of the units:  $B = \text{kg} \cdot \text{m}^2 \cdot \text{s}^{-2} \cdot \text{s}^{-1} = \text{kg} \cdot \text{m}^2 \cdot \text{s}^{-3} = \text{W}$

Example: calculate the power required to produce a kinetic energy of 300,000 J in 10 seconds:

$$B = 300,000 / 10 = 30,000 \text{ W}$$

**Acceleration:**

$$Y = V / T$$

**Y**: acceleration, expressed in **m.s<sup>-2</sup>**

**V**: velocity, expressed in **m.s<sup>-1</sup>**

**T**: duration, expressed in **s**

consistency of the units :  $Y = \text{m} \cdot \text{s}^{-1} \cdot \text{s}^{-1} = \text{m} \cdot \text{s}^{-2}$

Example: calculate the acceleration of a car when speed varies from 0 to 25 m.s<sup>-1</sup> (55 mph) in 10 seconds:

$$Y = 25 / 10 = 2.5 \text{ m} \cdot \text{s}^{-2}$$

**Transversal acceleration:**

$$Y = V^2 / R$$

**Y**: transversal acceleration, expressed in **m.s<sup>-2</sup>**

**V**: velocity, expressed in **m.s<sup>-1</sup>**

**R**: trajectory radius, expressed in **m**

consistency of the units:  $Y = (\text{m} \cdot \text{s}^{-1})^2 \cdot \text{m}^{-1} = \text{m}^2 \cdot \text{s}^{-2} \cdot \text{m}^{-1} = \text{m} \cdot \text{s}^{-2}$

Example: calculate the transverse acceleration of a car in a circle of 100 m in radius at a speed of 20 m.s<sup>-1</sup> (45 mph):

$$Y = 20^2 / 100 = 400 / 100 = 4 \text{ m} \cdot \text{s}^{-2}$$

**Deceleration:**

$$Y = V / T$$

**Y**: deceleration, expressed in **m.s<sup>-2</sup>**

**V**: velocity, expressed in **m.s<sup>-1</sup>**

**T**: duration, expressed in **s**

consistency of the units:  $Y = \text{m.s}^{-1} \cdot \text{s}^{-1} = \text{m.s}^{-2}$

Example: calculate the acceleration of a car when the speed varies from 20 m.s<sup>-1</sup> (45 mph) to 0 in 2.5 seconds:

$$Y = 20 / 2.5 = 8 \text{ m.s}^{-2}$$

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