Scheme of work for jss2

Week 1; revision of last term work

Week 2; quadrilaterals

Week 3; plane figures[polygon]

Week 4&5; area of plane figures

Week 6; wood work machine

Week 7; metal work machine

Week 8; care and maintenance of metal work machine

Week 9; friction

Week 10; reduction of friction

Week 11; revision

Week 12; examination

Week 1; revision

Rescue comprises responsive operations that usually involve the saving of life, or prevention of injury during an incident or dangerous situation.

Tools used might include search and rescue dogs, mounted search and rescue horses, helicopters, the “jaws of life”, and other hydraulic cutting and spreading tools used to extricate individuals from wrecked vehicles. Rescue operations are sometimes supported by special vehicles such as fire department’s or EMS heavy rescue vehicle.

Overview  
Ropes and special devices can reach and remove individuals and animals from difficult locations including:

Air-sea rescue  
Cave rescue  
Combat search and rescue  
Confined space rescue  
Mine rescue  
Rope rescue  
Search and rescue  
Ski patrol  
Surface water rescue  
Swiftwater rescue  
Urban search and rescue  
Vehicle extrication  
Wilderness  
Rescue operations require a high degree of training and are performed by rescue squads, either independent or part of larger organizations such as fire, police, military, first aid, or ambulance service.

Week 2; quadrilaterals

In this tutorial on basic geometry concepts, we cover the types and properties of quadrilaterals: Parallelogram, rectangle, square, rhombus, trapezium.

**Definition:**

A quadrilateral is a simple closed figure with four sides.

**Types of quadrilaterals**

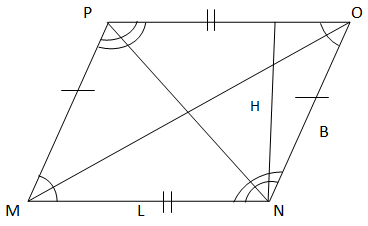
There are five types of quadrilaterals.

* Parallelogram
* Rectangle
* Square
* Rhombus
* Trapezium

One common property of all quadrilaterals is that the sum of all their angles equals 360°.

Let us look into the properties of different quadrilaterals.

**Parallelogram**



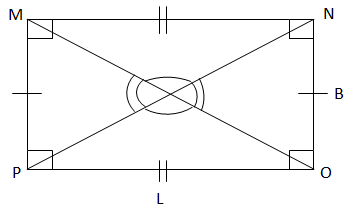
**Properties of a parallelogram**

* Opposite sides are parallel and congruent.
* Opposite angles are congruent.
* Adjacent angles are supplementary.
* Diagonals bisect each other and each diagonal divides the parallelogram into two congruent triangles.
* If one of the angles of a parallelogram is a right angle then all other angles are right and it becomes a rectangle.

**Important formulas of parallelograms**

* Area = L \* H
* Perimeter = 2(L+B)

**Rectangles**



**Properties of a Rectangle**

* Opposite sides are parallel and congruent.
* All angles are right.
* The diagonals are congruent and bisect each other (divide each other equally).
* Opposite angles formed at the point where diagonals meet are congruent.
* A rectangle is a special type of parallelogram whose angles are right.

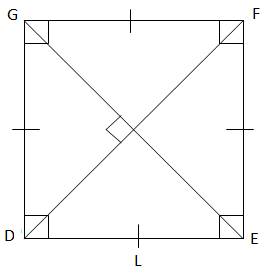
**Important formulas for rectangles**

* If the length is L and breadth is B, then

Length of the diagonal of a rectangle = √(L2 + B2)

* Area = L \* B
* Perimeter = 2(L+B)

**Squares**



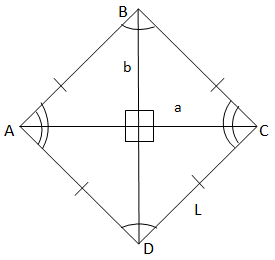
**Properties of a square**

* All sides and angles are congruent.
* Opposite sides are parallel to each other.
* The diagonals are congruent.
* The diagonals are perpendicular to and bisect each other.
* A square is a special type of parallelogram whose all angles and sides are equal.
* Also, a parallelogram becomes a square when the diagonals are equal and right bisectors of each other.

**Important formulas for Squares**

* If ‘L’ is the length of the side of a square then length of the diagonal = L √2.
* Area = L2.
* Perimeter = 4L

**Rhombus**



**Properties of a Rhombus**

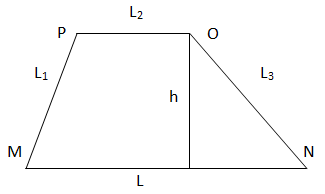
* All sides are congruent.
* Opposite angles are congruent.
* The diagonals are perpendicular to and bisect each other.
* Adjacent angles are supplementary (For eg., ∠A + ∠B = 180°).
* A rhombus is a parallelogram whose diagonals are perpendicular to each other.

**Important formulas for a Rhombus**

If a and b are the lengths of the diagonals of a rhombus,

* Area = (a\* b) / 2
* Perimeter = 4L

**Trapezium**



**Properties of a Trapezium**

* The bases of the trapezium are parallel to each other (MN ⫽ OP).
* No sides, angles and diagonals are congruent.

**Important Formulas for a Trapezium**

* Area = (1/2) h (L+L2)
* Perimeter = L + L1 + L2 + L3

**Summary of properties**

Summarizing what we have learnt so far for easy reference and remembrance:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| S.No. | Property | Parallelogram | Rectangle | Rhombus | Square |
| 1 | All sides are congruent | ✕ | ✕ | ✓ | ✓ |
| 2 | Opposite sides are parallel and congruent | ✓ | ✓ | ✓ | ✓ |
| 3 | All angles are congruent | ✕ | ✓ | ✕ | ✓ |
| 4 | Opposite angles are congruent | ✓ | ✓ | ✓ | ✓ |
| 5 | Diagonals are congruent | ✕ | ✓ | ✕ | ✓ |
| 6 | Diagonals are perpendicular | ✕ | ✕ | ✓ | ✓ |
| 7 | Diagonals bisect each other | ✓ | ✓ | ✓ | ✓ |
| 8 | Adjacent angles are supplementary | ✓ | ✓ | ✓ | ✓ |

Assignment

1. Define quadrilaterals
2. Define polygon

Week 3; plane figure

**Plane figures**

Any shape that can be drawn in the plane is called a plane figure. A shape with only straight sides as edges is called a polygon(POL-ee-gone). Polygons must have at least three sides, thus the polygons with the fewest number of sides are triangles. Circles and semicircles are not polygons because they have curved sides.

When all the sides of a polygon are equal, it is equilateral (ee-quee-LAH-teh-roll). When all the angles of a polygon are equal, it is equiangular (ee-quee-ANG-ger-lah). When a polygon is both equilateral and equiangular, it is a regular shape. When doing mathematics problems, it is very important that an equilateral shape may not be equiangular (such as a rhombus), and an equiangular shape may not be equilateral (such as a rectangle). However, an equilateral triangle is always both (see below).

When dealing with plane figures, there are two measurements that are important to find: the area and the perimeter. The perimeter is the length around the shape while the area is the size of the shape. They can be calculated with different formulae.

**Triangles**

|  |  |
| --- | --- |
| [Elements title page.jpg](https://commons.wikimedia.org/wiki/File:Elements_title_page.jpg) | The corresponding material in Euclid's elements can be found on [page 27 of Book I, Definition(s) 24-29](https://en.wikisource.org/wiki/Page:The_Elements_of_Euclid_for_the_Use_of_Schools_and_Colleges_-_1872.djvu/27) in Issac Todhunter's 1872 translation, [*The Elements of Euclid for the Use of Schools and Colleges*](https://en.wikisource.org/wiki/Index:The_Elements_of_Euclid_for_the_Use_of_Schools_and_Colleges_-_1872.djvu). |

A triangle is a shape with three sides. It can be classified according to its sides or angles, with three kinds each. Here they are:

* **Equilateral triangles**, which are also **equiangular triangles**, have three sides equal and three angles equal. Their angles are always 60°.
* **Isosceles triangles** are triangles in which two of the sides are equal. The non-included angles of the sides are also equal.
* **Scalene triangles** have no equivalence in any way.
* **Right triangles** are triangles with a right angle. The longest side of such triangles is called a hypotenuse.
* **Obtuse triangles** are triangles with an obtuse angle.
* **Acute triangles** are triangles with no right or obtuse angle.

It is interesting to note that the interior angles of triangles must add up to 180°. This is commonly used in proofs and other problems. Imagine a triangle whose points are marked A, B and C, angle A is 60 degrees, and angle B is 70 degrees:

∠ B A C + ∠ A B C + ∠ A C B = 180 ∘ ( ∠  sum of  △ ) 60 ∘ + 70 ∘ + ∠ A C B = 180 ∘ ∠ A C B = 180 ∘ − 60 ∘ − 70 ∘ = 50 ∘ {\displaystyle {\begin{aligned}\angle BAC+\angle ABC+\angle ACB&=180^{\circ }(\angle {\text{ sum of }}\triangle )\\60^{\circ }+70^{\circ }+\angle ACB&=180^{\circ }\\\angle ACB&=180^{\circ }-60^{\circ }-70^{\circ }\\&=50^{\circ }\end{aligned}}}

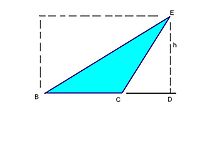
Usually, when drawing a triangle, we draw one side horizontally. This side is usually called the **base**. There is nothing special about the base. By turning your paper you can make any side into the base. There is no mathematical reason to call one side a base; we do it to make talking about the triangle easier. When you have a triangle and think of one of the sides as the base, then there is one corner of the triangle that is not on the base and this point is the furthest point on the triangle from the base. The **height** of the triangle is the line that is perpendicular to the base and goes through that furthest point. Sometimes instead of being called the **height** it is called the **altitude** of the triangle. (So if your teacher calls it an altitude, don't worry, it's really the same thing.) The length of the base and the height are the only two numbers you need to know when calculating the area of any triangle. Just multiply base and height and divide by two (or multiply it by a half if you like.) and you have the area of the triangle!

The perimeter of the triangle is easy: just add up all the sides and voilà, you have the perimeter. You can multiply one side of an equilateral triangle by three as well. As for isosceles triangles, simply multiply one of the equal sides by two and add the shorter one. There we go.

**Quadrilaterals**

A quadrilateral is a shape with four sides. You will spend a lot of time with these. They can be classified into many different categories:

* **Parallelograms** are shapes where opposite sides and angles are equal. The opposite sides are parallel, hence the name.
  + **Rectangles** are parallelograms where the angles are all 90°. Its width or breadth refers to the shorter sides, while its length refers to its longer ones.
  + **Rhombuses** are parallelograms where all the sides are equal, and opposite angles are equal.
  + **Squares** are parallelograms that are both rectangles and rhombuses, i.e. all angles are right and all sides are equal.
* **Trapeziums**, called **trapezoids** in American English, have two opposite sides that are parallel. The parallel sides are sometimes called the upper and lower bases.
  + **Right-angles trapeziums** are trapeziums with a right angle.
  + **Isosceles trapeziums** are trapeziums where the laterals sides are equal but not parallel.
  + **Scalene trapeziums** are trapeziums that fall into neither category.
* **Kites** are quadrilaterals where two pairs of adjacent sides are equal and one pair of opposite angles is equal.
* **Irregular quadrilaterals** are any quadrilaterals that do not fit into one of the groups above.

[](https://commons.wikimedia.org/wiki/File:Area_of_triangle.JPG)

An example of how filling can be put to use.

Calculating the area of these shapes can be very easy. For parallelograms, simply multiply the base with the height, the way with do with triangles, except we don't need to divide by two. The square is especially easy: just square one of the sides, which would be the length. For the others, we can cut them up into bite-sized pieces before we calculate. For example, we can dissect the right-angled trapeziums into a right-angled triangle and a rectangle.

The perimeter of these shapes are just as easy. For rectangles, we simply add up the length and the width, then multiply by two. You can simply multiply the length of a square by four. The isosceles trapeziums are just as easy: multiply one of the lateral sides by two, then add it up with the other two. The kite is easy as well: Just add up the two different sides and multiply that by two. For the rest, you can just add up everything.

**Other polygons**

Many other polygons have a name. The following are the ones you need to know in elementary school:

* **Pentagons** have five sides.
* **Hexagons** have six sides.
* **Heptagons** or septagons have seven sides.
* **Octagons** have eight sides.
* **Nonagons** have nine sides.
* **Decagons** have ten sides.

And here are two more extras:

* **Hendecagons** (also known as **undecagons**) have eleven sides.
* **Dodecagons** have twelve sides.

Calculating the perimeter and area of these shapes can be more difficult. Sometimes you have to come up with ways of doing it yourself. When you come across an equilateral polygon, you can of course multiply one of the sides by the number of sides of the shape. In other cases, you may need to find some dimensions yourself. Keep your eyes peeled for equivalences, and the problems cannot be that difficult.

When calculating the area of these shapes, there are two main ways of doing so: dissecting and filling. With dissecting, you cut up the figure into many pieces, such as parallelograms, squares and triangles. Then you can simply add up all those areas to find out the total. With filling, you add extra bits to shapes so as to make it look like the shapes you usually come across with. For example, when you don't known the altitude of a triangle, you can put three surrounding triangles around it. Then you can calculate the area of the rectangle formed and the surrounding triangles, thereby finding the area of the triangle.

**Circles and other plane figures**

Apart from polygons, there are other shapes that have wavy sides, round corners or other peculiarities that disqualify them as polygons. Among them, the most famous are the circle, the ellipse, and the semicircle. These shapes are different from polygons, and have their special formulae that you must learn by heart. Let's start with the most basic: the circle.

|  |  |
| --- | --- |
| [Elements title page.jpg](https://commons.wikimedia.org/wiki/File:Elements_title_page.jpg) | The corresponding material in Euclid's elements can be found on [page 27 of Book I, Definition(s) 15-17](https://en.wikisource.org/wiki/Page:The_Elements_of_Euclid_for_the_Use_of_Schools_and_Colleges_-_1872.djvu/27) in Issac Todhunter's 1872 translation, [*The Elements of Euclid for the Use of Schools and Colleges*](https://en.wikisource.org/wiki/Index:The_Elements_of_Euclid_for_the_Use_of_Schools_and_Colleges_-_1872.djvu). |

Circles are shapes with infinite loci around its centre. Its perimeter is called the circumference. The line running from one side of the circle, through the centre and to the other side is called the diameter. The line running from the centre to any point on the circumference is called the radius. Any other line running from one point of the circumference to another is called a chord. An arc is any part of the circumference.

For thousands of years, mathematicians have been trying to find out the relationship between the circumference and the diameter. When we divide the circumference by the diameter, we get a number that is slightly larger than 3. That number is called π (spelt pi and pronounced pie). Supercomputers have discovered millions of digits of π, but you only need to remember that π is roughly 3.14 or 22/7. That is close enough. If you know the circumference of a circle, dividing that by π will result in the diameter; multiplying the diameter by π will result in the circumference. To find out the area of a circle, calculate πr2.

You don't really get to know much about ellipses and semicircles in elementary school. Ellipses look like ovals, except they have a stricter way of constructing that is more than a crushed circle. They have two 'centres' called foci. Semicircles are circles cut along the diameter, and if you draw a line from one end to a point on the circumference, then to another end, you always get a right angle. These two shapes are seldom taught in elementary school, and aside from knowing their names you don't need to study them.

Assignment

* 1. List 5 types of polygon
  2. Construct a pentagon [ab 40mm]

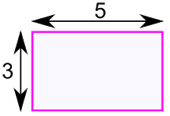
Week 4&5; area of plane figure

# Area of Plane Shapes

*Area is the size of a surface!  
Learn more about* [*Area*](http://www.mathsisfun.com/geometry/area.html)*, or try the* [*Area Calculator*](http://www.mathsisfun.com/area-calculation-tool.html)*.*

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| [triangle base height](http://www.mathsisfun.com/triangle.html) | [Triangle](http://www.mathsisfun.com/triangle.html) Area = ½ × b × h b = base h = vertical height | | | |  | [square](http://www.mathsisfun.com/geometry/square.html) | [Square](http://www.mathsisfun.com/geometry/square.html) Area = a2 a = length of side |
| [rectangle](http://www.mathsisfun.com/geometry/rectangle.html) | [Rectangle](http://www.mathsisfun.com/geometry/rectangle.html) Area = w × h w = width h = height | | | |  | [parallelogram](http://www.mathsisfun.com/geometry/parallelogram.html) | [Parallelogram](http://www.mathsisfun.com/geometry/parallelogram.html) Area = b × h b = base h = vertical height |
| [trapezoid](http://www.mathsisfun.com/geometry/trapezoid.html) | [Trapezoid (US)](http://www.mathsisfun.com/geometry/trapezoid.html) [Trapezium (UK)](http://www.mathsisfun.com/geometry/trapezoid.html) Area = ½(a+b) × h h = vertical height | | | |  | [circle](http://www.mathsisfun.com/geometry/circle-area.html) | [Circle](http://www.mathsisfun.com/geometry/circle-area.html)  Area = π × r2  Circumference = 2 × π × r r = radius |
| [ellipse](http://www.mathsisfun.com/geometry/ellipse.html) | [Ellipse](http://www.mathsisfun.com/geometry/ellipse.html) Area = πab | | | |  | [sector](http://www.mathsisfun.com/geometry/circle-sector-segment.html) | [Sector](http://www.mathsisfun.com/geometry/circle-sector-segment.html) Area = ½ × r2 × θ  r = radius θ = angle in **radians** |
| Note: **h** is at [right angles](http://www.mathsisfun.com/rightangle.html) to **b:** | |  | altitude |

### Example: What is the area of this rectangle?



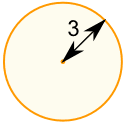
The formula is:

Area = w × h  
w = width  
h = height

We know **w = 5** and **h = 3**, so:

Area = 5 × 3 = **15**

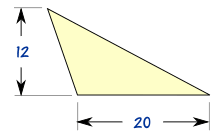
### Example: What is the area of this circle?



Radius = r = 3

|  |  |  |
| --- | --- | --- |
| Area |  | = π × r2 |
|  |  | = π × 32 |
|  |  | = π × (3 × 3) |
|  |  | = 3.14159... × 9 |
|  |  | = **28.27** (to 2 decimal places) |

### Example: What is the area of this triangle?



Height = h = 12

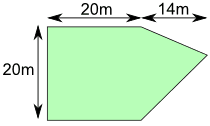
Base = b = 20

Area = ½ × b × h = ½ × 20 × 12 = **120**

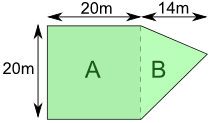
A harder example:

### Example: Sam cuts grass at $0.10 per square meter

### How much does Sam earn cutting this area:



Let's break the area into two parts:



Part A is a square:

Area of A = a2 = 20m × 20m = 400m2

Part B is a triangle. Viewed sideways it has a base of 20m and a height of 14m.

Area of B = ½b × h = ½ × 20m × 14m = 140m2

So the total area is:

Area = Area of A + Area of B = 400m2 + 140m2 = 540m2

Sam earns $0.10 per square meter

Sam earns = $0.10 × 540m2 = $54

Assignment

* 1. Construct a rectangle equal to the area of a given triangle

Week 6; wood work machine

### Artisanal and hobby machines

These machines are used both in small-scale commercial production of timber products and by hobbyists. Most of these machines may be used on solid timber and on composite products. Machines can be divided into the bigger **stationary machines** where the machine remains stationary while the material is moved over the machine, and **hand-held** [**power tools**](https://en.wikipedia.org/wiki/Power_tool), where the tool is moved over the material.

#### Hand-held power tools

* [Biscuit joiner](https://en.wikipedia.org/wiki/Biscuit_joiner)
* [Domino jointer](https://en.wikipedia.org/wiki/Domino_jointer)
* [Chain saw](https://en.wikipedia.org/wiki/Chain_saw)
* Hand-held [circular saw](https://en.wikipedia.org/wiki/Circular_saw)
* Electric [drill](https://en.wikipedia.org/wiki/Drill)
* [Jig saw](https://en.wikipedia.org/wiki/Jig_saw)
* [Miter saw](https://en.wikipedia.org/wiki/Miter_saw)
* [Nail gun](https://en.wikipedia.org/wiki/Nail_gun)
* Hand-held electric [plane](https://en.wikipedia.org/wiki/Plane_(tool))
* [Reciprocating saw](https://en.wikipedia.org/wiki/Reciprocating_saw)
* [Rotary tool](https://en.wikipedia.org/wiki/Rotary_tool)
* [Router](https://en.wikipedia.org/wiki/Wood_router)
* Hand-held [sanders](https://en.wikipedia.org/wiki/Sander), including belt sander, orbital sander, random orbit sander

#### Stationary machines

* [Bandsaw](https://en.wikipedia.org/wiki/Bandsaw)
* [Combination machine](https://en.wikipedia.org/wiki/Combination_machine)
* [Double side planer](https://en.wikipedia.org/w/index.php?title=Double_side_planer&action=edit&redlink=1)
* [Four sided planer](https://en.wikipedia.org/w/index.php?title=Four_sided_planer&action=edit&redlink=1) or timber sizer
* [Drill press](https://en.wikipedia.org/wiki/Drill_press)
* [Drum sander](https://en.wikipedia.org/w/index.php?title=Drum_sander&action=edit&redlink=1)
* [Bench grinder](https://en.wikipedia.org/wiki/Bench_grinder)
* [Jointer](https://en.wikipedia.org/wiki/Jointer)
* [Wood lathe](https://en.wikipedia.org/wiki/Lathe)
* [Mortiser](https://en.wikipedia.org/wiki/Mortiser)
* [Panel saw](https://en.wikipedia.org/wiki/Panel_saw)
* [Pin router](https://en.wikipedia.org/w/index.php?title=Pin_router&action=edit&redlink=1)
* [Radial arm saw](https://en.wikipedia.org/wiki/Radial_arm_saw)
* [Scroll saw](https://en.wikipedia.org/wiki/Scroll_saw)
* [Spindle moulder](https://en.wikipedia.org/wiki/Spindle_moulder) (Wood shaper)
* Stationary [sanders](https://en.wikipedia.org/wiki/Sander), including stroke sanders, oscillating spindle sander, belt sander, disc sander (and combination disc-belt sander).
* [Table saw](https://en.wikipedia.org/wiki/Table_saw)
* [Tenoner](https://en.wikipedia.org/w/index.php?title=Tenoner&action=edit&redlink=1) or tenoning machine
* [Thicknesser](https://en.wikipedia.org/wiki/Thicknesser) or Thickness planer
* [Round pole milling machine](https://en.wikipedia.org/w/index.php?title=Round_pole_milling_machine&action=edit&redlink=1)
* [Round pole sanding machine](https://en.wikipedia.org/w/index.php?title=Round_pole_sanding_machine&action=edit&redlink=1)

### Panel Line Woodworking machines

These machines are used in large-scale [manufacturing](https://en.wikipedia.org/wiki/Manufacturing) of cabinets and other wooden or panel products.

### Panel surface processing

#### Panel dividing equipment

[Panel dividing equipment](https://en.wikipedia.org/wiki/Panel_dividing_equipment), classified by number of beam, loading system, saw carriage speed

#### Double end tenoner

Double end tenoner, classified by conveyor type

* Rolling chain system conveyor speed 40 to 120 m/min
* Sliding chain system conveyor speed 10 to 30 m/min

### Panel edge processing equipment

Panel edge processing equipment, classified by conveyor speed

* High speed edgebander conveyor speed >= 100 m/min
* Heavy duty edgebander conveyor speed >= 24 m/min
* Light duty edgebander conveyor speed < 20 m/min (i.e. 8, 12 or 16 m/min)

### Panel boring equipment

classified by number of boring heads

* Single line boring machine
* Multi line boring machine

### Panel automatic packing equipment

Assignment

1. List 2 types of sawing machine
2. State the functions of surface planer

Week 7; metal work machine

* + [Coolant Systems](http://www.warco.co.uk/2962-coolant-systems)
  + [Digital Readouts DRO](http://www.warco.co.uk/7-digital-readouts-scales-dro)
  + [Dividing & Indexing Heads](http://www.warco.co.uk/2972-dividing-indexing-heads)
  + [Drilling Machines](http://www.warco.co.uk/8-drilling-machines-bench-pillar-drills)
  + [Drill Sets & Accessories](http://www.warco.co.uk/9-drill-accessories-sets)
  + [Gift Vouchers](http://www.warco.co.uk/10-gift-vouchers)
  + [Grinders](http://www.warco.co.uk/11-metal-grinders)
  + [Lathes](http://www.warco.co.uk/12-metal-lathes-metalworking-lathe-machine)
  + [Lathe Tools](http://www.warco.co.uk/28-metal-lathe-tools-turning-cutting-tooling)
  + [Lights](http://www.warco.co.uk/13-lights)
  + [Lubricants, Cutting Oil](http://www.warco.co.uk/14-lubricants-neatcut-cutting-oil)
  + [Marking Out Equipment](http://www.warco.co.uk/17-marking-out-equipment-tools)
  + [Measuring Tools](http://www.warco.co.uk/18-measuring-tools)
  + [Milling Machines](http://www.warco.co.uk/20-milling-machines)
  + [Milling Tools & Accessories](http://www.warco.co.uk/21-milling-tools-cutters-metalworking-accessories)
  + [Other Accessories](http://www.warco.co.uk/2961-accessories)
  + [Polishers](http://www.warco.co.uk/2973-polishers)
  + [Punches](http://www.warco.co.uk/2982-punches)
  + [Rotary Tables](http://www.warco.co.uk/2964-rotary-tables-engineering-tools)
  + [Sanders](http://www.warco.co.uk/23-disc-sander-bench-sanders)
  + [Sheet Metal Machinery](http://www.warco.co.uk/19-sheet-metal-fabrication-machinery-metalwork)
  + [Stands & Trays](http://www.warco.co.uk/25-machine-stands)
  + [Tool Cabinets & Trolleys](http://www.warco.co.uk/27-tool-cabinets-chests-machine-trolleys)
  + [Vee Blocks & Angle Plates](http://www.warco.co.uk/2966-vee-blocks-angle-plates)
  + [Vices & Vice Jaws](http://www.warco.co.uk/2971-machine-vices-vice-jaws)
  + [Work Holding](http://www.warco.co.uk/29-work-holding-tools-equipment)
* [Wood Working](http://www.warco.co.uk/2904-wood-working-machines-tools)
* [Education](http://www.warco.co.uk/2905-schools-education-engineering-training-machines)

#### [Special offers](http://www.warco.co.uk/reduced-price-tools-machines)

* [](http://www.warco.co.uk/tool-cabinets-chests-machine-trolleys/83-tool-chest.html)

##### [Tool Chest](http://www.warco.co.uk/tool-cabinets-chests-machine-trolleys/83-tool-chest.html)

£123.00 £162.38

Metal Working

The Warco range of metal working machine tools and accessories. Find a metalworking lathe, milling machine, drilling machines, lathe tools and parts, DRO, sheet metal fabrication equipment and much more. Get started by looking at our comprehensive range of metal work tooling for sale below. Quality machine tools, at affordable prices.

Subcategories

* [](http://www.warco.co.uk/6-abrasives)

##### [Abrasives](http://www.warco.co.uk/6-abrasives)

* [](http://www.warco.co.uk/24-metal-bandsaws-metalworking-saws)

##### [Bandsaws & Saws](http://www.warco.co.uk/24-metal-bandsaws-metalworking-saws)

* [](http://www.warco.co.uk/2983-engineering-books)

##### [Books](http://www.warco.co.uk/2983-engineering-books)

* [](http://www.warco.co.uk/2970-clamping-kits-tee-nuts-studs-clamps)

##### [Clamps, Nuts & Studs](http://www.warco.co.uk/2970-clamping-kits-tee-nuts-studs-clamps)

* [](http://www.warco.co.uk/2962-coolant-systems)

##### [Coolant Systems](http://www.warco.co.uk/2962-coolant-systems)

* [](http://www.warco.co.uk/7-digital-readouts-scales-dro)

##### [Digital Readouts DRO](http://www.warco.co.uk/7-digital-readouts-scales-dro)

* [](http://www.warco.co.uk/2972-dividing-indexing-heads)

##### [Dividing & Indexing Heads](http://www.warco.co.uk/2972-dividing-indexing-heads)

* [](http://www.warco.co.uk/8-drilling-machines-bench-pillar-drills)

##### [Drilling Machines](http://www.warco.co.uk/8-drilling-machines-bench-pillar-drills)

* [](http://www.warco.co.uk/9-drill-accessories-sets)

##### [Drill Sets & Accessories](http://www.warco.co.uk/9-drill-accessories-sets)

* [](http://www.warco.co.uk/10-gift-vouchers)

##### [Gift Vouchers](http://www.warco.co.uk/10-gift-vouchers)

* [](http://www.warco.co.uk/11-metal-grinders)

##### [Grinders](http://www.warco.co.uk/11-metal-grinders)

* [](http://www.warco.co.uk/12-metal-lathes-metalworking-lathe-machine)

##### [Lathes](http://www.warco.co.uk/12-metal-lathes-metalworking-lathe-machine)

* [](http://www.warco.co.uk/28-metal-lathe-tools-turning-cutting-tooling)

##### [Lathe Tools](http://www.warco.co.uk/28-metal-lathe-tools-turning-cutting-tooling)

* [](http://www.warco.co.uk/13-lights)

##### [Lights](http://www.warco.co.uk/13-lights)

* [](http://www.warco.co.uk/14-lubricants-neatcut-cutting-oil)

##### [Lubricants, Cutting Oil](http://www.warco.co.uk/14-lubricants-neatcut-cutting-oil)

* [](http://www.warco.co.uk/17-marking-out-equipment-tools)

##### [Marking Out Equipment](http://www.warco.co.uk/17-marking-out-equipment-tools)

* [](http://www.warco.co.uk/18-measuring-tools)

##### [Measuring Tools](http://www.warco.co.uk/18-measuring-tools)

* [](http://www.warco.co.uk/20-milling-machines)

##### [Milling Machines](http://www.warco.co.uk/20-milling-machines)

* [](http://www.warco.co.uk/21-milling-tools-cutters-metalworking-accessories)

##### [Milling Tools &...](http://www.warco.co.uk/21-milling-tools-cutters-metalworking-accessories)

* [](http://www.warco.co.uk/2961-accessories)

##### [Other Accessories](http://www.warco.co.uk/2961-accessories)

* [](http://www.warco.co.uk/2973-polishers)

##### [Polishers](http://www.warco.co.uk/2973-polishers)

* [](http://www.warco.co.uk/2982-punches)

##### [Punches](http://www.warco.co.uk/2982-punches)

* [](http://www.warco.co.uk/2964-rotary-tables-engineering-tools)

##### [Rotary Tables](http://www.warco.co.uk/2964-rotary-tables-engineering-tools)

* [](http://www.warco.co.uk/23-disc-sander-bench-sanders)

##### [Sanders](http://www.warco.co.uk/23-disc-sander-bench-sanders)

* [](http://www.warco.co.uk/19-sheet-metal-fabrication-machinery-metalwork)

##### [Sheet Metal Machinery](http://www.warco.co.uk/19-sheet-metal-fabrication-machinery-metalwork)

* [](http://www.warco.co.uk/25-machine-stands)

##### [Stands & Trays](http://www.warco.co.uk/25-machine-stands)

* [](http://www.warco.co.uk/27-tool-cabinets-chests-machine-trolleys)

##### [Tool Cabinets & Trolleys](http://www.warco.co.uk/27-tool-cabinets-chests-machine-trolleys)

* [](http://www.warco.co.uk/2966-vee-blocks-angle-plates)

##### [Vee Blocks & Angle Plates](http://www.warco.co.uk/2966-vee-blocks-angle-plates)

* [](http://www.warco.co.uk/2971-machine-vices-vice-jaws)

##### [Vices & Vice Jaws](http://www.warco.co.uk/2971-machine-vices-vice-jaws)

* [](http://www.warco.co.uk/29-work-holding-tools-equipment)

##### [Work Holding](http://www.warco.co.uk/29-work-holding-tools-equipment)

Assignment

1. List 5 basic machine tools
2. State 3 uses of centre lathe

Week 8; maintenance and care of machines

Here are five top tips for large machinery maintenance:

**1. Stay on top of large machinery operator training**

Many types of large machinery have multiple operators. One of the ongoing inspections on any checklist should be overseeing the correct operation of the equipment.

Large machinery should be inspected as soon as it is purchased. Operator training is usually done at that point, but training needs to be kept up. Employees come and go, skills become rusty and poor operation leads to breakdowns.

Operator manuals can be revised for the specific work situation. They can be rewritten in simpler language. A short manual can be provided to each operator for easy reference. And, if you operate in a paperless environment, you can rest assured operators use the most current version of each manual.

One other note is to identify best practices, which can then be applied to other facilities or geographic locations. The knowledge you learn about how to maintain your equipment can become quite valuable – be sure to best leverage this important knowledge and use it at every applicable location.

**2. Add and test lubricants frequently**

Lubricants reduce friction around any moving part. A schedule of good lubrication maintenance extends the life of large machinery equipment and parts.

Lubrication is one of the first and most important of maintenance checks. Look for signs of excess oil or grease build-up on pistons. Check for leaks around oil seals.

Be sure to use the right lubricant. There are specific kinds of oil and grease for every component. Check the manufacturer’s recommendations.

Getting the lubricants checked is a good way to diagnose problems with large machinery. Experts analyze particles in the used oil. The makeup of any contaminants will indicate which part may be suffering from wear or breakdown.

**3. Check for signs of wear**

Vibration, shock, high temperatures, friction and age all contribute to the breakdown of parts in heavy machinery.

* Vibration can come from gears and belts that are out of alignment
* Shock can come from accidents and from poor operator technique
* High temperatures can come from extended use, friction, poor lubrication and worn parts, among other reasons
* Age affects many key components. Over time, belts will warp. Seals will dry and crack. Bolts will loosen and stretch out of shape. Age is a factor to monitor in equipment.

Should you discover wear and tear on any moving parts within your heavy equipment, be sure to quickly perform the necessary replacement of any worn parts.

**4. Keep large machinery clean, and maintain a clean environment**

There are many seals and filters in place on heavy machinery to keep working parts clean and free of contamination. Seals should be inspected regularly to make sure they’re in good condition. Filters should be inspected and changed regularly. Breathers should be kept clean to avoid creating a vacuum in the cab which will suck contaminants into the cab. The electronics in the cab are susceptible to breakdown if contaminated. This impacts the clutch, for example.

Large machinery should be stored in a shed or other building if at all possible. Exposure to wind and weather can lead to rust and rot. The machinery should be run periodically if it is not in use.

**5. Have a maintenance and repair schedule, and keep good records**

Fluids, tires, tracks and electrical systems are among the components that have to be checked regularly for preventive maintenance. Know what needs to be inspected and when. Here are some examples.

* Power transmissions have many moving parts that need to be maintained in top condition. Gearboxes need to be checked for lubrication, vibration and damage to parts.
* Friction materials, seals, gaskets and bearings all need to be inspected for wear and replaced. Gears and shafts usually last a long time and don’t need to be replaced often, if at all.
* Drive train components need constant monitoring. Check pulleys and v-belts on CVT transmissions for alignment and wear. Check sprockets for correct meshing with chains and for breaks.
* Test the oil to diagnose problems. Change filters frequently.
* Bearings keep great amounts of force running smoothly and are vital to large machinery performance. Check bearing lubrication often. Maintaining bearings well extends their life.
* Lubricate gears frequently.
* Do a seal check to prevent bearing raceway contamination.
* Run torque checks on the bolts. Bolts can elongate and creep over time.

To conclude, following the above 5 steps can significantly extend the useful life of heavy machinery, improving the Return on Investment from these important purchases. In today’s global manufacturing world, even greater value can be extracted if you have a global knowledge capture and distribution system such that this knowledge of machinery maintenance can be effectively shared across your organization – letting you reap even greater benefits on a much wider scale.

Assignment

* + 1. Define maintenance
    2. Mention 3 types of maintenance

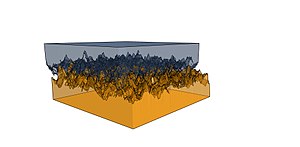
Week 9; friction

# Friction

From Wikipedia, the free encyclopedia

For other uses, see [Friction (disambiguation)](https://en.wikipedia.org/wiki/Friction_(disambiguation)).

|  |
| --- |
| [**Classical mechanics**](https://en.wikipedia.org/wiki/Classical_mechanics) |
| F → = m a → {\displaystyle {\vec {F}}=m{\vec {a}}}  [*Second law of motion*](https://en.wikipedia.org/wiki/Second_law_of_motion) |
| * [**History**](https://en.wikipedia.org/wiki/History_of_classical_mechanics) * [**Timeline**](https://en.wikipedia.org/wiki/Timeline_of_classical_mechanics) |
| Branches[[show]](https://en.wikipedia.org/wiki/Friction) |
| Fundamentals[[show]](https://en.wikipedia.org/wiki/Friction) |
| Formulations[[show]](https://en.wikipedia.org/wiki/Friction) |
| Core topics[[show]](https://en.wikipedia.org/wiki/Friction) |
| [Rotation](https://en.wikipedia.org/wiki/Rotation_around_a_fixed_axis)[[show]](https://en.wikipedia.org/wiki/Friction) |
| Scientists[[show]](https://en.wikipedia.org/wiki/Friction) |
| * [v](https://en.wikipedia.org/wiki/Template:Classical_mechanics) * [t](https://en.wikipedia.org/wiki/Template_talk:Classical_mechanics) * [e](https://en.wikipedia.org/w/index.php?title=Template:Classical_mechanics&action=edit) |

[](https://en.wikipedia.org/wiki/File:Friction_between_surfaces.jpg)

Simulated blocks with [fractal](https://en.wikipedia.org/wiki/Fractal) rough surfaces, exhibiting static frictional interactions[[1]](https://en.wikipedia.org/wiki/Friction#cite_note-statfric-1)

**Friction** is the [force](https://en.wikipedia.org/wiki/Force) resisting the relative motion of solid surfaces, fluid layers, and material elements sliding against each other.[[2]](https://en.wikipedia.org/wiki/Friction#cite_note-2) There are several types of friction:

* **Dry friction** is a force that opposes the relative lateral motion of two solid surfaces in contact. Dry friction is subdivided into *static friction* ("[stiction](https://en.wikipedia.org/wiki/Stiction)") between non-moving surfaces, and *kinetic friction* between moving surfaces. With the exception of atomic or molecular friction, dry friction generally arises from the interaction of surface features, known as [asperities](https://en.wikipedia.org/wiki/Asperity_(materials_science))
* **Fluid friction** describes the friction between layers of a [viscous](https://en.wikipedia.org/wiki/Viscous) fluid that are moving relative to each other.[[3]](https://en.wikipedia.org/wiki/Friction#cite_note-Beer-3)[[4]](https://en.wikipedia.org/wiki/Friction#cite_note-Meriam-4)
* **Lubricated friction** is a case of fluid friction where a [lubricant](https://en.wikipedia.org/wiki/Lubricant) fluid separates two solid surfaces.[[5]](https://en.wikipedia.org/wiki/Friction#cite_note-Ruina-5)[[6]](https://en.wikipedia.org/wiki/Friction#cite_note-Hibbeler-6)[[7]](https://en.wikipedia.org/wiki/Friction#cite_note-Soutas-Little-7)
* **Skin friction** is a component of [drag](https://en.wikipedia.org/wiki/Drag_(physics)), the force resisting the motion of a fluid across the surface of a body.
* **Internal friction** is the force resisting motion between the elements making up a solid material while it undergoes [deformation](https://en.wikipedia.org/wiki/Deformation_(mechanics)).[[4]](https://en.wikipedia.org/wiki/Friction#cite_note-Meriam-4)

When surfaces in contact move relative to each other, the friction between the two surfaces converts [kinetic energy](https://en.wikipedia.org/wiki/Kinetic_energy) into [thermal energy](https://en.wikipedia.org/wiki/Thermal_energy) (that is, it converts [work](https://en.wikipedia.org/wiki/Work_(physics)) to [heat](https://en.wikipedia.org/wiki/Heat)). This property can have dramatic consequences, as illustrated by the use of friction created by rubbing pieces of wood together to start a fire. Kinetic energy is converted to thermal energy whenever motion with friction occurs, for example when a [viscous](https://en.wikipedia.org/wiki/Viscous_flow) fluid is stirred. Another important consequence of many types of friction can be [wear](https://en.wikipedia.org/wiki/Wear), which may lead to performance degradation or damage to components. Friction is a component of the science of [tribology](https://en.wikipedia.org/wiki/Tribology).

Friction is desirable and important in supplying [traction](https://en.wikipedia.org/wiki/Traction_(engineering)) to facilitate motion on land. Most [land vehicles](https://en.wikipedia.org/wiki/Land_vehicle) rely on friction for acceleration, deceleration and changing direction. Sudden reductions in traction can cause loss of control and accidents.

Friction is not itself a [fundamental force](https://en.wikipedia.org/wiki/Fundamental_force). Dry friction arises from a combination of inter-surface adhesion, surface roughness, surface deformation, and surface contamination. The complexity of these interactions makes the calculation of friction from [first principles](https://en.wikipedia.org/wiki/First_principle) impractical and necessitates the use of [empirical methods](https://en.wikipedia.org/wiki/Empirical_method) for analysis and the development of theory.

Friction is a [non-conservative force](https://en.wikipedia.org/wiki/Conservative_force#Nonconservative_forces) - work done against friction is path dependent. In the presence of friction, some energy is always lost in the form of heat. Thus [mechanical energy](https://en.wikipedia.org/wiki/Mechanical_energy) is not conserved.

## Laws of dry friction

The elementary property of sliding (kinetic) friction were discovered by experiment in the 15th to 18th centuries and were expressed as three empirical laws:

* [**Amontons' First Law**](https://en.wikipedia.org/wiki/Guillaume_Amontons#Amontons'_Laws_of_Friction): The force of friction is directly proportional to the applied load.
* **Amontons' Second Law**: The force of friction is independent of the apparent area of contact.
* **Coulomb's Law of Friction**: Kinetic friction is independent of the sliding velocity.

## Dry friction

Dry friction resists relative lateral motion of two solid surfaces in contact. The two regimes of dry friction are 'static friction' ("[stiction](https://en.wikipedia.org/wiki/Stiction)") between non-moving surfaces, and *kinetic friction* (sometimes called sliding friction or dynamic friction) between moving surfaces.

Coulomb friction, named after [Charles-Augustin de Coulomb](https://en.wikipedia.org/wiki/Charles-Augustin_de_Coulomb), is an approximate model used to calculate the force of dry friction. It is governed by the model:

F f ≤ μ F n , {\displaystyle F\_{\mathrm {f} }\leq \mu F\_{\mathrm {n} },}

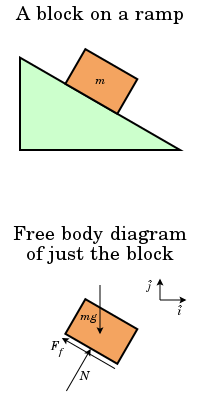
where

* F f {\displaystyle F\_{\mathrm {f} }\,} is the force of friction exerted by each surface on the other. It is parallel to the surface, in a direction opposite to the net applied force.
* μ {\displaystyle \mu \,} is the coefficient of friction, which is an empirical property of the contacting materials,
* F n {\displaystyle F\_{\mathrm {n} }\,} is the [normal force](https://en.wikipedia.org/wiki/Normal_force) exerted by each surface on the other, directed perpendicular (normal) to the surface.

The Coulomb friction F f {\displaystyle F\_{\mathrm {f} }\,} may take any value from zero up to μ F n {\displaystyle \mu F\_{\mathrm {n} }\,} , and the direction of the frictional force against a surface is opposite to the motion that surface would experience in the absence of friction. Thus, in the static case, the frictional force is exactly what it must be in order to prevent motion between the surfaces; it balances the net force tending to cause such motion. In this case, rather than providing an estimate of the actual frictional force, the Coulomb approximation provides a threshold value for this force, above which motion would commence. This maximum force is known as [traction](https://en.wikipedia.org/wiki/Traction_(engineering)).

The force of friction is always exerted in a direction that opposes movement (for kinetic friction) or potential movement (for static friction) between the two surfaces. For example, a [curling](https://en.wikipedia.org/wiki/Curling) stone sliding along the ice experiences a kinetic force slowing it down. For an example of potential movement, the drive wheels of an accelerating car experience a frictional force pointing forward; if they did not, the wheels would spin, and the rubber would slide backwards along the pavement. Note that it is not the direction of movement of the vehicle they oppose, it is the direction of (potential) sliding between tire and road.

### Normal force

[](https://en.wikipedia.org/wiki/File:Free_body_diagram2.svg)

[Free-body diagram](https://en.wikipedia.org/wiki/Free-body_diagram) for a block on a ramp. Arrows are [vectors](https://en.wikipedia.org/wiki/Euclidean_vector) indicating directions and magnitudes of forces. *N* is the normal force, *mg* is the force of [gravity](https://en.wikipedia.org/wiki/Gravity), and *Ff* is the force of friction.

Main article: [Normal force](https://en.wikipedia.org/wiki/Normal_force)

The normal force is defined as the net force compressing two parallel surfaces together; and its direction is perpendicular to the surfaces. In the simple case of a mass resting on a horizontal surface, the only component of the normal force is the force due to gravity, where N = m g {\displaystyle N=mg\,} . In this case, the magnitude of the friction force is the product of the mass of the object, the acceleration due to gravity, and the coefficient of friction. However, the coefficient of friction is not a function of mass or volume; it depends only on the material. For instance, a large aluminum block has the same coefficient of friction as a small aluminum block. However, the magnitude of the friction force itself depends on the normal force, and hence on the mass of the block.

If an **object is on a level surface** and the force tending to cause it to slide is horizontal, the normal force N {\displaystyle N\,} between the object and the surface is just its weight, which is equal to its [mass](https://en.wikipedia.org/wiki/Mass) multiplied by the [acceleration](https://en.wikipedia.org/wiki/Acceleration) due to earth's gravity, [*g*](https://en.wikipedia.org/wiki/Standard_gravity). If the **object is on a tilted surface** such as an inclined plane, the normal force is less, because less of the force of gravity is perpendicular to the face of the plane. Therefore, the normal force, and ultimately the frictional force, is determined using [vector](https://en.wikipedia.org/wiki/Vector_(geometric)) analysis, usually via a [free body diagram](https://en.wikipedia.org/wiki/Free_body_diagram). Depending on the situation, the calculation of the normal force may include forces other than gravity.

### Coefficient of friction

The **coefficient of friction** (COF), often symbolized by the Greek letter [µ](https://en.wikipedia.org/wiki/Mu_(letter)), is a [dimensionless](https://en.wikipedia.org/wiki/Dimensionless_quantity) [scalar](https://en.wikipedia.org/wiki/Scalar_(physics)) value which describes the ratio of the force of friction between two bodies and the force pressing them together. The coefficient of friction depends on the materials used; for example, ice on steel has a low coefficient of friction, while rubber on pavement has a high coefficient of friction. Coefficients of friction range from near zero to greater than one. It is an axiom of the nature of friction between metal surfaces that it is greater between two surfaces of the similar metals than between two surfaces of different metals— hence, brass will have a higher coefficient of friction when moved against brass, but less if moved against steel or aluminum.[[22]](https://en.wikipedia.org/wiki/Friction#cite_note-Association1921-22)

For surfaces at rest relative to each other μ = μ s {\displaystyle \mu =\mu \_{\mathrm {s} }\,} , where μ s {\displaystyle \mu \_{\mathrm {s} }\,} is the *coefficient of static friction*. This is usually larger than its kinetic counterpart. The coefficient of static friction exhibited by a pair of contacting surfaces depends upon the combined effects of material deformation characteristics and [surface roughness](https://en.wikipedia.org/wiki/Surface_roughness), both of which have their origins in the [chemical bonding](https://en.wikipedia.org/wiki/Chemical_bonding) between atoms in each of the bulk materials and between the material surfaces and any [adsorbed material](https://en.wikipedia.org/wiki/Adsorption). The [fractality](https://en.wikipedia.org/wiki/Fractal) of surfaces, a parameter describing the scaling behavior of surface asperities, is known to play an important role in determining the magnitude of the static friction.[[1]](https://en.wikipedia.org/wiki/Friction#cite_note-statfric-1)

For surfaces in relative motion μ = μ k {\displaystyle \mu =\mu \_{\mathrm {k} }\,} , where μ k {\displaystyle \mu \_{\mathrm {k} }\,} is the *coefficient of kinetic friction*. The Coulomb friction is equal to F f {\displaystyle F\_{\mathrm {f} }\,} , and the frictional force on each surface is exerted in the direction opposite to its motion relative to the other surface.

[Arthur Morin](https://en.wikipedia.org/wiki/Arthur_Morin) introduced the term and demonstrated the utility of the coefficient of friction.[[12]](https://en.wikipedia.org/wiki/Friction#cite_note-Dowson-12) The coefficient of friction is an [empirical](https://en.wikipedia.org/wiki/Empirical) [measurement](https://en.wikipedia.org/wiki/Measurement) – it has to be measured [experimentally](https://en.wikipedia.org/wiki/Experiment), and cannot be found through calculations.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] Rougher surfaces tend to have higher effective values. Both static and kinetic coefficients of friction depend on the pair of surfaces in contact; for a given pair of surfaces, the coefficient of static friction is *usually* larger than that of kinetic friction; in some sets the two coefficients are equal, such as teflon-on-teflon.

Most dry materials in combination have friction coefficient values between 0.3 and 0.6. Values outside this range are rarer, but [teflon](https://en.wikipedia.org/wiki/Polytetrafluoroethylene), for example, can have a coefficient as low as 0.04. A value of zero would mean no friction at all, an elusive property. Rubber in contact with other surfaces can yield friction coefficients from 1 to 2. Occasionally it is maintained that µ is always < 1, but this is not true. While in most relevant applications µ < 1, a value above 1 merely implies that the force required to slide an object along the surface is greater than the normal force of the surface on the object. For example, [silicone rubber](https://en.wikipedia.org/wiki/Silicone_rubber) or [acrylic rubber](https://en.wikipedia.org/wiki/Acrylic_rubber)-coated surfaces have a coefficient of friction that can be substantially larger than 1.

While it is often stated that the COF is a "material property," it is better categorized as a "system property." Unlike true material properties (such as conductivity, dielectric constant, yield strength), the COF for any two materials depends on system variables like [temperature](https://en.wikipedia.org/wiki/Temperature), [velocity](https://en.wikipedia.org/wiki/Velocity), [atmosphere](https://en.wikipedia.org/wiki/Atmosphere) and also what are now popularly described as aging and deaging times; as well as on geometric properties of the interface between the materials, namely [surface structure](https://en.wikipedia.org/wiki/Surface_roughness).[[1]](https://en.wikipedia.org/wiki/Friction#cite_note-statfric-1) For example, a [copper](https://en.wikipedia.org/wiki/Copper) pin sliding against a thick copper plate can have a COF that varies from 0.6 at low speeds (metal sliding against metal) to below 0.2 at high speeds when the copper surface begins to melt due to frictional heating. The latter speed, of course, does not determine the COF uniquely; if the pin diameter is increased so that the frictional heating is removed rapidly, the temperature drops, the pin remains solid and the COF rises to that of a 'low speed' test

Assignment

* 1. Define friction
  2. State 2 advantages of friction

Week 10; reducing friction

## Reducing friction

### Devices

Devices such as wheels, [ball bearings](https://en.wikipedia.org/wiki/Ball_bearing), [roller bearings](https://en.wikipedia.org/wiki/Roller_bearing), and air cushion or other types of [fluid bearings](https://en.wikipedia.org/wiki/Fluid_bearing) can change sliding friction into a much smaller type of rolling friction.

Many [thermoplastic](https://en.wikipedia.org/wiki/Thermoplastic) materials such as [nylon](https://en.wikipedia.org/wiki/Nylon), [HDPE](https://en.wikipedia.org/wiki/HDPE) and PTFE are commonly used in low friction [bearings](https://en.wikipedia.org/wiki/Bearing_(mechanical)). They are especially useful because the coefficient of friction falls with increasing imposed load.[[*citation needed*](https://en.wikipedia.org/wiki/Wikipedia:Citation_needed)] For improved wear resistance, very high [molecular weight](https://en.wikipedia.org/wiki/Molecular_weight) grades are usually specified for heavy duty or critical bearings.

### Lubricants

A common way to reduce friction is by using a [lubricant](https://en.wikipedia.org/wiki/Lubricant), such as oil, water, or grease, which is placed between the two surfaces, often dramatically lessening the coefficient of friction. The science of friction and lubrication is called [tribology](https://en.wikipedia.org/wiki/Tribology). Lubricant technology is when lubricants are mixed with the application of science, especially to industrial or commercial objectives.

Superlubricity, a recently discovered effect, has been observed in [graphite](https://en.wikipedia.org/wiki/Graphite): it is the substantial decrease of friction between two sliding objects, approaching zero levels. A very small amount of frictional energy would still be dissipated.

Lubricants to overcome friction need not always be thin, turbulent fluids or powdery solids such as graphite and [talc](https://en.wikipedia.org/wiki/Talc); [acoustic lubrication](https://en.wikipedia.org/wiki/Acoustic_lubrication) actually uses sound as a lubricant.

Another way to reduce friction between two parts is to superimpose micro-scale vibration to one of the parts. This can be sinusoidal vibration as used in ultrasound-assisted cutting or vibration noise, known as [dither](https://en.wikipedia.org/wiki/Dither).

## Energy of friction

According to the law of [conservation of energy](https://en.wikipedia.org/wiki/Conservation_of_energy), no energy is destroyed due to friction, though it may be lost to the system of concern. Energy is transformed from other forms into thermal energy. A sliding hockey puck comes to rest because friction converts its kinetic energy into heat which raises the thermal energy of the puck and the ice surface. Since heat quickly dissipates, many early philosophers, including [Aristotle](https://en.wikipedia.org/wiki/Aristotle), wrongly concluded that moving objects lose energy without a driving force.

When an object is pushed along a surface along a path C, the energy converted to heat is given by a [line integral](https://en.wikipedia.org/wiki/Line_integral), in accordance with the definition of work

E t h = ∫ C F f r i c ( x ) ⋅ d x   = ∫ C μ k   F n ( x ) ⋅ d x , {\displaystyle E\_{th}=\int \_{C}\mathbf {F} \_{\mathrm {fric} }(\mathbf {x} )\cdot d\mathbf {x} \ =\int \_{C}\mu \_{\mathrm {k} }\ \mathbf {F} \_{\mathrm {n} }(\mathbf {x} )\cdot d\mathbf {x} ,}

where

F f r i c {\displaystyle \mathbf {F} \_{\mathrm {fric} }\,} is the friction force,

F n {\displaystyle \mathbf {F} \_{\mathrm {n} }\,} is the vector obtained by multiplying the magnitude of the normal force by a unit vector pointing *against* the object's motion,

μ k {\displaystyle \mu \_{\mathrm {k} }\,} is the coefficient of kinetic friction, which is inside the integral because it may vary from location to location (e.g. if the material changes along the path),

x {\displaystyle \mathbf {x} \,} is the position of the object.

Energy lost to a system as a result of friction is a classic example of thermodynamic [irreversibility](https://en.wikipedia.org/wiki/Irreversibility).

### Work of friction

In the reference frame of the interface between two surfaces, static friction does *no* [work](https://en.wikipedia.org/wiki/Mechanical_work), because there is never displacement between the surfaces. In the same reference frame, kinetic friction is always in the direction opposite the motion, and does *negative* work.[[64]](https://en.wikipedia.org/wiki/Friction#cite_note-64) However, friction can do *positive* work in certain [frames of reference](https://en.wikipedia.org/wiki/Frames_of_reference). One can see this by placing a heavy box on a rug, then pulling on the rug quickly. In this case, the box slides backwards relative to the rug, but moves forward relative to the frame of reference in which the floor is stationary. Thus, the kinetic friction between the box and rug accelerates the box in the same direction that the box moves, doing *positive* work.[[65]](https://en.wikipedia.org/wiki/Friction#cite_note-65)

The work done by friction can translate into deformation, wear, and heat that can affect the contact surface properties (even the coefficient of friction between the surfaces). This can be beneficial as in [polishing](https://en.wikipedia.org/wiki/Polishing). The work of friction is used to mix and join materials such as in the process of [friction welding](https://en.wikipedia.org/wiki/Friction_welding). Excessive erosion or wear of mating sliding surfaces occurs when work due to frictional forces rise to unacceptable levels. [Harder](https://en.wikipedia.org/wiki/Hardness) corrosion particles caught between mating surfaces in relative motion ([fretting](https://en.wikipedia.org/wiki/Fretting)) exacerbates wear of frictional forces. Bearing seizure or failure may result from excessive wear due to work of friction. As surfaces are worn by work due to friction, [fit](https://en.wikipedia.org/wiki/Tolerance_(engineering)) and [surface finish](https://en.wikipedia.org/wiki/Surface_roughness) of an object may degrade until it no longer functions properly.

## Applications

Friction is an important factor in many [engineering](https://en.wikipedia.org/wiki/Engineering) disciplines.

### Transportation

* [Automobile brakes](https://en.wikipedia.org/wiki/Vehicle_brake) inherently rely on friction, slowing a vehicle by converting its kinetic energy into heat. Incidentally, dispersing this large amount of heat safely is one technical challenge in designing brake systems. [Disk brakes](https://en.wikipedia.org/wiki/Disk_brakes) rely on friction between a disc and [brake pads](https://en.wikipedia.org/wiki/Brake_pads) that are squeezed transversely against the rotating disc. In [Drum brakes](https://en.wikipedia.org/wiki/Drum_brakes), [brake shoes](https://en.wikipedia.org/wiki/Brake_shoes) or pads are pressed outwards against a rotating cylinder (brake drum) to create friction. Since braking discs can be more efficiently cooled than drums, disc brakes have better stopping performance.
* [Rail adhesion](https://en.wikipedia.org/wiki/Rail_adhesion) refers to the grip wheels of a train have on the rails, see [Frictional contact mechanics](https://en.wikipedia.org/wiki/Frictional_contact_mechanics).
* [Road slipperiness](https://en.wikipedia.org/wiki/Road_slipperiness) is an important design and safety factor for automobiles[[67]](https://en.wikipedia.org/wiki/Friction#cite_note-HighFrictionRoad-67)
  + [Split friction](https://en.wikipedia.org/wiki/Split_friction) is a particularly dangerous condition arising due to varying friction on either side of a car.
  + [Road texture](https://en.wikipedia.org/wiki/Texture_(roads)) affects the interaction of tires and the driving surface.

Assignment

1. Define lubrication
2. Mention 3 types of lubricant

Week 11; revision

Week 12; examination