AP Physics Study Guide

Further Applications of Newton's Laws - Friction, Drag, and Elasticity

From Simple Studies, https://simplestudies.edublogs.org & @simplestudiesinc on Instagram

All images are from the Openstax college physics textbook

Friction is a force that opposes relative motion between systems in contact

- It is parallel to the contact surface between systems and always in a direction that opposes motion or attempted motion of the systems relative to each other
- If two systems are in contact and moving relative to one another, the friction between them is called **kinetic friction**
  - Ex: A hockey puck slowing down on ice
- When objects are stationary, **static friction** can act between them
  - Ex: Pushing a heavy crate that won't move
  - The static friction is usually greater than the kinetic friction between objects

The **magnitude of static friction** is $f_s \leq \mu_s N$

- μ_s is the coefficient of static friction
- N is the magnitude of the normal force
- Once the applied force exceeds $f_{s(max)}$, the object will move
  - $f_{s(max)} = \mu_s N$

The **magnitude of kinetic friction is** $f_k = \mu_k N$

- μ_k is the coefficient of kinetic friction
- N is the magnitude of the applied force

The coefficients of static and kinetic friction depend on the system the objects are acting upon:

Table 5.1 Coefficients of Static and Kinetic Friction

System	Static friction μ_s	Kinetic friction μ_k
Rubber on dry concrete	1.0	0.7
Rubber on wet concrete	0.7	0.5
Wood on wood	0.5	0.3
Waxed wood on wet snow	0.14	0.1
Metal on wood	0.5	0.3
Steel on steel (dry)	0.6	0.3
Steel on steel (oiled)	0.05	0.03
Teflon on steel	0.04	0.04
Bone lubricated by synovial fluid	0.016	0.015
Shoes on wood	0.9	0.7
Shoes on ice	0.1	0.05
Ice on ice	0.1	0.03
Steel on ice	0.4	0.02

The **drag force** is found to be proportional to the square of the speed of the object

- It depends on the shape of the object, its size, its velocity, and the fluid it is in
- $F_D = .5C\rho Av^2$
  - C is the drag coefficient
  - A is the area of the object facing the fluid
  - v is the speed of the object
  - $\rho$is the density of the fluid
- Using Newton's second law, we can determine that at the terminal velocity $mg = F_D$

- So, $mg = .5C\rho Av^2$

Table 5.2 Drag Coefficient Values **Typical values of drag coefficient C.**

Object	C
Airfoil	0.05
Toyota Camry	0.28
Ford Focus	0.32
Honda Civic	0.36
Ferrari Testarossa	0.37
Dodge Ram pickup	0.43
Sphere	0.45
Hummer H2 SUV	0.64
Skydiver (feet first)	0.70
Bicycle	0.90
Skydiver (horizontal)	1.0
Circular flat plate	1.12

Stokes' Law states that $F_s = 6\pi r\eta v$

- r is the radius of the object
- η is the viscosity of the fluid
- v is the object's velocity

Deformation is a change in shape due to the application of a force

- Even very small forces are known to cause some deformation
- **Hooke's Law** states that $F = k\Delta L$
  - ΔL is the amount of deformation (like change in length) produced by F
  - k is a proportionality constant that depends on the shape and composition of the object and the direction of the force
    - The proportionality constant depends on a number of factors for the material

Stress is the ratio of force to area

- Stress = F/A
- **Strain** is the ratio of the change in length to length
  - Strain = $\Delta L/L_0$

- **Shear deformation** behaves similarly to tension and compression and can be described with similar equations
  - $\Delta x = \frac{1F}{SA} L_0$
    - S is the shear modulus
    - F is the force applied perpendicular to L_0 and parallel to the cross-sectional area A