



The Engineering ToolBox

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Friction - Friction Coefficients and Calculator

Friction theory with calculator and friction coefficients for combinations of materials like ice, aluminum, steel, graphite and many more.

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The friction **force** is the force exerted by a surface when an object moves across it - or makes an effort to move across it.

The frictional force can be expressed as

$$F_f = \mu N \quad (1)$$

where

F_f = frictional force (N, lb)

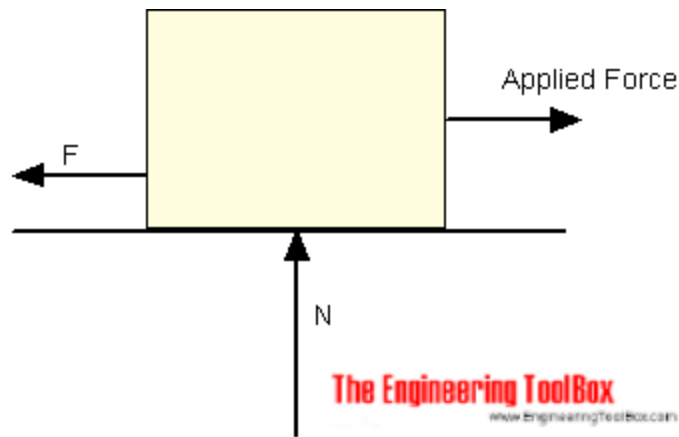
μ = static (μ_s) or kinetic (μ_k) frictional coefficient

N = normal force between the surfaces (N, lb)

There are at least two types of friction forces

- kinetic (sliding) friction force- when an object moves
- static friction force - when an object makes an effort to move

Provisur EX1067
U.S. Patent No. 9,457,487



For an object pulled or pushed horizontally the normal force - N - is simply the **gravity force - or weight**:

$$N = F_g$$

$$= m a_g \quad (2)$$

where

F_g = **gravity force - or weight** (N, lb)

m = mass of object (kg, **slugs**)

a_g = acceleration of gravity (9.81 m/s^2 , 32 ft/s^2)

The friction force due to gravity (1) can with (2) be modified to

$$F_f = \mu m a_g \quad (3)$$

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Friction Force Calculator



calculate!

- Friction forces on inclined planes
- Weight vs mass - the difference

Friction Coefficients for some Common Materials and Materials Combinations

Friction Coefficients vs. Materials and Surface Conditions

Materials and Material Combinations		Surface Conditions, Lubricant	Frictional Coefficient	
			Static - μ_{static} -	Kinetic (sliding) - $\mu_{sliding}$ -
Aluminum	Aluminum	Clean and Dry	1.05 - 1.35	0.4
Aluminum	Aluminum	Lubricated and Greasy	0.3	
Aluminum-bronze	Steel	Clean and Dry	0.45	
Aluminum	Mild Steel	Clean and Dry	0.61	0.47
Aluminum	Snow	Wet 0°C	0.4	
Aluminum	Snow	Dry 0°C	0.35	
Brake material ⁽²⁾	Cast iron	Clean and Dry	0.4	
Brake material ⁽²⁾	Cast iron (wet)	Clean and Dry	0.2	
Brass	Steel	Clean and Dry	0.51	0.44
Brass	Steel	Grease	0.19	
Brass	Steel	Castor oil	0.11	
Brass	Cast Iron	Clean and Dry		0.3
Brass	Ice	Clean 0°C		0.02
Brass	Ice	Clean -80°C		0.15
Brick	Wood	Clean and Dry	0.6	
Bronze	Steel	Grease	0.16	
Bronze	Cast Iron	Clean and Dry		0.22
Bronze - sintered	Steel	Grease	0.13	
Cadmium	Cadmium	Clean and Dry	0.5	
Cadmium	Cadmium	Grease	0.05	
Cadmium	Chromium	Clean and Dry	0.41	
Cadmium	Chromium	Grease	0.34	
Cadmium	Mild Steel	Clean and Dry		0.46
Cast Iron	Cast Iron	Clean and Dry	1.1	0.15



Cast Iron	Cast Iron	Grease		0.07
Cast Iron	Oak	Clean and Dry		0.49
Cast Iron	Oak	Grease		0.075
Cast iron	Steel	Clean and Dry	0.4	
Cast iron	Steel	Clean and Dry		0.23
Cast iron	Steel	Grease	0.21	0.133
Car tire	Asphalt	Clean and Dry	0.72	
Car tire	Grass	Clean and Dry	0.35	
Carbon (hard)	Carbon	Clean and Dry	0.16	
Carbon (hard)	Carbon	Grease	0.12 - 0.14	
Carbon	Steel	Clean and Dry	0.14	
Carbon	Steel	Grease	0.11 - 0.14	
Chromium	Chromium	Clean and Dry	0.41	
Chromium	Chromium	Grease	0.34	
Copper-Lead alloy	Steel	Clean and Dry	0.22	
Copper	Copper	Clean and Dry	1.6	
Copper	Copper	Grease	0.08	
Copper	Cast Iron	Clean and Dry	1.05	0.29
Copper	Steel	Clean and Dry	0.53	0.36
Copper	Steel	Grease		0.18
Copper	Steel	Oleic acid		0.18
Copper	Glass	Clean and Dry	0.68	0.53
Cotton	Cotton	Threads	0.3	
Diamond	Diamond	Clean and Dry	0.1	
Diamond	Diamond	Grease	0.05 - 0.1	
Diamond	Metals	Clean and Dry	0.1 - 0.15	
Diamond	Metal	Grease	0.1	
Garnet	Steel	Clean and Dry		0.39
Glass	Glass	Clean and Dry	0.9 - 1.0	0.4
Glass	Glass	Grease	0.1 - 0.6	0.09 - 0.12
Glass	Metal	Clean and Dry	0.5 - 0.7	
Glass	Metal	Grease	0.2 - 0.3	
Glass	Nickel	Clean and Dry	0.78	
Glass	Nickel	Grease	0.56	
Graphite	Steel	Clean and Dry	0.1	



Graphite	Graphite (in vacuum)	Clean and Dry	0.5 - 0.8	
Graphite	Graphite	Clean and Dry	0.1	
Graphite	Graphite	Grease	0.1	
Hemp rope	Timber	Clean and Dry	0.5	
Horseshoe	Rubber	Clean and Dry	0.68	
Horseshoe	Concrete	Clean and Dry	0.58	
Ice	Ice	Clean 0°C	0.1	0.02
Ice	Ice	Clean -12°C	0.3	0.035
Ice	Ice	Clean -80°C	0.5	0.09
Ice	Wood	Clean and Dry	0.05	
Ice	Steel	Clean and Dry	0.03	
Iron	Iron	Clean and Dry	1.0	
Iron	Iron	Grease	0.15 - 0.20	
Lead	Cast Iron	Clean and Dry		0.43
Leather	Oak	Parallel to grain	0.61	0.52
Leather	Metal	Clean and Dry	0.4	
Leather	Metal	Grease	0.2	
Leather	Wood	Clean and Dry	0.3 - 0.4	
Leather	Clean Metal	Clean and Dry	0.6	
Leather	Cast Iron	Clean and Dry	0.6	0.56
Leather fiber	Cast iron	Clean and Dry	0.31	
Leather fiber	Aluminum	Clean and Dry	0.30	
Magnesium	Magnesium	Clean and Dry	0.6	
Magnesium	Magnesium	Grease	0.08	
Magnesium	Steel	Clean and Dry		0.42
Magnesium	Cast Iron	Clean and Dry		0.25
Masonry	Brick	Clean and Dry	0.6 - 0.7	
Mica	Mica	Freshly cleaved	1.0	
Nickel	Nickel	Clean and Dry	0.7 - 1.1	0.53
Nickel	Nickel	Grease	0.28	0.12
Nickel	Mild Steel	Clean and Dry		0.64
Nickel	Mild Steel	Grease		0.178
Nylon	Nylon	Clean and Dry	0.15 - 0.25	
Nylon	Steel	Clean and Dry	0.4	



Nylon	Snow	Dry -10°C	0.3	
Oak	Oak (parallel grain)	Clean and Dry	0.62	0.48
Oak	Oak (cross grain)	Clean and Dry	0.54	0.32
Oak	Oak (cross grain)	Grease		0.072
Paper	Cast Iron	Clean and Dry	0.20	
Phosphor-bronze	Steel	Clean and Dry	0.35	
Platinum	Platinum	Clean and Dry	1.2	
Platinum	Platinum	Grease	0.25	
Plexiglas	Plexiglas	Clean and Dry	0.8	
Plexiglas	Plexiglas	Grease	0.8	
Plexiglas	Steel	Clean and Dry	0.4 - 0.5	
Plexiglas	Steel	Grease	0.4 - 0.5	
Polystyrene	Polystyrene	Clean and Dry	0.5	
Polystyrene	Polystyrene	Grease	0.5	
Polystyrene	Steel	Clean and Dry	0.3 - 0.35	
Polystyrene	Steel	Grease	0.3 - 0.35	
Polyethylene	Polyethylene	Clean and Dry	0.2	
Polyethylene	Steel	Clean and Dry	0.2	
Polyethylene	Steel	Grease	0.2	
Rubber	Rubber	Clean and Dry	1.16	
Rubber	Cardboard	Clean and Dry	0.5 - 0.8	
Rubber	Dry Asphalt	Clean and Dry	0.9	0.5 - 0.8
Rubber	Wet Asphalt	Clean and Dry		0.25 - 0.75
Rubber	Dry Concrete	Clean and Dry		0.6 - 0.85
Rubber	Wet Concrete	Clean and Dry		0.45 - 0.75
Silk	Silk	Clean	0.25	
Silver	Silver	Clean and Dry	1.4	
Silver	Silver	Grease	0.55	
Sapphire	Sapphire	Clean and Dry	0.2	
Sapphire	Sapphire	Grease	0.2	
Silver	Silver	Clean and Dry	1.4	
Silver	Silver	Grease	0.55	
Skin	Metals	Clean and Dry	0.8 - 1.0	
Steel	Steel	Clean and Dry	0.5 - 0.8	0.42



Steel	Steel	Castor oil	0.15	0.081
Steel	Steel	Stearic Acid		0.15
Steel	Steel	Light mineral oil	0.23	
Steel	Steel	Lard	0.11	0.084
Steel	Steel	Graphite		0.058
Steel	Graphite	Clean and Dry	0.21	
Straw Fiber	Cast Iron	Clean and Dry	0.26	
Straw Fiber	Aluminum	Clean and Dry	0.27	
Tarred fiber	Cast Iron	Clean and Dry	0.15	
Tarred fiber	Aluminum	Clean and Dry	0.18	
Polytetrafluoroethylene (PTFE) (Teflon)	Polytetrafluoroethylene (PTFE)	Clean and Dry	0.04	0.04
Polytetrafluoroethylene (PTFE)	Polytetrafluoroethylene (PTFE)	Grease	0.04	
Polytetrafluoroethylene (PTFE)	Steel	Clean and Dry	0.05 - 0.2	
Polytetrafluoroethylene (PTFE)	Snow	Wet 0°C	0.05	
Polytetrafluoroethylene (PTFE)	Snow	Dry 0°C	0.02	
Tungsten Carbide	Steel	Clean and Dry	0.4 - 0.6	
Tungsten Carbide	Steel	Grease	0.1 - 0.2	
Tungsten Carbide	Tungsten Carbide	Clean and Dry	0.2 - 0.25	
Tungsten Carbide	Tungsten Carbide	Grease	0.12	
Tungsten Carbide	Copper	Clean and Dry	0.35	
Tungsten Carbide	Iron	Clean and Dry	0.8	
Tin	Cast Iron	Clean and Dry		0.32
Tire, dry	Road, dry	Clean and Dry	1	
Tire, wet	Road, wet	Clean and Dry	0.2	
Wax, ski	Snow	Wet 0°C	0.1	
Wax, ski	Snow	Dry 0°C	0.04	
Wax, ski	Snow	Dry -10°C	0.2	
Wood	Clean Wood	Clean and Dry	0.25 - 0.5	
Wood	Wet Wood	Clean and Dry	0.2	
Wood	Clean Metal	Clean and Dry	0.2 - 0.6	
Wood	Wet Metals	Clean and Dry	0.2	



Wood	Concrete	Clean and Dry	0.62	
Wood	Brick	Clean and Dry	0.6	
Wood - waxed	Wet snow	Clean and Dry	0.14	0.1
Wood - waxed	Dry snow	Clean and Dry		0.04
Zinc	Cast Iron	Clean and Dry	0.85	0.21
Zinc	Zinc	Clean and Dry	0.6	
Zinc	Zinc	Grease	0.04	

Kinetic or sliding frictional coefficient only when there is a relative motion between the surfaces.

Note! It is commonly thought that the static coefficients of friction are higher than the dynamic or kinetic values. This is a very simplistic statement and quite misleading for brake materials. With many brake materials the dynamic coefficient of friction quoted is an "average" value when the material is subject to a range of sliding speeds, surface pressures and most importantly operating temperatures. If the static situation is considered at the same pressure, but at ambient temperature, then the static coefficient of friction is often significantly LOWER than the average quoted dynamic value. It can be as low as 40 - 50% of the quoted dynamic value.

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Kinetic (Sliding) versus Static Frictional Coefficients

Kinetic or sliding frictional coefficients are used with relative motion between objects. Static frictional coefficients are used for objects without relative motion. Note that static coefficients are somewhat higher than the kinetic or sliding coefficients. More force are required to start a motion

Example - Friction Force

A 100 lb wooden crate is pushed across a concrete floor. The friction coefficient between the object



$$= \underline{0.2} \text{ (10)}$$

- 1 lb = 0.4536 kg

Example - Car, Braking, Friction Force and Required Distance to Stop



A car with mass 2000 kg drives with speed 100 km/h on a wet road with friction coefficient 0.2.

Note! - The friction **work** required to stop the car is equal to the **kinetic energy** of the car.

The kinetic energy of the car is

$$E_{kinetic} = 1/2 m v^2 \quad (4)$$

where

$E_{kinetic}$ = kinetic energy of the moving car (J)

m = mass (kg)

v = velocity (m/s)

$$\begin{aligned} E_{kinetic} &= 1/2 (2000 \text{ kg}) ((100 \text{ km/h}) (1000 \text{ m/km}) / (3600 \text{ s/h}))^2 \\ &= \underline{771605 \text{ J}} \end{aligned}$$

The friction **work** (energy) to stop the car can be expressed as

$$W_{friction} = F_f d \quad (5)$$

where

$W_{friction}$ = friction work to stop the car (J)

F_f = friction force (N)

d = braking (stopping) distance (m)

Since the kinetic energy of the car is converted to friction energy (work) - we have the expression



$$= 0.2 (2000 \text{ kg}) (9.81 \text{ m/s}^2)$$

$$= \underline{3924 \text{ N}}$$

The stop distance for the car can be calculated by modifying (5) to

$$d = W_{\text{friction}} / F_f$$

$$= (771605 \text{ J}) / (3924 \text{ N})$$

$$= \underline{197 \text{ m}}$$

Note! - since the mass of the car is present on both sides of eq. 6 it cancels out. The stop distance is not dependent on the mass of the car.

"Laws of Friction"

Unlubricated Dry Surfaces

1. for low pressure the friction is proportional to the normal force between the surfaces. With rising pressure the friction will not rise proportionally. With extreme pressure friction will rise and surfaces seize.
2. at moderate pressure the friction force - and coefficient - is not dependent of the surface areas in contact as long as the normal force is the same. With extreme pressure friction will rise and surfaces seize.
3. at very low velocity between the surfaces the friction is independent of the velocity of rubbing. With increased velocity the the friction decrease.

Lubricated Surfaces

1. friction force is almost independent of pressure - normal force - if the surfaces are flooded with lubricant
2. friction varies with speed at low pressure. At higher pressure the minimum friction is at velocity 2 ft/s (0.7 m/s) and friction increases with approximately square root of velocity afterwards.
3. friction varies with temperature
4. for well lubricated surfaces the friction is almost independent of surface material

Typically *steel on steel dry* static friction coefficient 0.8 drops to 0.4 when sliding is initiated - and *steel on steel lubricated* static friction coefficient 0.16 drops to 0.04 when sliding is initiated.

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- **Mechanics**

The relationships between forces, acceleration, displacement, vectors, motion, momentum, energy of objects and more.

- **Miscellaneous**

Engineering related topics like Beaufort Wind Scale, CE-marking, drawing standards and more.

Related Documents

- **Bodies Moving on Inclined Planes - Acting Forces**

Required forces to move bodies up inclined planes.

- **Bollard Forces**

Friction, load and effort forces acting in ropes turned around bollards.

- **Car - Traction Force**

Adhesion and tractive force between car wheel and surface.

- **Disk Brakes - Torque and Force**

Forces and torque activated with disk brakes.

- **Drag Coefficient**

The drag coefficient quantifies the drag or resistance of an object in a fluid environment.

- **Efficiency of Small Machine Elements**

Friction and efficiency in bearings and roller chains.

- **Forces acting on Body Moving on a Horizontal Plane**

The forces acting on bodies moved in horizontal planes.

- **Grease - Temperature Limits**

Temperature limits for grease - a combination of oil and thickener.

- **Ice - Safe Loads vs. Thickness**

Safe loads vs. thickness for clear and solid ice.

- **Ice - Thermal Properties**

Thermal and thermodynamic properties of ice like density, thermal conductivity and specific heat at temperatures from 0 to -100 °C.



- **Screw Jack - Effort Force vs. Load**

Screw jacks and effort forces.

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Unit Converter

Temperature

0.0

☒ °C

☐ K

☐ °F

Convert!



- ☐ *in*
☐ *ft*
☐ *yards*
☐ *miles*
☐ *naut miles*

Convert!

Area

1.0

- ☒ m^2
☐ km^2
☐ in^2
☐ ft^2
☐ $miles^2$
☐ *acres*

Convert!

Volume

1.0

- ☒ m^3
☐ *liters*
☐ in^3
☐ ft^3
☐ *us gal*

Convert!

Weight

1.0

- ☒ kg_f
☐ N
☐ lbf

Convert!



- ☐ *ft/min*
☐ *ft/s*
☐ *mph*
☐ *knots*

Convert!

Pressure

1.0

- ☒ *Pa*
☐ *bar*
☐ *mm H₂O*
☐ *kg/cm²*
☐ *psi*
☐ *inches H₂O*

Convert!

Flow

1.0

- ☒ *m³/s*
☐ *m³/h*
☐ *US gpm*
☐ *cfm*

Convert!

8.21.8

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