Friction

When a force attempts to slide a body across a surface, a frictional force is exerted on the body by the surface. The frictional force is parallel to the surface and directed opposite to the sliding. When the body doesn't slide there is a static frictional force, f_s; when the body is sliding there is a kinetic frictional force, f_k. The friction force is calculated by multiplying the normal force (F_n) which the surface exerts on the body by a coefficient of friction, μ, which changes depending on the body and surface materials. The coefficient of static friction, μ_s, and the coefficient of kinetic friction, μ_k, will also vary, even when the same materials are involved.

NOTES

→ When the body doesn't move, $f_s = F_{app}$.

→ When an object is just on the verge of moving, $f_s = \mu_s F_n$. if $F_{app} > f_s$ then the body begins to slide.

→ When the body begins to slide along the surface, the frictional force decreases rapidly to $f_k = \mu_k F_n$.

EXERCISES

Use a gravitational acceleration of 9.8 m/s^2 in these exercises.

A. A 5500-kg car is moving at constant speed when the brakes are suddenly applied. The wheels lock and it slides to a stop after a displacement of 36 m. The coefficient of kinetic friction between the tire rubber and asphalt is $\mu_k = 0.18$.

1) Draw the free-body diagram for the car.

2) Determine the friction force.

3) Determine the acceleration due to the friction force.

4) How fast was the car going when the brakes locked?

B. A man is pulling his daughter on a sled by a rope which makes an angle of 42° with the horizontal, at a constant velocity. The sled and the daughter have a mass of 60 kg altogether.

1) Draw the free-body diagram for the sled. Separate the tension force into reasonable component vectors.

2) The father is exerting a force of 60 N on the rope. Calculate the normal force exerted on the sled by the ground.

3) Determine the friction force. [*Hint: What is the net horizontal force?*]

4) Determine μ_k.

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C. A 70-g coin is resting on a book that is slowly being tilted up. When the book is raised to a 13° angle with the table, the coin starts to slide.

1) Draw the free-body diagram for the coin. Separate the gravitational force into reasonable component vectors.

2) Determine the weight of the coin.

3) Determine the normal force exerted on the coin by the book.

4) Calculate the component of the weight that's (only just) pulling the coin down the book.

5) Determine μ_s.

D. Two movers are handling a 720-kg piano on a 36° ramp leading up to a truck. They're pushing perfectly horizontally with a combined force of 4200 N. The coefficient of kinetic friction between the piano wheels and the ramp is 0.065.

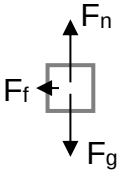
1) Determine the normal force on the piano.

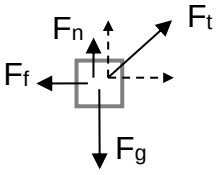
2) Determine the magnitude of the frictional force on the piano.

3) Determine the net force on the piano. Are the movers loading it into the truck or unloading it?

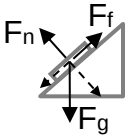
4) If the movers were being smarter and pushing parallel to the ramp, what force would they need to achieve the same acceleration on the ramp as they achieved pushing horizontally?

SOLUTIONS





A. (1) (2) 9.7×10^3 N (3) 1.8 $^{m}/_{s^2}$ (4) 11 $^{m}/_{s}$ B. (1) (2) 550 N (3) −45 N (4) 0.081



C. (1) (2) 0.69 N (3) 0.67 N (4) 0.15 N (5) 0.23

D. (1) 8200 N (2) 530 N (3) 2×10^2 N; they're unloading it, since the gravitation component down the ramp is much greater than the component of the applied force of the movers up the ramp. Friction is directed up the ramp. (4) 3600 N