202: Principles of electrical science  
**Handout 16: Levers**

**Learning outcome**

The learner will:

1. Understand basic mechanics and the relationship between force, work, energy and power.

**Assessment criteria**

The learner can:

3.2 explain the principles of basic mechanics as they apply to **levers**, gears and pulleys.

**Range**

**Levers**: Class I, Class II, Class III

**Levers**

A **lever** is a machine consisting of a beam or rigid rod pivoted at a fixed hinge, or **fulcrum**. A lever amplifies an input force to provide a greater output force, which is said to provide **leverage**.

**Classes of lever**

Levers are classified by the relative positions of the fulcrum and the input and output forces. It is common to call the input force the **effort** and the output force the **load**. This allows the identification of three classes of levers (or **order**) by the relative locations of the fulcrum, the load and the effort.

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| **Class 1**. Fulcrum in the middle: the effort is applied on one side of the fulcrum and the resistance on the other side; for example, a crowbar or a pair of scissors. | *01 lever - class 1b.png* |
| 01 lever - class 1.png | |

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| **Class 2**. Resistance in the middle: the effort is applied on one side of the resistance and the fulcrum is located on the other side; for example, a wheelbarrow or a nutcracker or a bottle opener. | 01 lever - class 2b.png |
| 01 lever - class 2a.png | |
| **Class 3.** Effort in the middle: the resistance is on one side of the effort and the fulcrum is located on the other side; for example, a pair of tweezers or the human mandible. | 01 lever - class 3b.png |
| 01 lever - class 3a.png | |

**Lever calculations**

The effort to be applied to a lever will depend on the weight of the load, how far from the fulcrum the load is and how far from the fulcrum the effort is applied. This can be summarised as follows:

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| **Example 1**  A crowbar is used to lift a packing case. The load exerted by the packing case is 1,200N. Determine the effort needed to lift the packing case if the load is 10cm from the pivot and the effort is 1.0m from the pivot. | | | | EP24p03a |
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**Example 2**

A horizontal bar 1.75m in length is pivoted at a point 0.75m from one end and a downward force of 150N is applied at right angles to this end of the bar. Calculate the force that must be applied to the other end of the bar to maintain it in a horizontal position. Ignore the weight of the bar.

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**Gears**

Gears are used for transmitting power from one part of a machine to another. For example, an electric motor in a factory transferring power via the gear train to piece of equipment being driven.

You can have any number of gears connected together and they can be in different shapes and sizes. Each time you pass power from one gear wheel to another, you can do one of three things:

* Increase/decrease speed
* Increase/decrease force
* Change direction.

The amount by which a pair of gears increases or decrease speed or power depend on the ratio between the two gears which can be found simply by counting the number of teeth on each.

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| In the diagram to the right, the left‑hand cog has 12‑teeth and the right‑hand cog has 24‑teeth.  If the 12‑teeth cog is coupled to the motor it is referred to as the ‘**driving cog**’; the 24‑teeth cog is connected to the load and is referred to as the ‘**driven cog**’.  The ratio of this simple gear train is: |  |

Very simply, if the driving cog is smaller than the driven cog then there will be a reduction in speed of the driven cog according to the gear ratio. In the example above, the 12‑teeth driving cog would have to rotate twice for every single rotation of the driven cog so speed would be reduced by a half. However, there would be twice as much power available in this case at the driven cog despite going slower.

Also, note that if the driving cog rotates clockwise the driven cog will rotate anti‑clockwise. I direction of rotation is crucial an extra cog, called an ‘**idler cog**’, is placed between the driving and driven cogs to restore the direction of rotation.

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| In this example, the larger 24‑teeth cog is now the driving cog and the smaller 12‑teeth cog is now the driven cog.  The ratio of this simple gear train is:  If the driving cog is larger than the driven cog there will be an increase in speed of the driven cog according to the gear ratio but it will deliver half as much power in this case. |  |

If only a drive direction change is required then two cogs with the same number of teeth could be used. These would have a ratio of **1:1** so there would be no change in speed or power available.

**Pulleys**

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| A pulley is simply a collection of one or more wheels over which you loop a rope to make it easier to lift things. Pulleys help us multiply forces and are examples of what scientists call simple machines. If you want to lift a very heavy weight, there's only so much force your muscles can supply, even if you are very strong. But use a simple machine such as a pulley and you can effectively multiply the force your body produces.  The more wheels you have, and the more times you loop the rope around them, the more you can lift. The only drawback with using pulleys is that whilst you can lift heavier loads you have to pull the rope further as can be seen on the following page. |  |

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**Diagram 1**: There is only one pulley to lift a load with a weight of 100N through a distance of 10cm. To achieve this the rope must be pulled with a force of 100N through a distance of 10cm; therefore, the **mechanical advantage** = **1**.

**Diagram 2**: There are two pulleys to lift a load with a weight of 100N through a distance of 10cm. To achieve this the rope must be pulled with a force of 50N through a distance of 20cm; therefore, the **mechanical advantage** = **2**.

**Diagram 3**: There are three pulleys to lift a load with a weight of 100N through a distance of 10cm. To achieve this the rope must be pulled with a force of 33 1/3N through a distance of 30cm; therefore, the **mechanical advantage** = **3**.

**Diagram 4**: There are four pulleys to lift a load with a weight of 100N through a distance of 10cm. To achieve this the rope must be pulled with a force of 25N through a distance of 40cm; therefore, the **mechanical advantage** = **4**.

It can be seen that by increasing the number of pulleys will mean less force needs to be applied to lift the same distance but the force needs to be applied over a greater distance.