Block on a Rough Variable Ramp

Apparatus

smooth variable ramp, one or more pieces of cloth with coarse surface to cover ramp, metal or wooden block

Action

The students experiment with changing the angle to find the angle at which slipping occurs. They should be able to estimate the coefficient of friction between the surface and the block for the smooth ramp and then the ramp with the rough (cloth covered) surface. They should draw a free body diagram showing the forces acting on the block.

The Physics

The forces acting on the block are the normal force, gravity and (static) friction. Decomposing these into components along the ramp and perpendicular to the ramp gives:

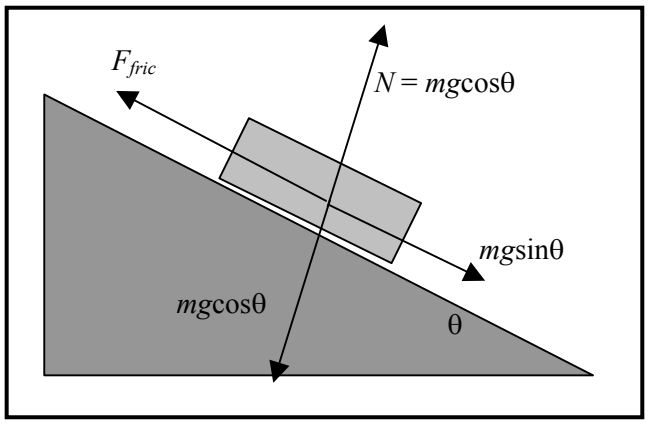
Forces perpendicular to ramp: N and $mg\cos\theta$, which are equal.

Forces along the ramp: $mg\sin\theta$ and F_{fric}, where $F_{fric} \leq \mu N = mg\sin\theta$.

Until the box begins to slide, $F_{fric} < \mu N$ and $F_{fric} = mg\sin\theta$.

At the point of sliding, $F_{fric} = \mu N = \mu mg\cos\theta = mg\sin\theta$.

The box starts to slide when $mg\sin\theta$ exceeds $\mu mg\cos\theta$, i.e. when $\mu < mg\sin\theta / mg\cos\theta = \tan\theta$. Hence the coefficient of static friction can be found by noting the angle at which slipping first occurs. This angle increases for rougher surfaces with larger μ.



Accompanying sheet

Block on a Rough Variable Ramp

Draw a free body diagram showing the forces acting on the block.

Adjust the angle of the ramp until the block just begins to slip.
Repeat using a different surface on the ramp.
What happens this time?

How can you estimate the coefficient of slipping from the angle?