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 $\mathbf{m^2}$), the unit of volume is the cubic meter (symbol $\mathbf{m^3}$).

- 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 able to change the speed or the 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 $m.s^{-2}$ 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 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 $m.s^{-1}$.

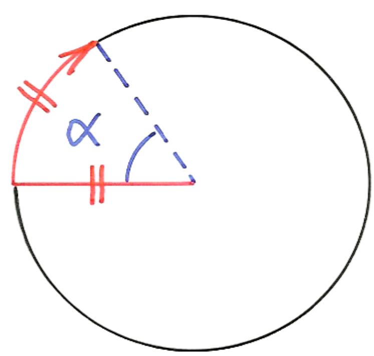
- The work refers to the energy required to move a force; work and energy have the same unit, the joule (symbol **J**); definition: 1 J is the work required to move a force of 1 N over a distance of 1 meter.

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 $\mathbf{m.s^{-1}}$); definition: 1 $m.s^{-1}$ is the velocity of a mass which travels a 1 meter distance in 1 second.

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



The radian is central angle intercepting an arc of length equal to the radius.
1 radian = 360 degrees / 2 π = 360 / 6.28 = 57.3 degrees.

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

ASSOCIATION ADILCA www.adilca.com * * *

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 **μ**) 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.

ASSOCIATION ADILCA www.adilca.com * * *

RELATIONSHIPS BETWEEN PHYSICAL QUANTITIES

Weight:

P = M . g

P: weight, expressed in **N**
M: mass, expressed in **kg**
g: gravitational acceleration, expressed in **$m.s^{-2}$**
(Earth: **g** = 9.8 $m.s^{-2}$)
consistency of the units: **P** = kg . $m.s^{-2}$ = **N**

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

P = 1,000 x 9.8 = 9,800 **N**

Force:

F = M . γ

F: force, expressed in **N**
M: mass, expressed in **kg**
γ: acceleration or deceleration, expressed in **$m.s^{-2}$**
consistency of the units: **F** = kg . $m.s^{-2}$ = **N**

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

F = 1,000 x 4 = 4,000 **N**

Torque:

T = F . D

T: torque, expressed in **Nm**
F: force, expressed in **N**
D: lever arm, expressed in **m**
consistency of the units: **T** = N . m = **Nm**

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

T = 20 x 0.5 = 10 **Nm**

Pressure:

$$Pr = F / S$$

Pr: pressure, expressed in **Pa**
F: force, expressed in **N**
S: surface, expressed in m^2
consistency of the units: **Pr** = $kg.m^{+1}.s^{-2} . m^{-2} = kg.m^{-1}.s^{-2}$ = **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^2):

Pr = 10,000 / 0.05 = 200,000 **Pa** = 2 bars

Work:

$$E = F . D$$

E: work, expressed in **J**
F: force, expressed in **N**
D: distance, expressed in **m**
consistency of the units: **E** = $kg.m^{+1}.s^{-2} . m^{+1} = kg.m^2.s^{-2}$ = **J**

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

E = 4,000 x 1,000 = 4,000,000 **J**

Kinetic energy:

$$E = ½ M . V^2$$

E: kinetic energy, expressed in **J**
M: mass, expressed in **kg**
V: velocity, expressed in $m.s^{-1}$
consistency of the units: **E** = $kg . (m.s^{-1})^2 = kg . m^2.s^{-2}$ = **J**

Example: calculate the kinetic energy of a mass of 1,000 kg car moving at 25 $m.s^{-1}$ (55 mph):

E = ½ x 1,000 x 25^2 = 500 x 625 = 312,500 **J**

Power:

$$\mathbf{B = E / T}$$

B: power, expressed in **W**
E: energy, expressed in **J**
T: duration, expressed in **s**
consistency of the units: $\mathbf{B} = kg.m^2.s^{-2} \;.\; s^{-1} = kg.m^2.s^{-3} = \mathbf{W}$

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

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

Acceleration:

$$\mathbf{Y = V / T}$$

Y: acceleration, expressed in $\mathbf{m.s^{-2}}$
V: velocity, expressed in $\mathbf{m.s^{-1}}$
T: duration, expressed in **s**
consistency of the units : $\mathbf{Y} = m.s^{-1} \;.\; s^{-1} = \mathbf{m.s^{-2}}$

Example: calculate the acceleration of a car when speed varies from 0 to 25 $m.s^{-1}$ (55 mph) in 10 seconds:

$$\mathbf{Y} = 25 / 10 = 2.5 \ \mathbf{m.s^{-2}}$$

Transverse acceleration:

$$\mathbf{Y = V^2 / R}$$

Y: transverse acceleration, expressed in $\mathbf{m.s^{-2}}$
V: velocity, expressed in $\mathbf{m.s^{-1}}$
R: trajectory radius, expressed in **m**
consistency of the units: $\mathbf{Y} = (m.s^{-1})^2 \;.\; m^{-1} = m^{+2}.s^{-2} \;.\; m^{-1} = \mathbf{m.s^{-2}}$

Example: calculate the transverse acceleration of a car in a circle of 100 m in radius at a speed of 20 $m.s^{-1}$ (45 mph):

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

Deceleration:

$$Y = V / T$$

Y: deceleration, expressed in **$m.s^{-2}$**
V: velocity, expressed in **$m.s^{-1}$**
T: duration, expressed in **s**
consistency of the units: $\mathbf{Y} = m.s^{-1} . s^{-1} = \mathbf{m.s^{-2}}$

Example: calculate the acceleration of a car when the speed varies from 20 $m.s^{-1}$ (45 mph) to 0 in 2.5 seconds:

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

ASSOCIATION ADILCA

www.adilca.com

* * *