PhyzExamples: Forces

Physical Quantities • Symbols • Units • Brief Definitions

Weight • W • N • Attractive force between two bodies; gravitational force; "heaviness"; acts along a line connecting centers of mass of the bodies.

Normal • N • N • Force of compression between two objects pressed together; acts perpendicular to the surface of compression.

Tension • T • N • Force transmitted through a cord; can act only in direction of cord.

Friction • f • N • Force that opposes slipping between two surfaces in contact; acts parallel to surface in direction opposed to slipping.

> **Coefficient of friction** • μ • unitless • Measure of surface-to-surface roughness; depends on characteristics of both surfaces; different values for static friction and kinetic friction.

Drag • D • N • Force that opposes motion of a body through a fluid (liquid or gas) or a fluid around a body; "air friction"; acts antiparallel to body's velocity through fluid or fluid's velocity around body.

> **Aerodynamic coefficient** • k • kg/m • A quantity that accounts for fluid density, surface geometry, and cross-sectional surface area.
>
> **Terminal speed** • v_T • m/s • The speed at which a body falls through a fluid when the upward drag force is equal in magnitude to the downward gravitational force.

Equations

$W = mg$ • weight = mass · acceleration due to gravity

$f_s(max) = \mu_s N$ • maximum static friction = coefficient of static friction · normal

$f_k = \mu_k N$ • kinetic friction = coefficient of kinetic friction · normal

$D = kv^2$ • drag = aerodynamic coefficient · speed squared

$D = W$ • drag = weight [true **only** when an object is falling at terminal speed]

Smooth Operations Examples

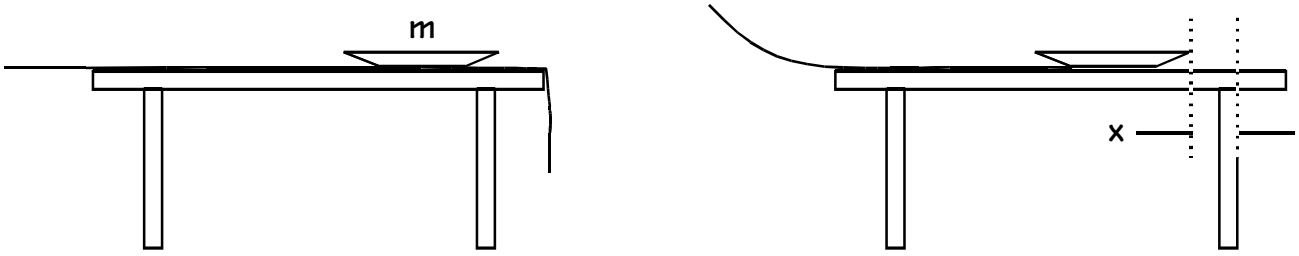
1. How much force is needed to push a 250 N crate across a floor if the coefficient of friction is 0.4?

1. W = 250 N μ = 0.4 f = ?
f = μN
N = W (level surface, no vertical acceleration)
f = 0.4 · 250 N
f = 100 N

2. What is the speed of a ball moving through air (k = 0.2 kg/m) that encounters 200 N of drag?

2. k = 0.2 kg/m D = 200N v = ?
$D = kv^2$
v = (D/k)
v = (200 N / 0.2 kg/m)
v = 32 m/s

3. A magician pulls a tablecloth out from under a 325 g plate resting on a table. If the tablecloth spent 0.083 s under the plate while sliding underneath it and the plate slid 1 cm during the process, what was the coefficient of kinetic friction between the cloth and the plate?



3. $m = 325\ g = 0.325\ kg$ $t = 0.083\ s$ $x = 1\ cm = 0.01\ m$ $v_0 = 0$ $v = ?$ $a = ?$ $\mu = ???$

$f = \mu N$

$\mu = f/N$

$f = ma$

a: $x = v_0 t + {}^1/_2 a t^2$

$a = 2x/t^2$

$f = 2mx/t^2$

$N = W$ (level surface, no vertical acceleration)

$W = mg$

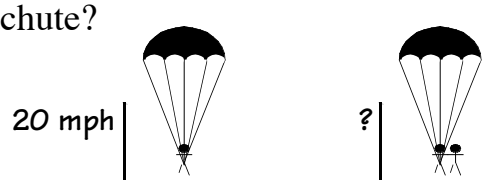
$\mu = 2mx/t^2 \,/\, mg$

$\mu = 2x/gt^2$

$\mu = 2 \cdot 0.01\ m \,/\, 9.8\ m/s^2\ (0.083\ s)^2$

$\mu = 0.30$

4. A typical parachute gives a 180 lb person a terminal speed of 20 mph. Suppose a skydiver rescues another who has lost consciousness in free fall. What would be the terminal speed of two people sharing one parachute?



4. $m = 180\ lb \,/\, 2.2\ lb/kg = 82\ kg$ $v_1 = 20\ mph \times 1609\ m/mi \,/\, 3600\ s/hr = 8.9\ m/s$

$v_2 = ???$

$D = 2W$

$kv_2^2 = 2mg$

$v_2 = (2mg/k)$

k: $D = W$ $\quad kv_1^2 = mg$ $\quad k = mg/v_1^2$

$v_2 = (2mg/[mg/v_1^2])$

$v_2 = (2v_1^2) = v_1\ 2$

$v_2 = 8.9\ m/s \cdot 2$

$v_2 = 12.6\ m/s = 28\ mph$