# SLE123 Physics for the Life Sciences

Week 3

Forces

DEAKIN COLLEGE
in association with
DEAKIN UNIVERSITY

# Forces

Topics:

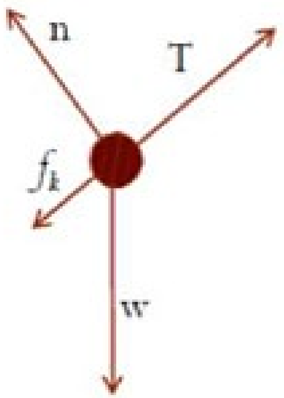
- Free Body Diagrams
- Friction
- Air resistance(Drag)

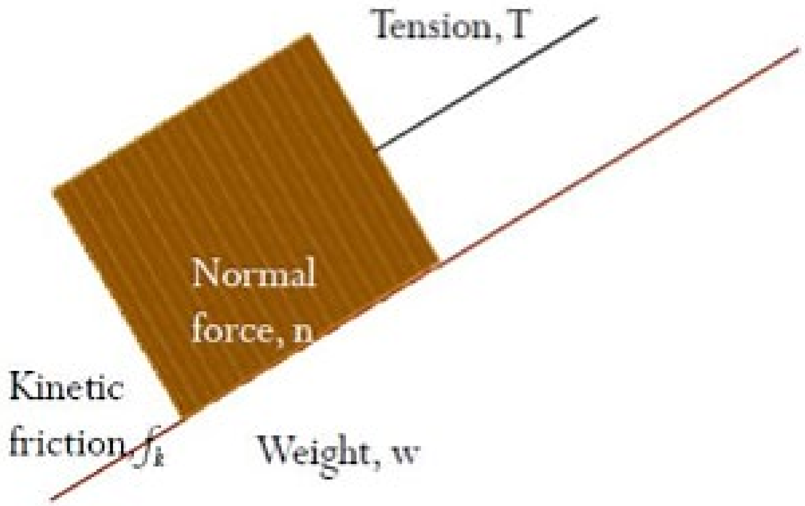

Sample question:

These ice boats sail across the ice at great speeds. What gets the boats moving in the first place? What keeps them from going even faster?

# Free-body diagram

- After identifying forces their magnitude and direction are drawn on a *free-body diagram*
- The object is replaced by a particle and all forces attached



# Free-body diagram

## Drawing a free-body diagram

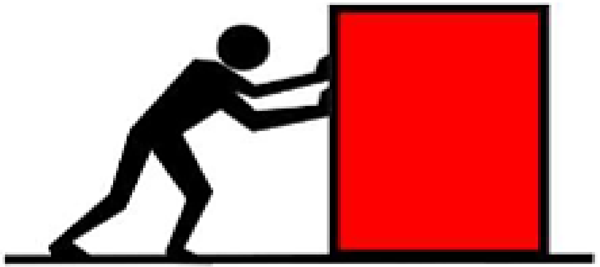
Identify all forces acting on the object

Draw a coordinate system

Represent the object as a dot at the origin of the coordinate axes

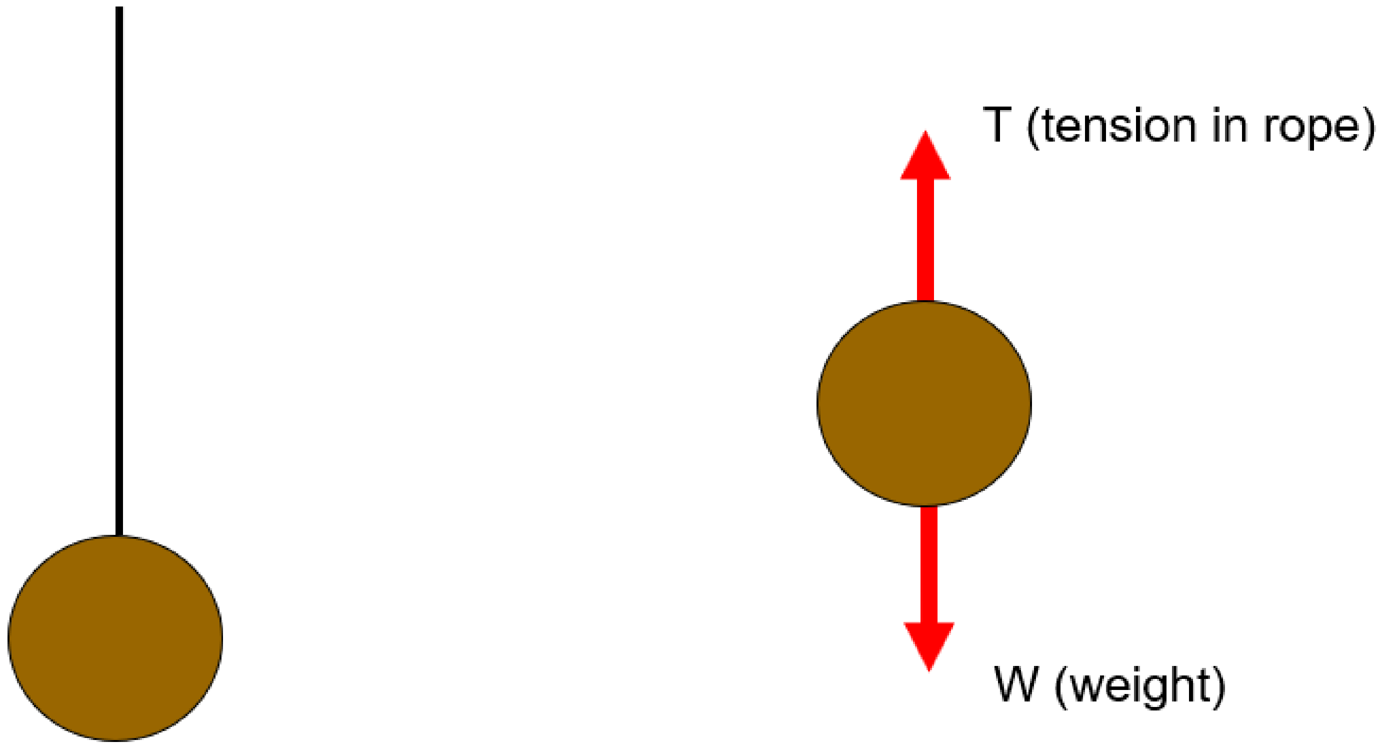
Draw vectors representing each of the identified forces

Draw and label the net force vector



# Free-body diagram

## Mass hanging on a rope



# Solving Forces Problems

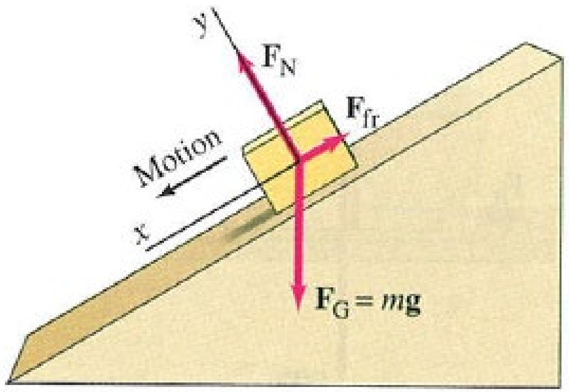
- Identify all Known and Unknown Values
- Identify all the forces acting on an object
- Draw Free-Body Diagram
- Use Kinematic Equations and Newton's Laws of motion to solve for Unknown values

$$F = ma$$

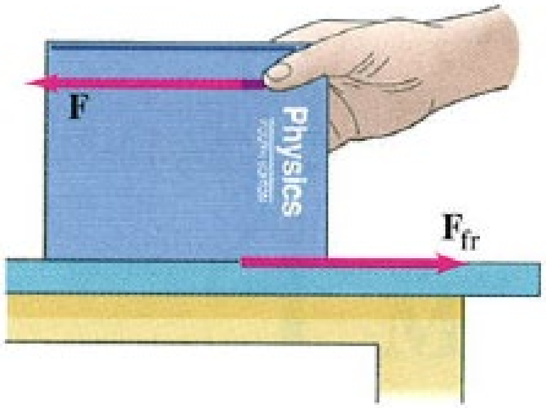
1. $v_f - v_i = a\Delta t$
2. $\Delta x = \frac{1}{2}(v_f + v_i)\Delta t$
3. $\Delta x = v_i\Delta t + \frac{1}{2}a(\Delta t)^2$
4. $v_f{}^2 - v_i{}^2 = 2a\Delta x$

# Friction

- When surfaces slide or tend to slide over one another the force of friction acts. Friction is caused by irregularities in the surfaces in mutual contact.
- Friction is the force opposing motion between systems (objects) in contact
- The direction of the friction is always in the opposite direction to the motion.
- An object sliding *down* an incline experiences friction *up* the incline

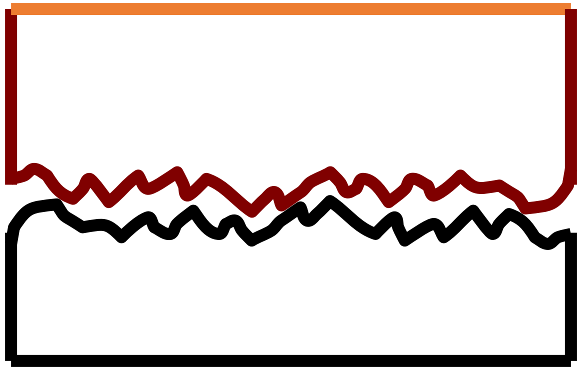


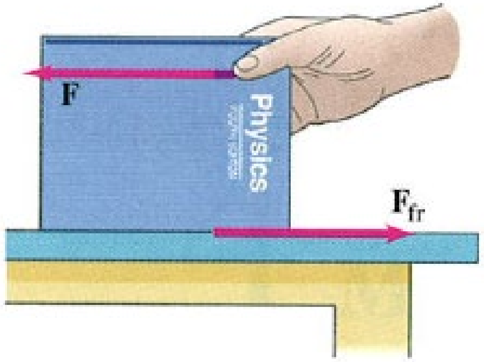

Giancoli, *Physics* 4e, p. 96

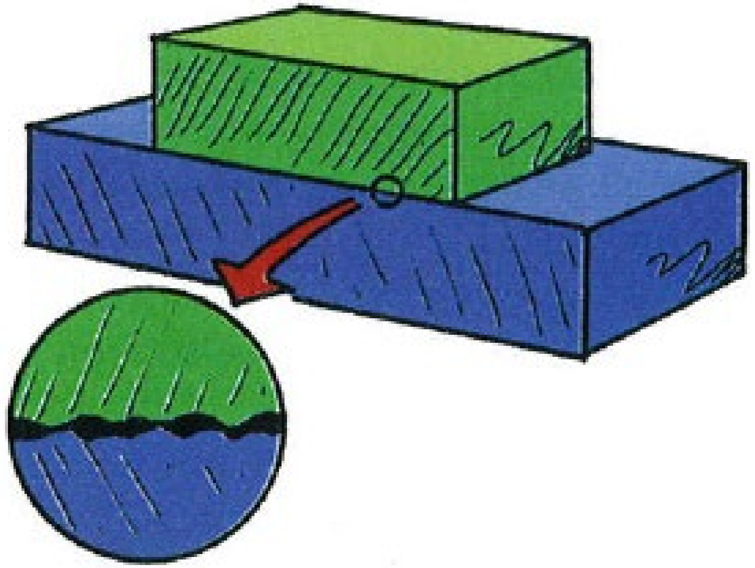


# Friction

Two surfaces in contact





Friction results from the mutual contact of irregularities in the surfaces of sliding objects. Even surfaces that appear to be smooth have irregular surfaces when viewed at the microscopic level.



P. Hewitt, *Conceptual Physics* 10e, p. 59

# Friction

- The friction that builds up before sliding takes place (static friction) is greater than the friction that is experienced when the object is sliding (kinetic friction)
- It is important when braking in an older car not to overdo it. When the tyres lock, they slide, providing less friction than if they are made to roll stop. (Braking hard will cause sliding) (Anti-lock  braking systems ABS)

# Static Friction

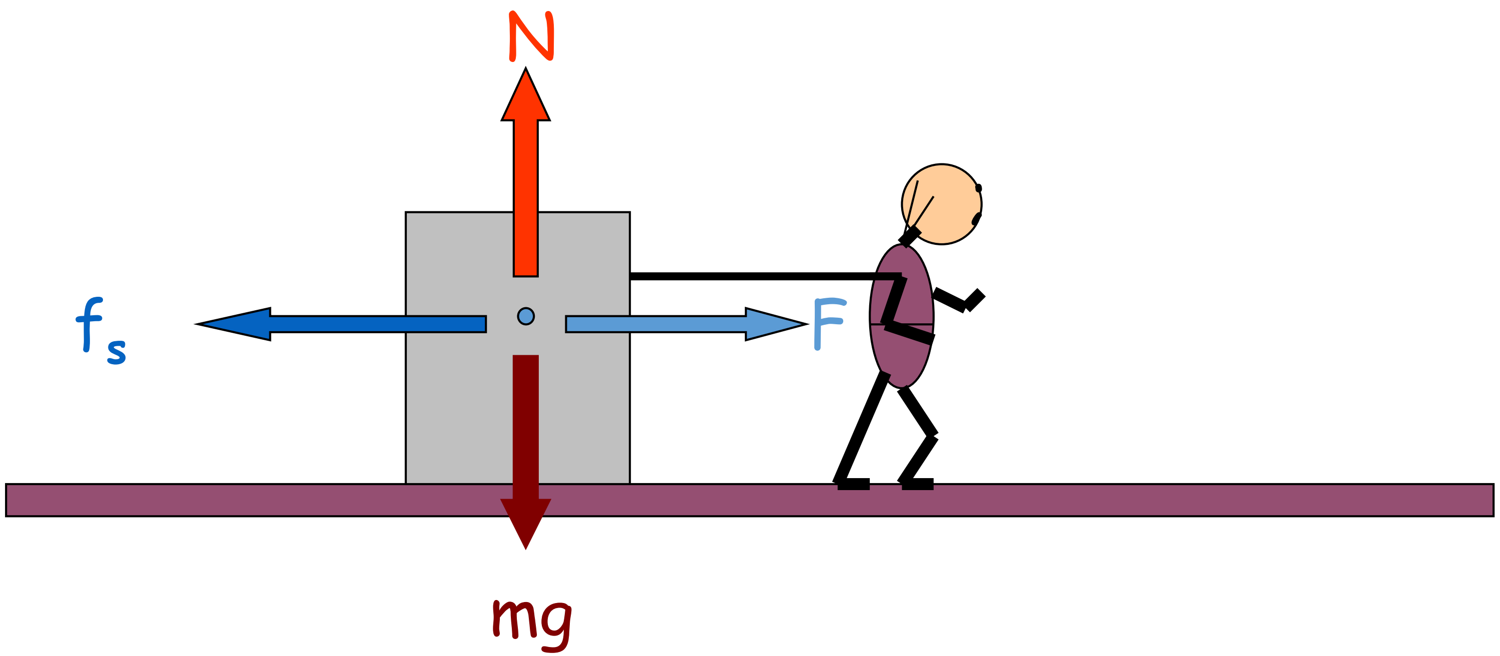
- Static Friction ($f_s$)
- When there is no motion between objects the size of the static friction is

$$f_s \geq u_s \, N$$

- Where N is the magnitude (size) of the force perpendicular to the surface and $u_s$ is the coefficient of friction.
- When $fs = u_s \, N$ have impending motion

# Coefficient of Friction, $u_s$

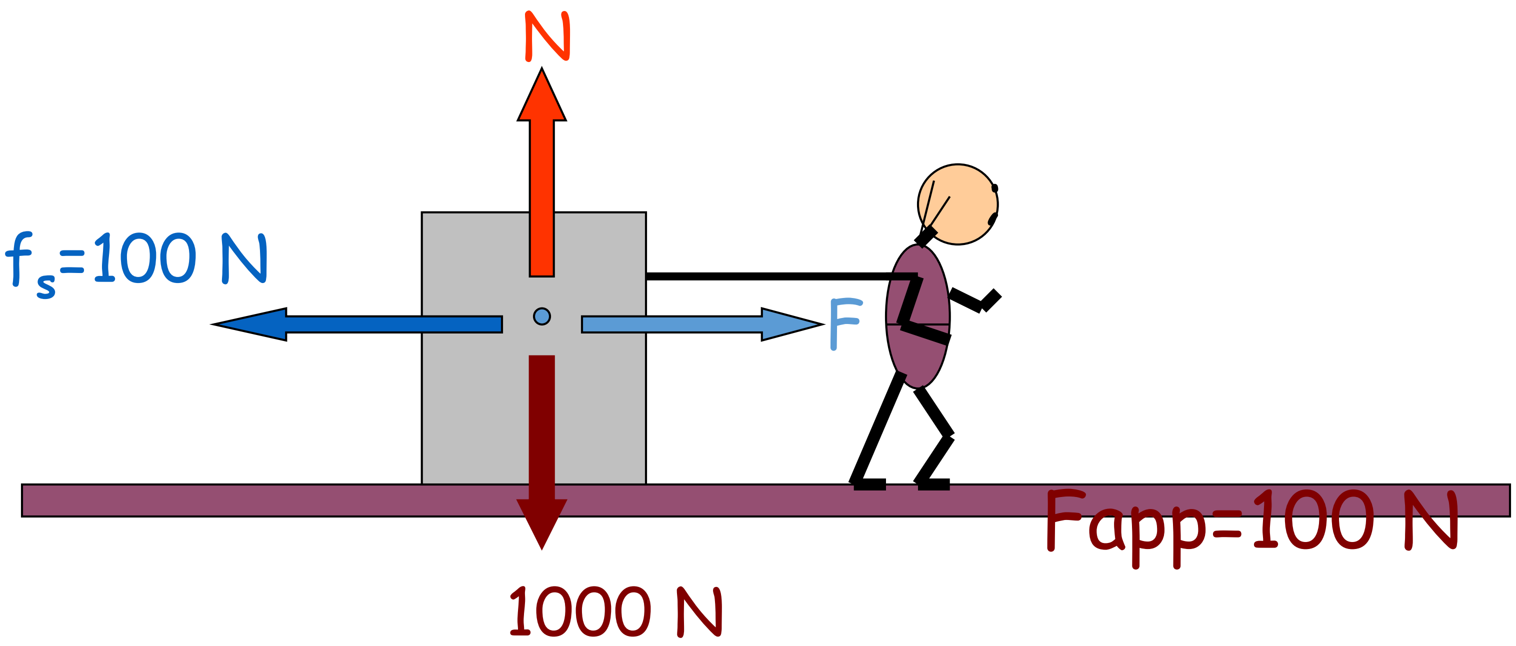
- Two surfaces in contact - no motion (Static Friction)




When $f_s = u_s N$ impending motion

# Coefficient of Static Friction, $u_s$ example

- Two surfaces in contact - no motion (Static Friction)
- Let $u_s$=0.8




When $f_{s(max)} = u_s N = 0.8.1000 = 800\ N > f_s = -Fapp$

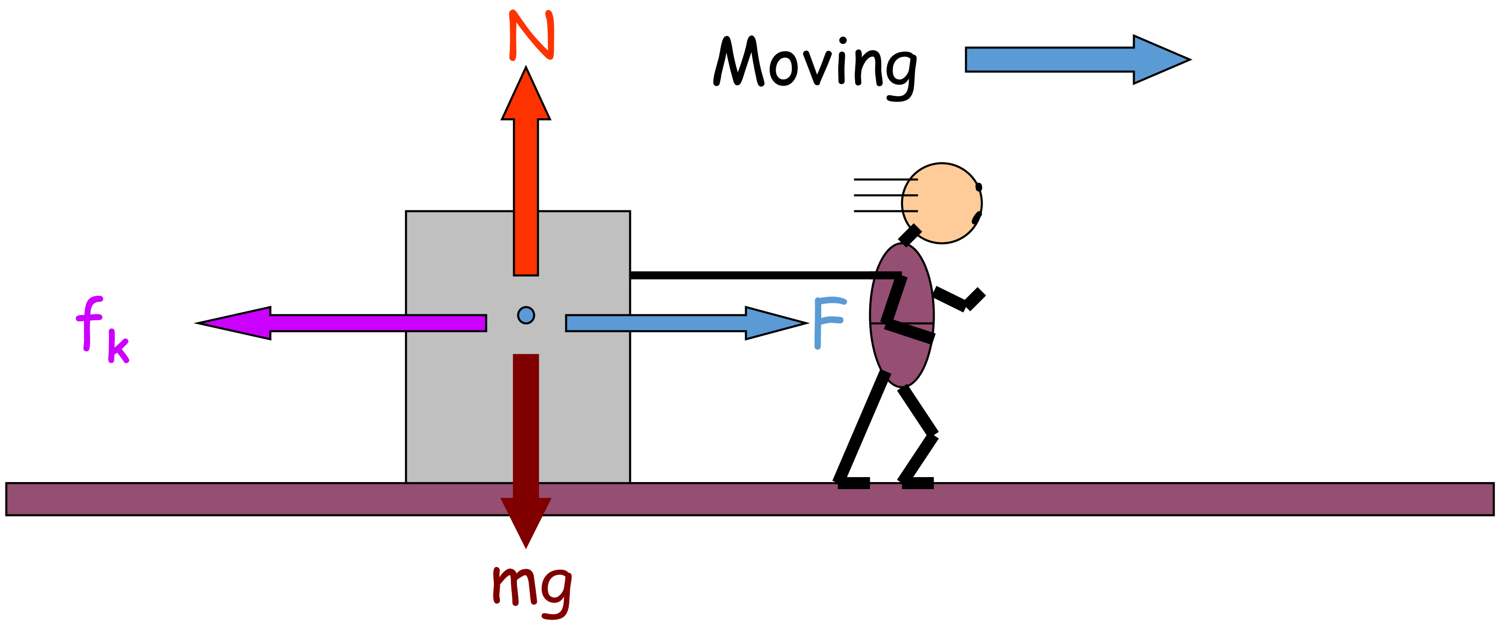
Hence no motion

# Kinetic Friction

- Kinetic Friction ($f_k$)
- Kinetic friction is the force experienced between two systems (objects) moving relative to each other.
- The magnitude (size) of the Kinetic friction is given by
- $$f_k = u_k N$$
- Where $u_k$ is the coefficient of kinetic friction

# Friction

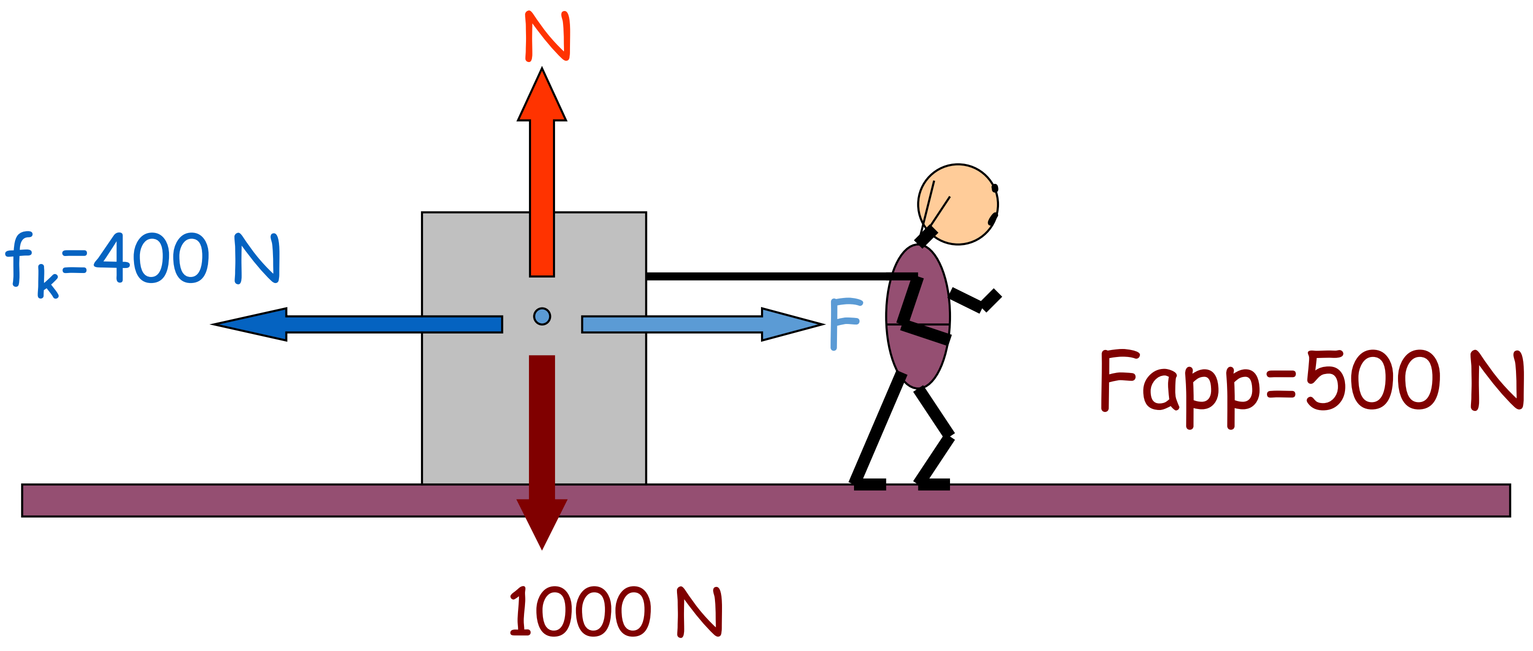
- Two surfaces in contact (kinetic friction)




$f_k = u_k N$ moving object

# Coefficient of Kinetic Friction, $u_k$ example

- Two surfaces in contact - with motion (Kinetic Friction)
- Let $u_k$=0.4




When $f_{k(max)} = u_k.N=0.4.1000 = 400\ N < Fapp$

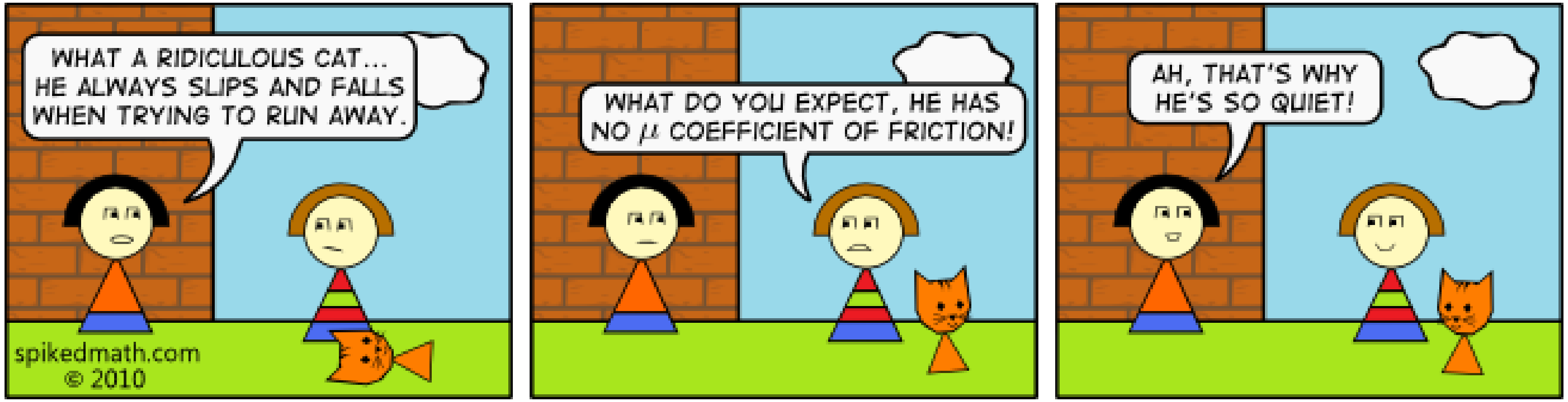
Hence motion

# Newton's Third Law

**Table 4.2** Coefficients of Friction[a]

| | $\mu_s$ | $\mu_k$ |
|---|---|---|
| Steel on steel | 0.74 | 0.57 |
| Aluminum on steel | 0.61 | 0.47 |
| Copper on steel | 0.53 | 0.36 |
| Rubber on concrete | 1.0 | 0.8 |
| Wood on wood | 0.25–0.5 | 0.2 |
| Glass on glass | 0.94 | 0.4 |
| Waxed wood on wet snow | 0.14 | 0.1 |
| Waxed wood on dry snow | — | 0.04 |
| Metal on metal (lubricated) | 0.15 | 0.06 |
| Ice on ice | 0.1 | 0.03 |
| Teflon on Teflon | 0.04 | 0.04 |
| Synovial joints in humans | 0.01 | 0.003 |

[a]All values are approximate.

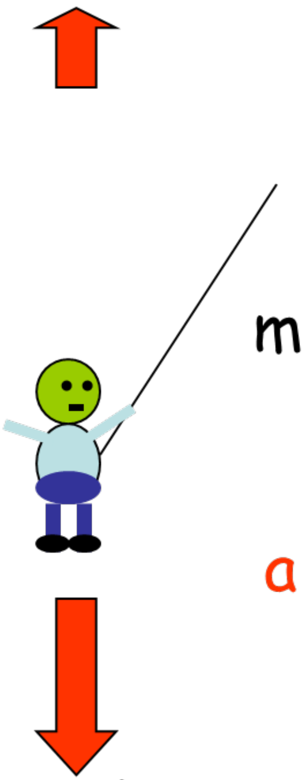

WHAT A RIDICULOUS CAT... HE ALWAYS SLIPS AND FALLS WHEN TRYING TO RUN AWAY.
spikedmath.com © 2010
WHAT DO YOU EXPECT, HE HAS NO $\mu$ COEFFICIENT OF FRICTION!
AH, THAT'S WHY HE'S SO QUIET!

# Air Resistance on a Free Falling body

- On Earth all  objects falling through a vacuum accelerate downwards at the same fairly constant rate regardless of weight.
- In a vacuum there is no Air Resistance.
- The resistance experienced to a body’s motion through Air is Drag.
- For a falling body the greater the rate of descent, the greater the drag.

# Parachutist

Air Resistance = R



$m$ = Mass person + Mass Parachute

$$a = \frac{\text{Net Force}}{m} = \frac{mg - R}{m}$$

Weight = mg

When $R = mg$ $a = 0$
Terminal Speed is reached

# Terminal Velocity

A point is reached when a body falling through air can not go any faster.

This is called the Terminal Velocity.

Depends on Shape
Surface
Weight

Sky Diver Spread Eagled 200 km/hr
Head Down 300 km/hr

# Approximate Terminal Speeds

| Object | Speed m/s | |
|---|---|---|
| Fluffy feather | 0.4 | |
| Sheet of paper | 0.5 | |
| Snowflake | 1.0 | |
| Parachutist | 7 | |
| Sky diver spread eagle | 58 | (10 s to 12 s) |
| Large Rock | 200 | |

# End of lecture

See the study guide for practice problems, with extra problems at the end of the study guide