


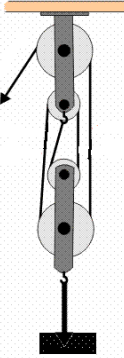


## VCE Systems Engineering

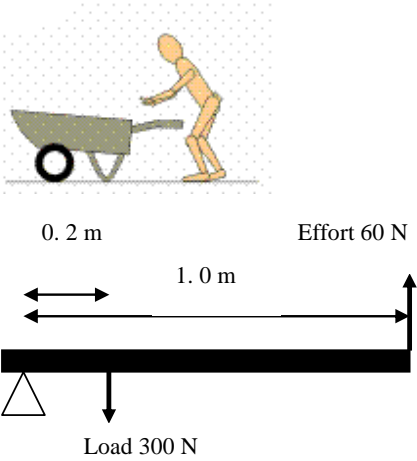
### Mechanical formula and Electrotechnology formula and worked examples

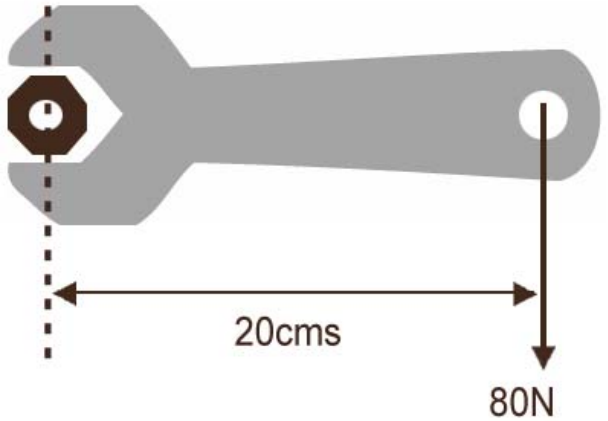
PHYSICAL QUANTITIES AND UNITS	RELATIONSHIP	WORKED EXAMPLE
speed (m/s) or (ms <sup>-1</sup> ) metre per second distance (m) metre time (s) second	$\text{speed} = \frac{\text{distance}}{\text{time}}$	<div style="text-align: center;">  </div> <p>A car travels 1000 metres in 50 seconds at a constant speed.            Its speed will be 20m/s.</p> $20\text{m/s} = \frac{1000\text{m}}{50\text{s}}$
force (N) Newton mass (kg) Kilogram acceleration (m/s <sup>2</sup> ) or (ms <sup>-2</sup> ) metre per second <sup>2</sup>	$\text{force} = \text{mass} \times \text{acceleration}$	<p>The car has a mass of 1500kg and accelerated at 2m/s<sup>2</sup> before reaching constant speed.            The force needed will be 3000N.</p> $3000\text{N} = 1500\text{kg} \times 2\text{m/s}^2$

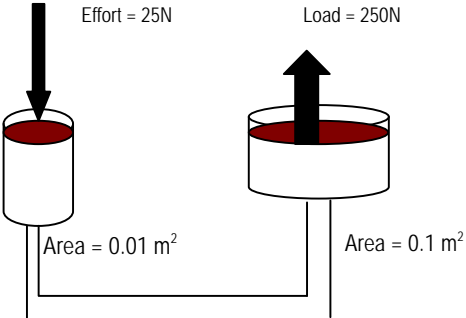
<b>PHYSICAL QUANTITIES AND UNITS</b>	<b>RELATIONSHIP</b>	<b>WORKED EXAMPLE</b>
work done (J) joule force (N) newton distance (m) metre	$\text{work done} = \text{force in the direction moved} \times \text{distance}$	<p>A car tyre weighing 150N is lifted straight up from the ground by a mechanic to a height of 0.6m. The force and the displacement are in the same direction. The work done is 90J.</p> $90\text{J} = 150\text{N} \times 0.6\text{m}$
power (W) watt work done (J) joule time (s) second	$\text{power} = \frac{\text{work done}}{\text{time}}$	<p>If the mechanic takes 2 seconds to perform the task, the power needed will be 45 watts.</p> $45\text{W} = \frac{90\text{J}}{2\text{s}}$
energy (J) joule work done (J) joule power (W) watt time (s) second	$\text{energy} = \text{work done}$ $\text{energy} = \text{power} \times \text{time}$	<p>The energy needed to lift the tyre will be 90 joules.</p> $90\text{J} = 45\text{W} \times 2\text{s}$

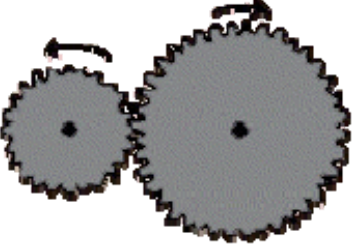
<b>PHYSICAL QUANTITIES AND UNITS</b>	<b>RELATIONSHIP</b>	<b>WORKED EXAMPLE</b>
mechanical advantage (MA) load (N) newton effort (N) newton	$\text{mechanical advantage} = \frac{\text{load}}{\text{effort}}$	 <p>If an effort of 150N is needed to lift a load of 300N using a block and tackle system the mechanical advantage will be <math>\frac{2}{1}</math> or 2:1 or 2</p> $\text{MA} = \frac{300\text{N}}{150\text{N}} = \frac{2}{1} \text{ or } 2:1 \text{ or } 2$
velocity ratio (VR) distance moved by effort (m) distance moved by load (m)	$\text{velocity ratio} = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$	<p>The effort, for the block and tackle system shown, will travel a distance four times that of the load. The velocity ratio will be 4 to 1.</p> $\text{VR} = \frac{4}{1} \text{ or } 4 : 1, \text{ expressed as a ratio}$

PHYSICAL QUANTITIES AND UNITS	RELATIONSHIP	WORKED EXAMPLE
efficiency (%) mechanical advantage (MA) velocity ratio (VR) input energy (J) joule useful output energy (J) joule	$\text{efficiency (\%)} = \frac{\text{mechanical advantage}}{\text{velocity ratio}} \times 100$ $\text{efficiency (\%)} = \frac{\text{useful output energy}}{\text{total energy input}} \times 100$	<p>The efficiency of the block and tackle system calculated using MA and VR is 50 %.</p> $\text{efficiency (\%)} = \frac{2}{4} \times 100 = 50$ <p>The efficiency calculated using energy values will also be 50%.</p> <p>If the 300N load is lifted through a height of 0.5m, the 150N effort is pulled a distance of 2m.</p> <p>The useful output energy is 150J (300 × 0.5)</p> <p>The total input energy is 300J (150 × 2)</p> $\text{efficiency(\%)} = \frac{150\text{J}}{300\text{J}} \times 100 = 50$

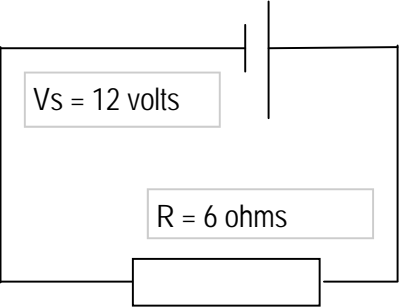
<b>PHYSICAL QUANTITIES AND UNITS</b>	<b>RELATIONSHIP</b>	<b>WORKED EXAMPLE</b>
moment (Nm) newton-metre force (N) newton distance (m) metre	$\text{moment} = \text{force} \times \text{perpendicular distance to turning point}$	 <p>The diagram illustrates a wheelbarrow and a corresponding lever system. In the wheelbarrow, a person is pushing it with an effort of 60 N at a distance of 1.0 m from the wheel. The lever system below shows a fulcrum on the left, a load of 300 N acting downwards at a distance of 0.2 m from the fulcrum, and an effort of 60 N acting upwards at a distance of 1.0 m from the fulcrum.</p> <p>The moment of the load about the turning point in the lever system shown is 60Nm.</p> $60\text{Nm} = 300\text{N} \times 0.2\text{m}$ <p>The moment of the effort will also be 60Nm if system is in equilibrium.</p> $60\text{Nm} = 60\text{N} \times 1\text{m}$

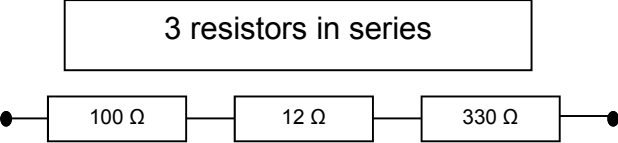
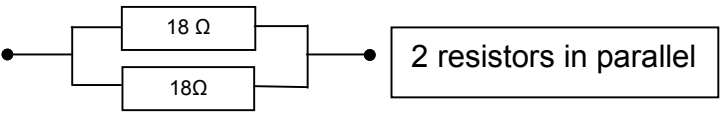
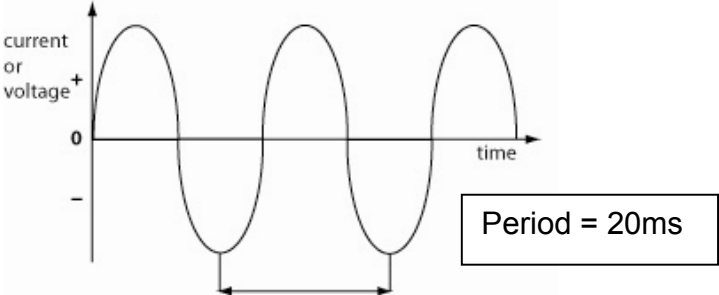
PHYSICAL QUANTITIES AND UNITS	RELATIONSHIP	WORKED EXAMPLE
torque (Nm) newton-metre twisting force (N) newton distance (m) metre	$\text{torque} = \text{twisting force} \times \text{perpendicular distance to turning point}$	 <p>A spanner is used to tighten a nut to the recommended torque of 16Nm.            A twisting force of 80N acting 20 cms from the turning point will be required.</p> $16 \text{ Nm} = 80\text{N} \times 0.2\text{m}$

PHYSICAL QUANTITIES AND UNITS	RELATIONSHIP	WORKED EXAMPLE
pressure (Pa) pascal force (N) newton area (m <sup>2</sup> ) metre <sup>2</sup>	$\text{pressure} = \frac{\text{force}}{\text{area}}$	 <p>The pressure exerted by the 25N effort over the 0.01m<sup>2</sup> area of the small cylinder in the hydraulic system shown is 2500 Pa.</p> $2500\text{Pa} = \frac{25\text{N}}{0.01\text{ m}^2}$ <p>The pressure will balance a load of 250N over the 0.1m<sup>2</sup> area of the larger cylinder.</p> $2500\text{Pa} = \frac{250\text{N}}{0.1\text{ m}^2}$

<b>PHYSICAL QUANTITIES AND UNITS</b>	<b>RELATIONSHIP</b>	<b>WORKED EXAMPLE</b>
gear ratio of simple gear train number of teeth on driver gear number of teeth on driven gear	$\text{gear ratio} = \frac{\text{number of teeth on driven gear}}{\text{number of teeth on driver gear}}$	<div style="text-align: center;">  </div> <p>Driver 30 teeth</p> <p>Driven 60 teeth</p> <p>The gear ratio of the simple gear train shown where the driver gear has 30 teeth and the driven gear 60 teeth is <math>\frac{2}{1}</math> or 2:1 .</p> <p><math>\frac{60 \text{ teeth}}{30 \text{ teeth}} = \frac{2}{1}</math> or 2:1 expressed as a ratio</p>
speed of driven gear (rpm) speed of driver gear (rpm) gear ratio	$\text{speed of driven gear} = \frac{\text{speed of driver gear}}{\text{gear ratio}}$	<p>The driven gear will rotate slower than the driver.                      The driven gear rotates at 50 rpm if the driver gear rotates at 100 rpm.</p> <p><math>50 \text{ rpm} = \frac{100 \text{ rpm}}{2}</math></p>

<b>PHYSICAL QUANTITIES AND UNITS</b>	<b>RELATIONSHIP</b>	<b>WORKED EXAMPLE</b>
<p>total gear ratio of compound gear trains</p> <p>gear ratios</p>	<p>total gear ratio = gear ratio 1 × gear ratio 2 × .....</p>	<div data-bbox="1317 327 1881 598" data-label="Diagram"> </div> <p>The four gears above make up a compound gear train.</p> <p>The 10 teeth driver 1 gear meshes with the 30 teeth driven 1 gear , giving a gear ratio of <math>\frac{3}{1}</math> or 3 : 1 ( gear ratio 1).</p> <p>The 10 teeth driver 2 gear meshes with the 40 teeth driven 2 gear , giving a gear ratio of <math>\frac{4}{1}</math> or 4 : 1 ( gear ratio 2).</p> <p>The total gear ratio of the compound gear train will be 12 : 1</p> $\frac{3}{1} \times \frac{4}{1} = \frac{12}{1} \text{ or } 12:1$ <p>The first driver gear will rotate 12 times faster than the final driven gear</p>

PHYSICAL QUANTITIES AND UNITS	RELATIONSHIP	WORKED EXAMPLE
voltage (V) volt current (I) amp resistance ( $\Omega$ ) ohm  ( Ohm's law )	$\text{voltage} = \text{current} \times \text{resistance}$	 <p>The current in the simple circuit above will be 2 amps.</p> $12 \text{ volts} = 2 \text{ amps} \times 6 \text{ ohms}$
power (W) watt volt (V) volt current (I) amp	$\text{power} = \text{voltage} \times \text{current}$	<p>The power dissipated in the 6 ohms resistor will be 24 watts.</p> $24 \text{ watts} = 12 \text{ volts} \times 2 \text{ amps}$

<b>PHYSICAL QUANTITIES AND UNITS</b>	<b>RELATIONSHIP</b>	<b>WORKED EXAMPLE</b>
<p>total resistance (<math>\Omega</math>) ohms</p> <p>resistors in series</p> <p>resistors in parallel</p>	$R_t = R_1 + R_2 + \dots$ $\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$	<p style="text-align: center;">3 resistors in series</p>  <p><math>R_t = 100 \text{ ohms} + 12 \text{ ohms} + 300 \text{ ohms} = 412 \text{ ohms}</math></p>  <p style="text-align: center;">2 resistors in parallel</p> <p><math>\frac{1}{R_t} = \frac{1}{18} + \frac{1}{18} = \frac{1}{9} \quad R_t = 9 \text{ ohms}</math></p>
<p>frequency (Hz) hertz</p> <p>period (s) second</p>	$\text{frequency} = \frac{1}{\text{period}}$	 <p>The frequency of the waveform shown is 50Hz.</p> $50\text{Hz} = \frac{1}{0.02\text{s}}$