

Newton's 2nd Law of Motion
Force and Acceleration

Newton 2 Slide 1

Mass and Acceleration

- Mass resists acceleration, this is the principle of inertia
- We call this relationship inversely proportional
- Acceleration $\sim 1/\text{mass}$

Newton 2 Slide 2

Newton's 2nd Law
Newton-2

- The acceleration produced by a **net force** acting on an object is directly proportional to the magnitude of the net force and in the same direction as the net force, and the acceleration is inversely proportional to the mass of the object.
- Acceleration = net force/mass
- $\mathbf{a} = \mathbf{F}_{\text{net}}/m$

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The Unit Newton


- Newton's 2nd law says $a = F_{\text{net}} / m$
- So $F_{\text{net}} = ma$ by algebra
 $1N = 1kg \cdot m / s^2$
- 1 Newton of force is the amount of force necessary to accelerate 1 kg at 1 m/s/s
- This is why 1 kg weighs 9.8 N on Earth, because the acceleration due to gravity on earth (g) is 9.8 m/s/s

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Pressure

- Pressure = Force/Area
- Pressure is directly proportional to force but is not the same thing as force
 - 10 N of force exerted by pushing on someone with the palm of your hand
 - 10 N of force exerted by pushing on someone with a pin

$$P = \frac{F}{A}$$



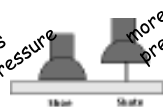
Which has the smaller surface area -- point of pin or palm of hand?

Pin has smaller area and larger pressure

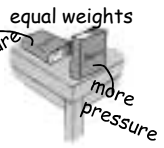
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Pressure Units

SI: $N/m^2 = \text{Pascal} = Pa$
 Named for Blaise Pascal (1623 - 1662)
 French mathematician & physicist

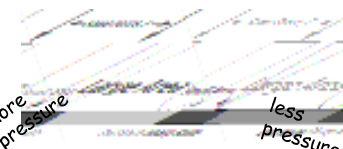


less pressure more pressure



equal weights
less pressure more pressure

More Pressure Information & Examples



more pressure less pressure

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Finding Acceleration

- Kinematics
 - Definition of Acceleration**

$$\bar{a} = \frac{\Delta \bar{v}}{\Delta t}$$
 - Constant Acceleration Motion From Rest**

$$d = \frac{1}{2} at^2$$
- Dynamics
 - Newton's Second Law**

$$\bar{a} = \frac{\bar{F}_{net}}{m}$$

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Two Ways to Find Net Force

- $F_{net} = \text{Vector Sum}$
 - $F_{NET} = \Sigma F$
- **Newton 2**
 - $F_{NET} = m a$

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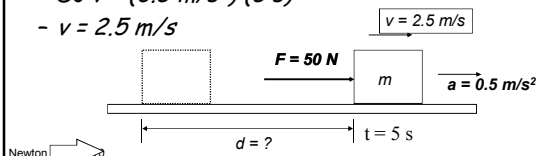
Example: Pushing a Box on Ice.

- A skater is pushing a heavy box (mass $m = 100 \text{ kg}$) across a sheet of ice (horizontal & frictionless). He applies a force of 50 N toward the right. If the box starts at rest, what is its speed v after being pushed for a time $t = 5 \text{ s}$?

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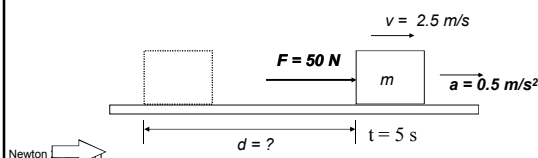
Example: Pushing a Box on Ice...

- Start with $F_{net} = ma$.
 - $a = F_{net} / m$.
 - $a = (50\text{ N}) / (100\text{ kg}) = 0.5\text{ N/kg} = (0.5\text{ kg m/s}^2) / \text{kg}$
 - $a = 0.5\text{ m/s}^2$
 - Recall that $v_f = v_i + at$ (from definition of a)
 - So $v = (0.5\text{ m/s}^2)(5\text{ s})$
 - $v = 2.5\text{ m/s}$



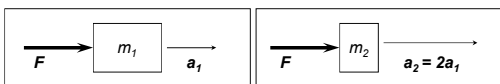
Example: Pushing a Box on Ice...

- Now, what distance will the block travel during the 5 seconds?
 - $d = \frac{1}{2} a t^2$
 - $d = (0.5)(0.5\text{m/s}^2)(5\text{ s})^2$
 - $d = 6.25\text{ m}$

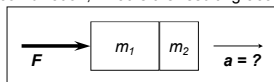


Force and acceleration

- A force F acting on a mass m_1 results in an acceleration a_1 .
The same force acting on a different mass m_2 results in an acceleration $a_2 = 2a_1$.



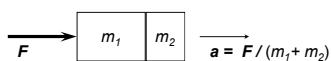
- If m_1 and m_2 are glued together and the same force F acts on this combination, what is the resulting acceleration?



- (a) $2/3 a_1$ (b) $3/2 a_1$ (c) $3/4 a_1$

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Force and acceleration



- Since $a_2 = 2a_1$ for the same applied force, $m_2 = (1/2)m_1$

- $m_1 + m_2 = 3m_1/2$

- So $a = (2/3)F / m_1$ \Rightarrow but $F/m_1 = a_1$

\Rightarrow $a = 2/3 a_1$

- (a) $2/3 a_1$ (b) $3/2 a_1$ (c) $3/4 a_1$

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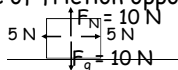
Friction: force that resists motion

- force between the surfaces of two objects
- Examples: sliding friction, air resistance
- Friction acts in the direction opposite to motion

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Friction Example

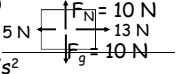
- A force of 5 N is used to drag a 1 kg object across the lecture table at a constant velocity of 1 m/s. What is the friction force opposing the motion?
 - What is the acceleration of the object?
 - Velocity constant - acceleration = 0
 - What is the net force on the object?
 - Acceleration = 0 $\rightarrow F_{net} = 0$
 - What is the force of friction opposing the motion?
 - 5 N



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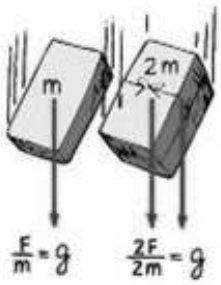
Friction Example

- A force of 5 N is used to drag a 1 kg object across the lecture table at a constant velocity of 1 m/s. What is the friction force opposing the motion?
 - What is the force of friction opposing the motion?
 - 5 N
- Now a force of 13 N is applied to the object. What is its acceleration?
 - $F_{net} = 13\text{ N} - 5\text{ N} = 8\text{ N}$
 - $a = F_{net}/m = 8\text{ N}/1\text{ kg} = 8\text{ m/s}^2$



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Freefall



- The ratio of weight (F) to mass (m) is the same for all objects in the same locality
- Therefore, their accelerations are the same in the absence of air resistance.

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Concept Check

- In a vacuum, a coin and a feather fall equally, side by side. Would it be correct to say that equal forces of gravity act on both the coin and the feather when in a vacuum?

Newton 2 Slide 18

Concept Check

- In a vacuum, a coin and a feather fall equally, side by side. Would it be correct to say that equal forces of gravity act on both the coin and the feather when in a vacuum?
- NO! These objects accelerate equally not because the forces of gravity on them are equal, but because the ratios of their weights to masses are equal.

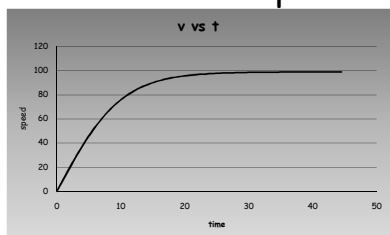
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Non-Freefall The Effect of Air Resistance

- Force of air drag on a falling object depends on two things.
 - the frontal area of the falling object—that is, on the amount of air the object must plow through as it falls
 - the speed of the falling object; the greater the speed, the greater the force
- As an object falls through air, the force of air resistance on it increases as its speed increases

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Terminal Speed



- When the force of air resistance is equal to the force of gravity on an object, it no longer accelerates. This speed is called terminal velocity.

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Terminal Speed

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- The heavier parachutist must fall faster than the lighter parachutist for air resistance to cancel his greater weight.

Golf Ball & Styrofoam Ball

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- A stroboscopic study of a golf ball (left) and a Styrofoam ball (right) falling in air. The air resistance is negligible for the heavier golf ball, and its acceleration is nearly equal to g . Air resistance is not negligible for the lighter Styrofoam ball, which reaches its terminal velocity sooner.

Air Resistance & Acceleration

- A skydiver jumps from a high-flying helicopter. As she falls faster and faster through the air, does her acceleration increase, decrease, or remain the same?
- Acceleration decreases because the net force on her decreases. Net force is equal to her weight minus her air resistance, and since air resistance increases with increasing speed, net force and hence acceleration decrease.

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