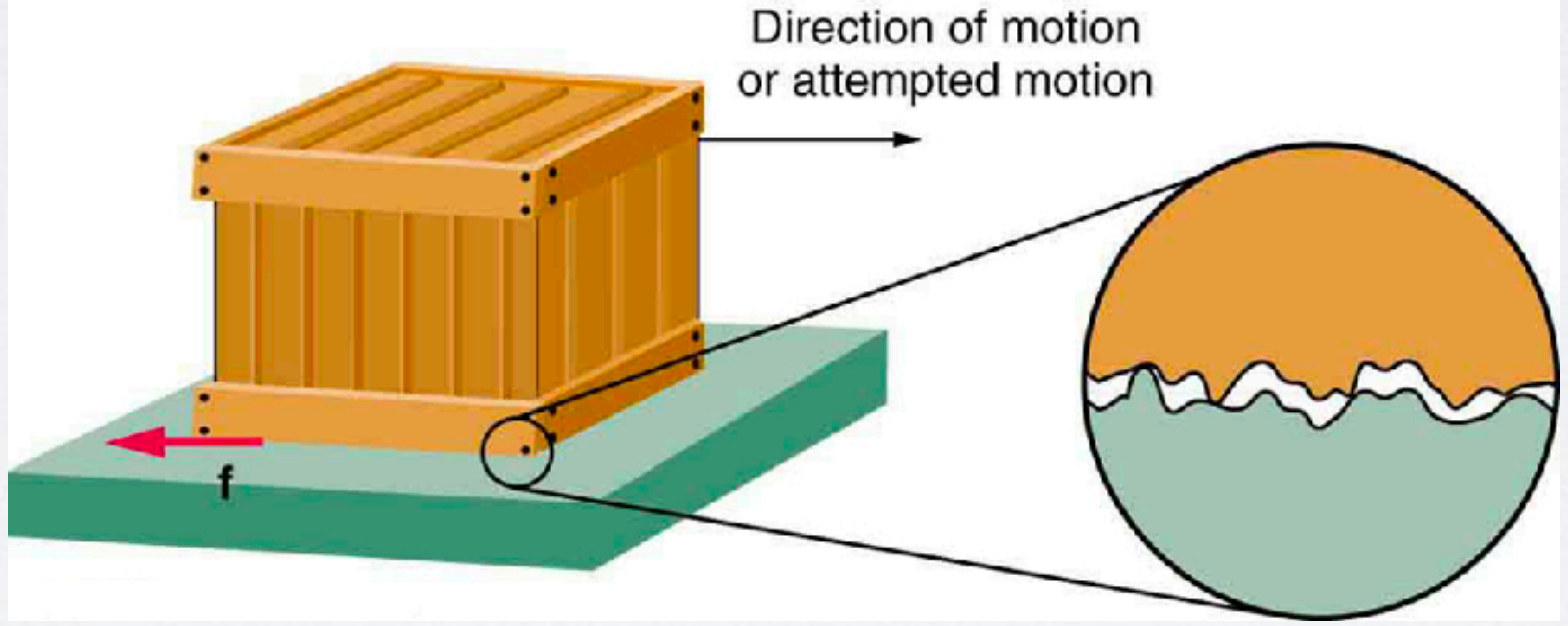
MORE FORCES

Chapter 5

FRICTION

- One of the most common forces we encounter is friction. Friction is a force that opposes the motion of objects whose surfaces are in contact or keeps an object from moving at all. It is caused by the forces between molecules and ruggedness of surfaces on small scales.



- While surfaces may appear smooth to us they actually have lots of ridges and holes on small scales. These interactions cause friction. Friction is very complicated, but we can use a simple model to get a good sense of how it works.

KINETIC FRICTION

- If you press an object harder into a surface the friction will be greater. If you barely touch it to the surface the friction will be less. This suggests the force of friction should depend on the force between the object and the surface.

- It also must depend on the substance as we know some substances are stickier than others. So we might guess that the friction force is given by

$$F_{fr,k} = \mu_k F_N$$

- where FN is the normal force and μ_k is a constant that depends on the substance. This is the equation for when an object is moving (kinetic).

STATIC FRICTION

- If an object is not moving (static) then the equation takes on a slightly different form and the constant μ_s can have a different value.

- If something is not moving and you give it a very small push, it only takes a very small frictional force to not move. If you give it a bigger push it takes a bigger frictional force. So like a normal force the static friction force will respond to other forces. There is some maximum value of the static friction force, we can write this as

$$F_{fr,s} \leq \mu_s F_N$$

EXAMPLE 5.1

- A skier with a mass of 62 kg is sliding down a snowy slope. Find the coefficient of kinetic friction for the skier if friction is known to be 45.0 N.

$$F_{fr,k} = \mu_k F_N$$

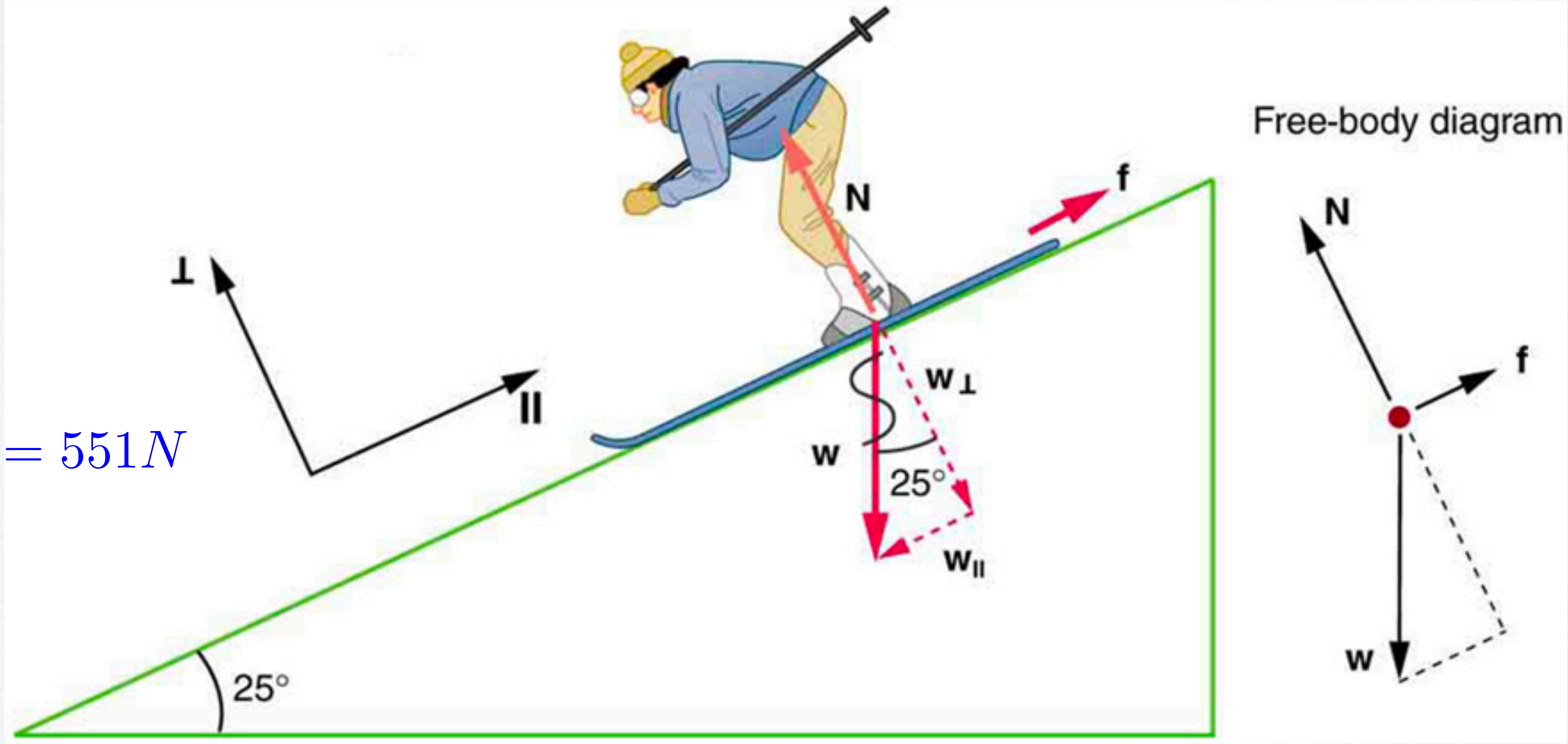
m = 62kg

F_{fr} = 45.0 N

μ_k = ?

$$F_N = mg\sin(90-25) \quad = 62kg(9.8m/s^2)sin(65) = 551N$$

$$\mu_k = \frac{F_{fr,k}}{F_N} \quad = \frac{45N}{551N} = 0.82$$



DRAG FORCE

- Another friction type force is called a drag force. This force occurs when an object moves in a fluid (gas or liquid). Unlike friction against a surface a drag force is often proportional to the speed of the object squared.

- The drag force can be written as

$$F_D = \frac{1}{2} C \rho A v^2$$

- where v is the speed of the object, ρ is the density of the fluid, A is the area of the object and C is a value that depends on the shape and material of the object.

TERMINAL VELOCITY

- Unfortunately, problems with a drag force are very hard to solve because the drag force depends on velocity but the velocity depends on acceleration which depends on the net force.
- A special case is when the object reaches what is called a terminal velocity. Since the drag force depends on velocity, that means eventually an object can go fast enough that the drag force becomes as large the force pushing the object. Thus there is a maximum velocity the object can reach, a terminal velocity.
- For example if gravity is accelerating the object then the terminal velocity is reached when the drag force equals the objects weight,
- $$mg = \frac{1}{2}C\rho A v^2 \qquad v = \sqrt{\frac{2mg}{\rho C A}}$$

EXAMPLE 5.2

- **A Terminal Velocity:** Find the terminal velocity of an 85-kg skydiver falling in a spread-eagle position.

m = 85 kg
ρ = 1.21 kg/m³
C = 1
A = ? = 2m(0.35m) = 0.7m²

$$v = \sqrt{\frac{2mg}{\rho C A}}$$

$$= \sqrt{\frac{2(85kg)(9.8m/s^2)}{(1.21kg/m^3)(1.0)(0.7m^2)}}$$

$$= 44m/s$$

HOOKE'S LAW

- For many substances if we squeeze they will push back. Likewise if we stretch them they will pull back. These elastic objects force can be described by what is called Hooke's Law.

$$F = k\Delta L$$

- where k called a spring constant depends on the object and ΔL is how much it has been squeezed or stretched.

HOME WORK

- Chap 5 - 4, 7, 17, 20