
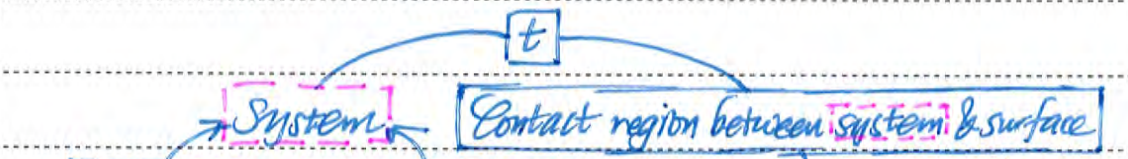
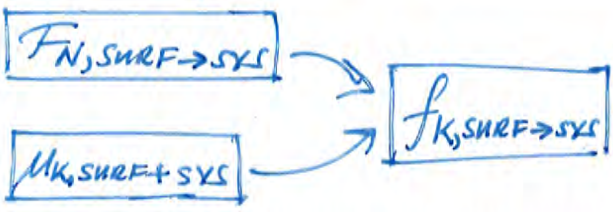
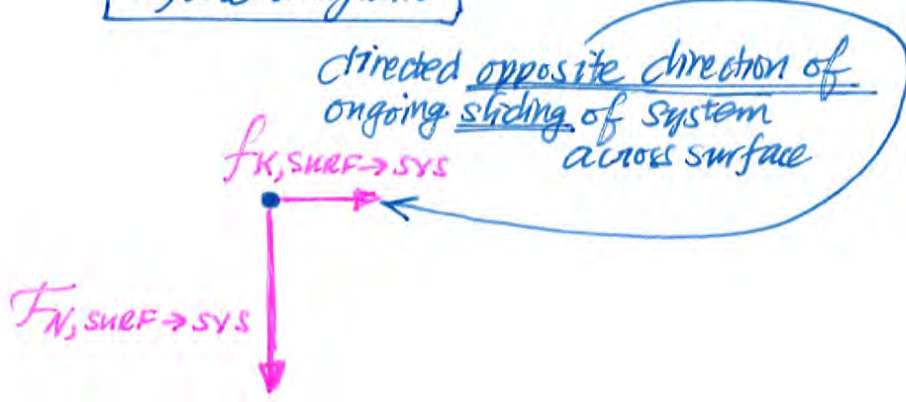


Title	Kinetic friction force exerted by a surface during sliding
Ingredients	
At/Through	
Owner	System
Quantity	<div style="display: flex; justify-content: space-around;"> <div style="border: 1px solid black; padding: 5px;">Normal force</div> <div style="border: 1px solid black; padding: 5px;">Kinetic friction force</div> <div style="border: 1px solid black; padding: 5px;">Coefficient of kinetic friction</div> </div>
Variable	<div style="display: flex; justify-content: space-around;"> <div style="border: 1px solid black; padding: 5px;"><math>\vec{F}_{N, SURF \rightarrow SYS}</math></div> <div style="border: 1px solid black; padding: 5px;"><math>\vec{f}_{K, SURF \rightarrow SYS}</math></div> <div style="border: 1px solid black; padding: 5px;"><math>\mu_{K, SURF + SYS}</math></div> </div>
Giver	Flat surface scraping system
Recipe	<div style="border: 1px solid black; padding: 10px; margin-bottom: 10px;"> <p>Diagram the relationship</p>  </div> <div style="border: 1px solid black; padding: 10px; margin-bottom: 10px;"> <p>Graphically present quantities</p> <p style="text-align: center;"><b>Force diagram</b></p>  <p style="text-align: center;"><i>directed opposite direction of ongoing sliding of system across surface</i></p> </div> <div style="border: 1px solid black; padding: 10px;"> <p>Mathematical relationship</p> <div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid black; padding: 5px;"><math>f_{K, SURF \rightarrow SYS} = \mu_{K, SURF + SYS} F_{N, SURF \rightarrow SYS}</math></div> <div style="border: 1px solid black; padding: 5px;">Direction of <math>\vec{f}_{K, SURF \rightarrow SYS}</math> = Opposes ongoing sliding</div> </div> </div>

The top half of this sheet consists of an **“Ingredients”** section with a row labeled “Sketch”, a row labeled “At/Through”, a row labeled “Owner”, a row labeled “Quantity”, a row labeled “Variable”, and a row labeled “Giver.”

Sketch: Block, underneath and in contact with a rough horizontal planar surface. Whooshies trailing to the left behind both the block and the surface indicate that the block and surface are moving toward the right, with the surface moving with greater speed. The block is surrounded by a dashed system bubble. A magnified view of a small portion of the region of contact between the block and the surface shows that at the molecular scale, both are bumpy and in contact only where a bump of the block and a bump of the surface meet. Otherwise, there are gaps. An example location where bumps meet is marked by an icon of a padlocks indicating molecular-level adhesion (not necessarily indicating interactions mediated by chemical bonds, but possibly interactions mediated by intermolecular forces). The padlock is sheared with its top toward the right, indicating that the surface is trying to drag the block toward the right and that the block is trying to fall behind toward the left. At another location, a bump from the block and a bump from the wall nearly meet, but are separated by a small gap and emphasized by an exclamation mark. This is a location of microscopic adhesion that had existed but has since been broken.

Remaining rows of Ingredients section are used for a flowchart illustrating the following: At time  $t$ , there are two Owners: the System and the Contact region between the system and surface. The System receives the Quantity Normal force, denoted by Variable  $F\text{-vector-sub-N,SURF-on-sys}$ , given by Giver Flat surface scraping system. The System also receives the Quantity Kinetic friction force, denoted by Variable lowercase  $f\text{-vector-sub-K,SURF-on-sys}$ , also from Giver Flat surface scraping system. The Contact region between system and surface owns the Quantity Coefficient of kinetic friction, denoted  $\mu\text{-sub-K,SURF+sys}$ .

The bottom half of this sheet consists of a **“Recipe”** section with a row labeled “Diagram the relationship”, a row labeled “Graphically present quantities”, and a row labeled “Mathematical relationship”.

#### Diagram the relationship

Flowchart arrows show that the magnitude of the normal force  $F\text{-sub-N,SURF-on-sys}$  contributes to the kinetic-friction-force strength lowercase  $f\text{-sub-K,SURF-on-sys}$  and that coefficient of kinetic friction  $\mu\text{-sub-K,SURF+sys}$  also contributes to the kinetic-friction-force strength lowercase  $f\text{-sub-K,SURF-on-sys}$ .

#### Graphically present quantities

Title: Force diagram

Dot represents system. Normal-force arrow originates from dot, points down the page, and is labeled  $F\text{-sub-N,SURF-on-sys}$ . Kinetic-friction-force arrow originates from dot, points toward right, and is labeled lowercase  $f\text{-sub-K,SURF-on-sys}$ . Direction of kinetic-friction-force arrow is emphasized by a caption that reads, “directed opposite direction of ongoing sliding of system across surface”, with an arrow pointing from the caption to the tip of the kinetic-friction-force arrow.

#### Mathematical relationship

Lowercase  $f\text{-sub-K,SURF-on-sys} = \mu\text{-sub-K,SURF+sys}$  times  $F\text{-sub-N,SURF-on-sys}$   
Direction of lowercase  $f\text{-vector-sub-K,SURF-on-sys} =$  Opposes ongoing sliding