Wrocław University of Science and Technology

Physics

JZL1001913C

summer semester

2020/2021

Wednesday, 18:20 - 19:50

Friday, 18:20 - 19:50

virtual room (ZOOM)

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Outline

- Introduction - Physics rules the world
- Motion phenomena - Kinematics
- **Motion phenomena - Dynamics**
- Rotational motion
- Harmonic motion
- Gravitational field
- Relativistic phenomena
- Basics of Thermodynamics
- Principles of Thermodynamics
- Kinetic theory of matter
- Electrostatics
- Electric current
- Magnetic field
- Vibrations and electromagnetic waves
- Optics
- Quantum nature of radiation
- Nuclear Physics

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Units - rewiev

Quantity	Unit Name	Unit Symbol
Time	second	s
Length	metre	m
Mass	kilogram	kg
electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	Cd

- SI Units
- Prefixes
- Scientifical notation
- Significant Figures
- Decimal Places

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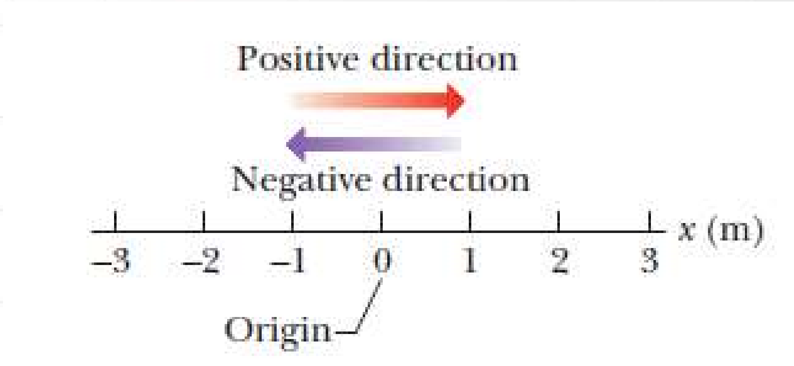
Kinematics - rewiev



Quantities:

- Position vs displacement
- Speed vs velocity
- Acceleration
- Free fal

$$\Delta x = x_2 - x_1$$

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1}.$$

$$s_{avg} = \frac{\text{total distance}}{\Delta t}.$$

Equation	Missing Quantity
$v = v_0 + at$	$x - x_0$
$x - x_0 = v_0 t + \frac{1}{2}at^2$	v
$v^2 = v_0^2 + 2a(x - x_0)$	t
$x - x_0 = \frac{1}{2}(v_0 + v)t$	a
$x - x_0 = vt - \frac{1}{2}at^2$	v_0

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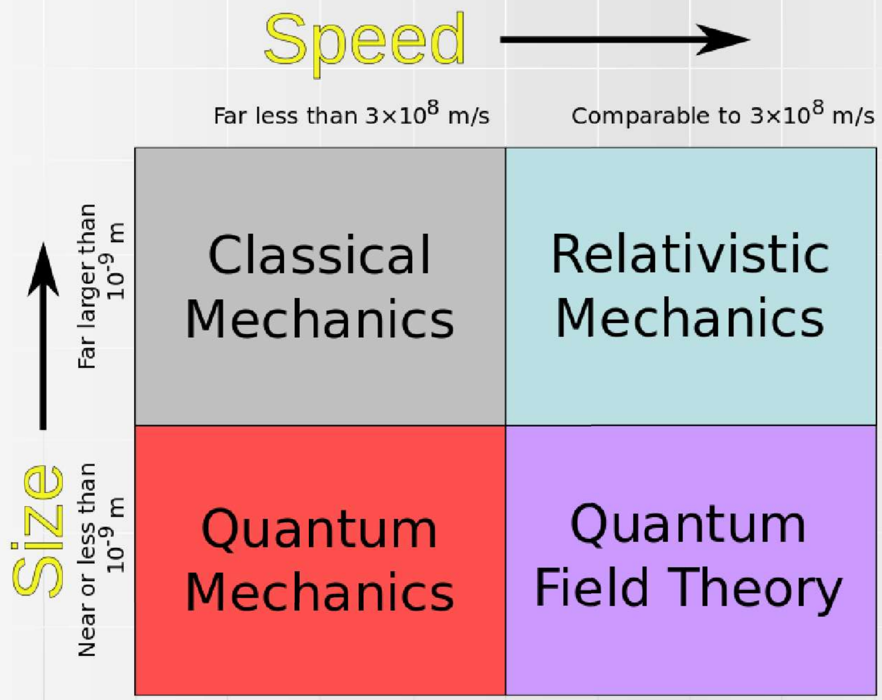
Newtonian Mechanics

Newtonian mechanics does not apply to all situations. If the speeds of the interacting bodies are very large —an appreciable fraction of the speed of light—we must replace Newtonian mechanics with Einstein's special theory of relativity, which holds at any speed, including those near the speed of light. If the interacting bodies are on the scale of atomic structure (for example, they might be electrons in an atom), we must replace Newtonian mechanics with quantum mechanics.



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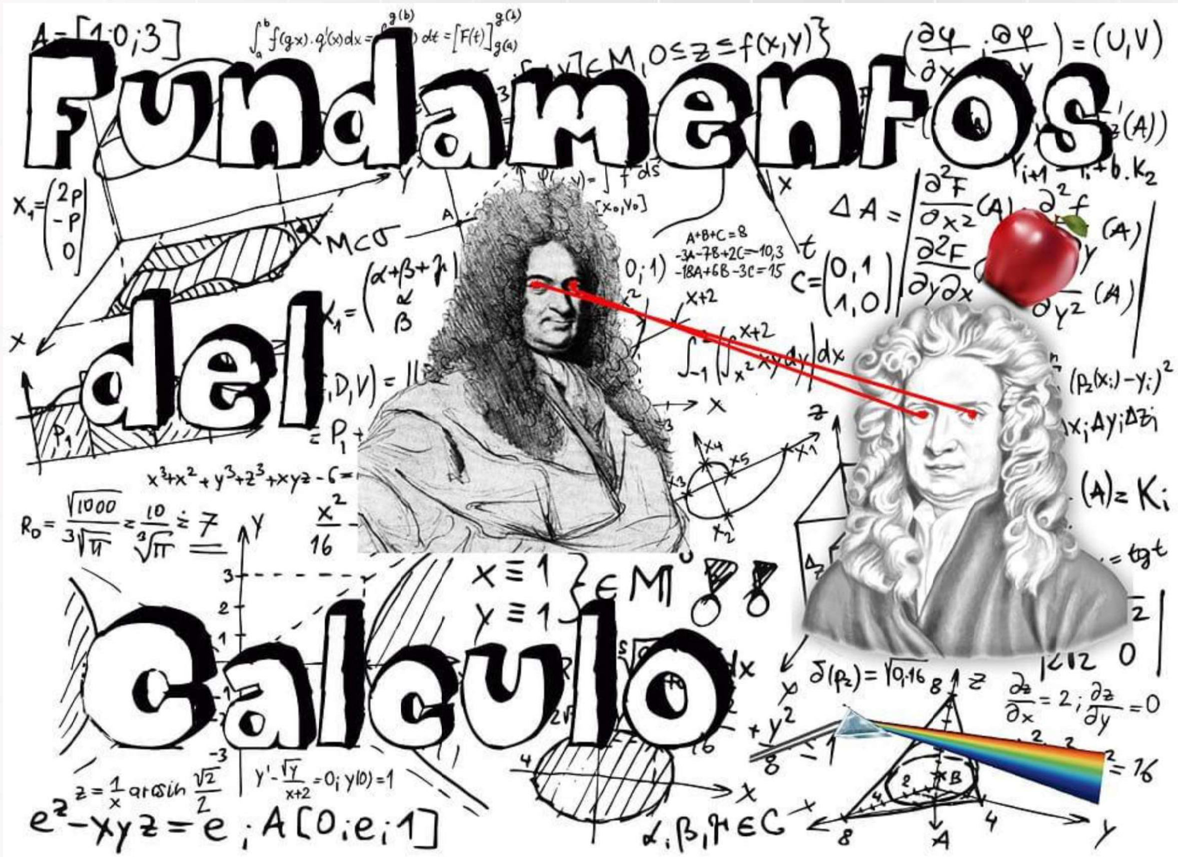
Motion phenomena - Dynamics

Dynamics is the study of why things move, in contrast to kinematics, which is concerned with describing the motion of objects. An object's motion typically is described using Newton's Laws of Motion.



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Newton's 1st Law of Motion

Newton's First Law: The Law of Inertia
Every body remains in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed thereon.

In other words, if the body is at rest, it stays at rest. If it is moving, it continues to move with the same velocity (same magnitude *and* same direction).

Physicists use the term **inertia** to describe this tendency of an object to resist a change in its motion.

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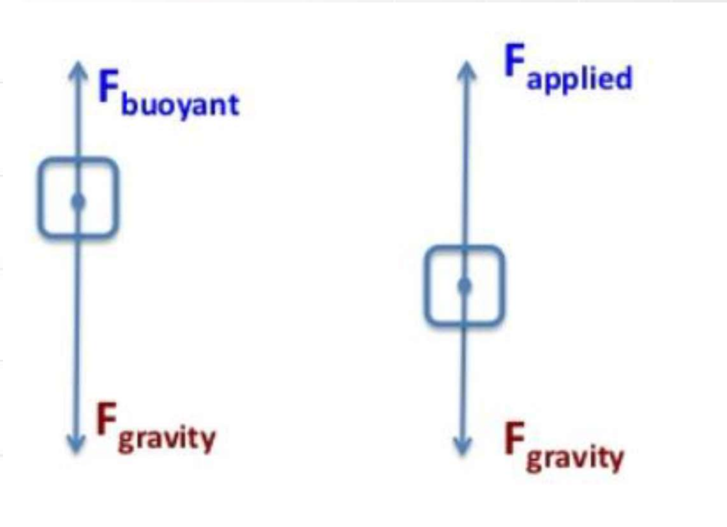
Force

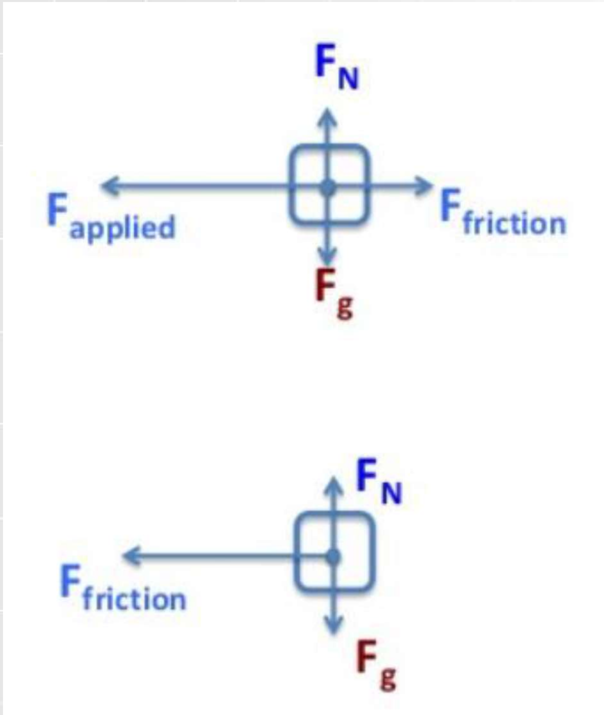
Unit. We can define the unit of force in terms of the acceleration a force would give to the standard kilogram, which has a mass defined to be exactly 1 kg. Suppose we put that body on a horizontal, frictionless surface and pull horizontally such that the body has an acceleration of 1 m/s^2. Then we can define our applied force as having a magnitude of 1 newton (abbreviated N).

Unit	Abbreviation	Equivalent Newton unit
Dyne	dyn	10^{-5} N
Gram-force	gf	9.806 65 mN
Poundal	pdl	138.255 0 mN
Pound-Force	lbf	4.448 222 N
Kilogram-Force	Kgf	9.806 65 N

Free Body Diagrams

Free body diagrams are vector diagrams. They show direction and magnitiude of the forces acting on an object. Forces are drawn as arrows acting from the centre of a box representing the object.





Identify: the slowing car, the acceleration bike, the lanuching angry bird and the sinking stone

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Example 1

Consider a bus moving steadily at 100 km/h along a highway. Although we can assume that many forces are acting on the bus, such as weight (force due to gravity), air resistance and/or friction with the highway, we know via Newton's 1st Law of Motion that the sum of the forces acting on the bus is zero, as it is at a constant velocity.

Example 2

Consider a truck going 40 km/hr down a straight road (it is important that the road is straight in this example!). If a grocery bag is sitting in the passenger seat and the driver slams on the brakes, the groceries will typically fly off of the seat, into the glove compartment, or onto the floor. This is because the brakes are creating an unbalanced force slowing the truck, but not the grocery bag. But why doesn't the driver also get thrown out of their seat?

Example 2

Consider a truck going 40 km/hr down a straight road (it is important that the road is straight in this example!). If a grocery bag is sitting in the passenger seat and the driver slams on the brakes, the groceries will typically fly off of the seat, into the glove compartment, or onto the floor. This is because the brakes are creating an unbalanced force slowing the truck, but not the grocery bag. But why doesn't the driver also get thrown out of their seat? The driver is (hopefully) wearing a seat belt, which is connected to the truck. The tension of the seat belt is providing a similar force to the driver.

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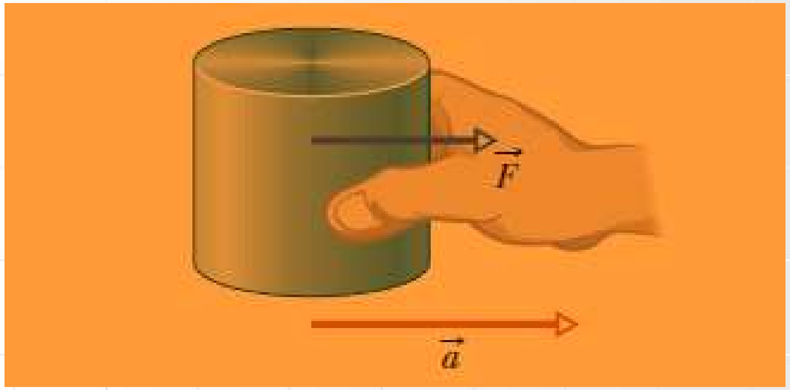
Newton’s 2nd Law of Motion

Newton's Second Law: The Law of Acceleration

The change in quantity of motion is proportional to the magnitude of the force; and is made in the direction of the straight line in which that force is directed.

$$\vec{F}_{net} = m\vec{a} \quad \text{(Newton's second law)}$$



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Example 1

A 1000 kg car accelerates at 0.5 m/s^2. Calculate the force that must be applied to it.

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A 1000 kg car accelerates at 0.5 m/s^2. Calculate the force that must be applied to it.

$$
\begin{aligned}
F &= ma \\
&= 1000\mathrm{kg} \times 0.5\mathrm{m/s}^2 \\
&= 500\mathrm{kg} \cdot \mathrm{m/s}^2 \\
&= 500\mathrm{N}
\end{aligned}
$$

Example 2

A 0.085 kg bullet is fired from a rifle and emerges with a speed of 400 m/s. Assuming that the bullet has constant acceleration over the 0.5 m length of gun barrel, calculate the force on the bullet.

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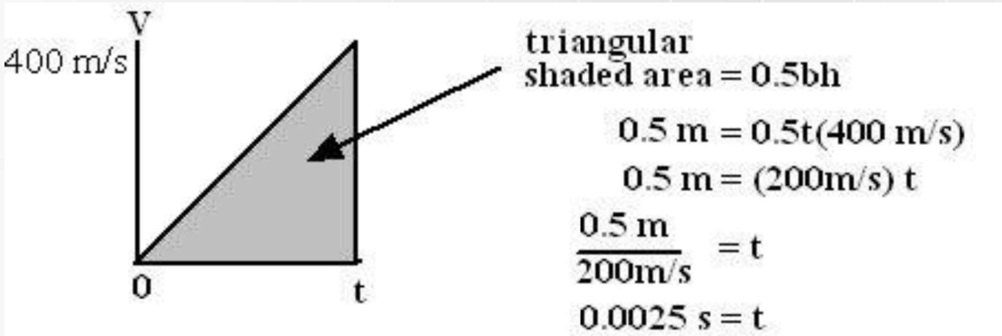

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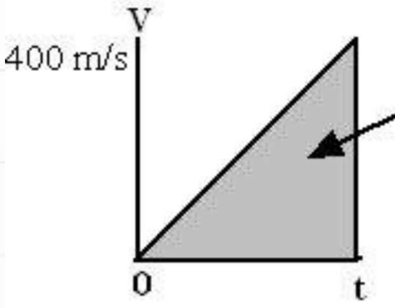

triangular shaded area = 0.5bh

$$0.5\ \text{m} = 0.5t(400\ \text{m/s})$$

$$0.5\ \text{m} = (200\text{m/s})\ t$$

$$\frac{0.5\ \text{m}}{200\text{m/s}} = t$$

$$0.0025\ \text{s} = t$$

$$\begin{aligned} F &= ma \\ &= m\frac{\Delta v}{\Delta t} \\ &= 0.085\frac{400}{0.0025} \\ &= 13600\text{N} \end{aligned}$$

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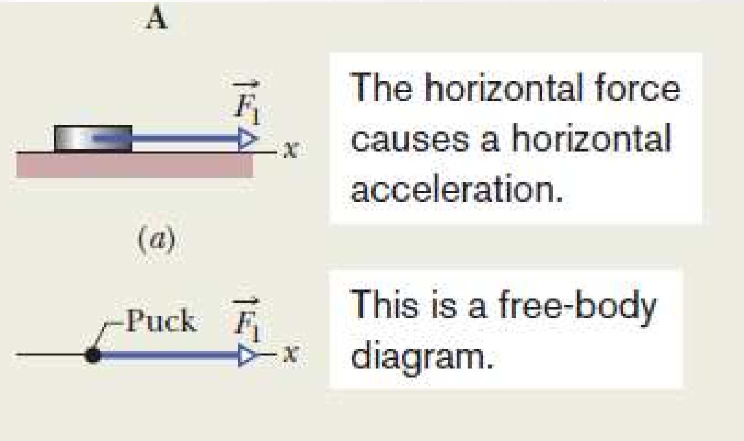
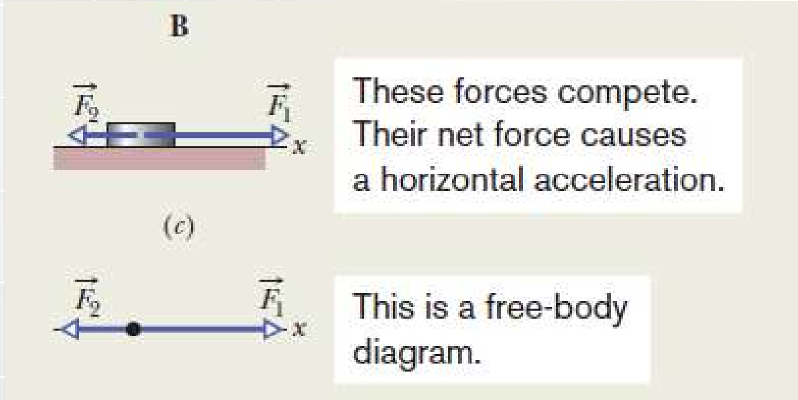
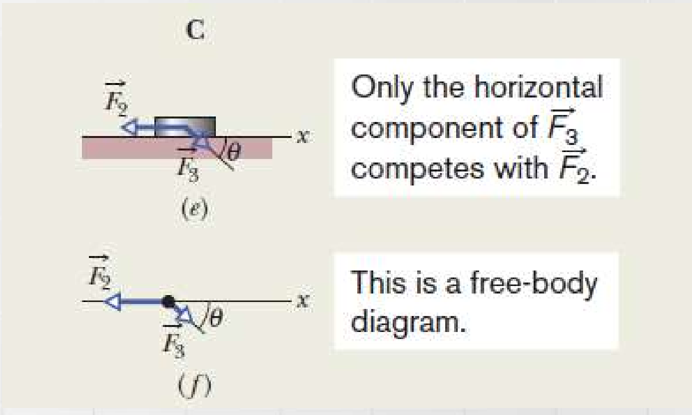
Example 3

The puck's mass is m = 0.20 kg. Forces F1 and F2 are directed along the axis and have magnitiudes F1=4.0N and F2 = 2.0N. Force F3 is directed at angle 30^o and magnitude F3 = 1.0N. In each situation, what is the acceteraton of the puck?







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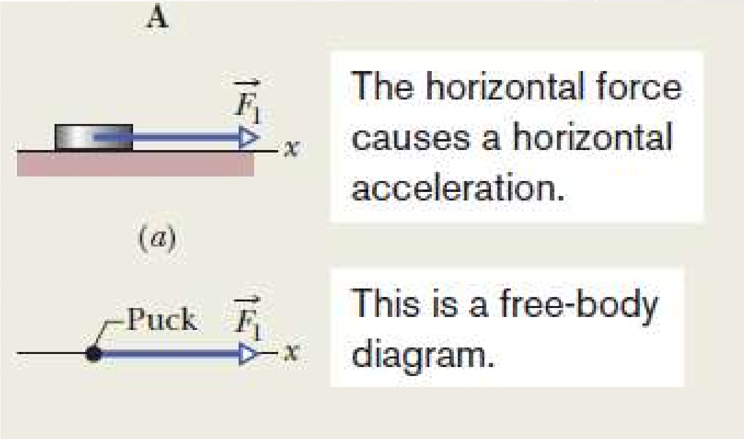

$$F_1 = ma_x$$

$$a_x = \frac{F_1}{m} = \frac{4.0\ \text{N}}{0.20\ \text{kg}} = 20\ \text{m/s}^2$$

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Example 3

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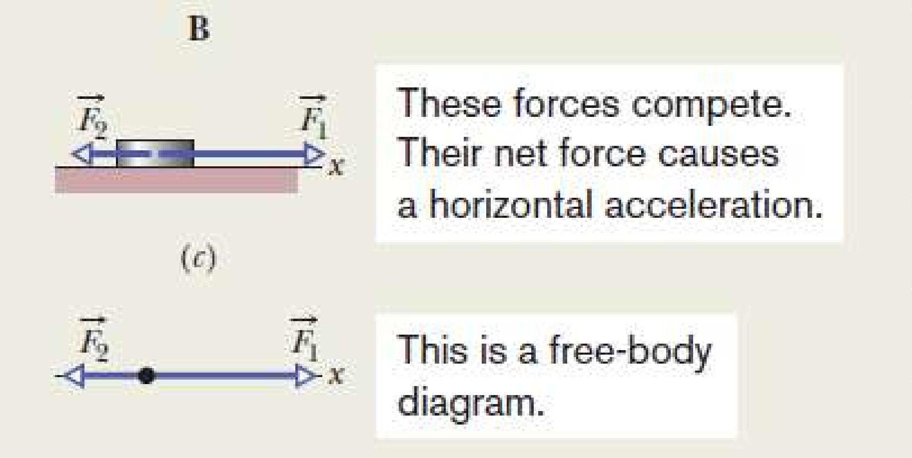
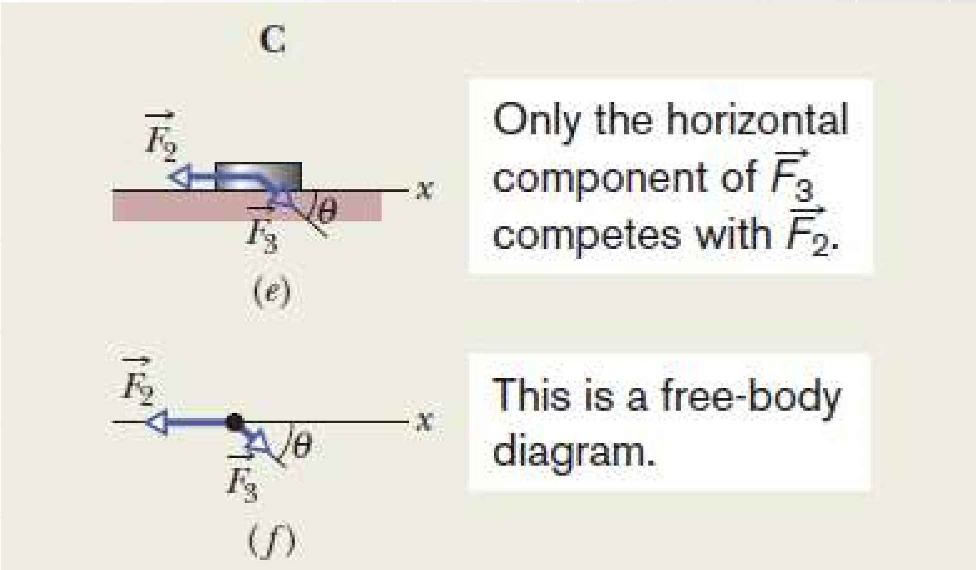


$$F_1 - F_2 = ma_x$$

$$a_x = \frac{F_1 - F_2}{m} = \frac{4.0\ \text{N} - 2.0\ \text{N}}{0.20\ \text{kg}} = 10\ \text{m/s}^2$$

Example 3

The puck's mass is m = 0.20 kg. Forces F1 and F2 are directed along the axis and have magnitiudes F1=4.0N and F2 = 2.0N. Force F3 is directed at angle 30^o and magnitude F3 = 1.0N. In each situation, what is the acceteraton of the puck?



$$F_{3,x} - F_2 = ma_x$$

$$F_{3,x} = F_3 \cos\theta$$

$$a_x = \frac{F_{3,x} - F_2}{m} = \frac{F_3 \cos\theta - F_2}{m}$$

$$= \frac{(1.0\ \mathrm{N})(\cos 30^\circ) - 2.0\ \mathrm{N}}{0.20\ \mathrm{kg}} = -5.7\ \mathrm{m/s^2}$$

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Newton’s 3rd Law of Motion

Newton's Third Law: The Law of Interaction
To every action there is always opposed an equal reaction; or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

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Main point of Newton's third law:
ACTION = REACTION
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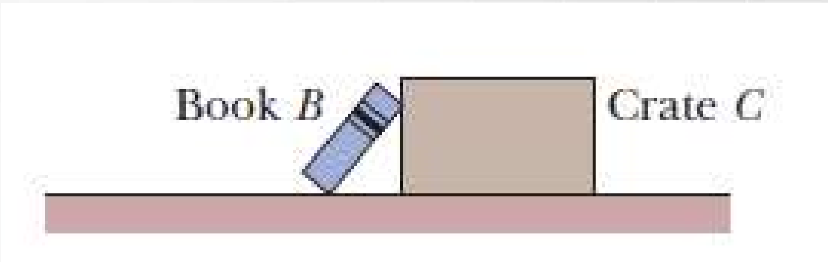


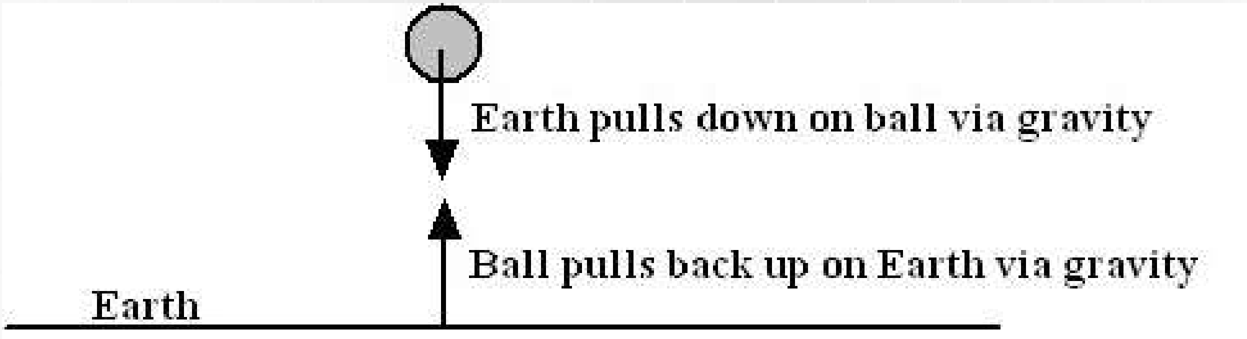
Example 1

Consider a car traveling. If the car accelerates due to a 500 N force on it there is another object that experiences a 500 N force in the opposite direction. In this case, it would be the road. Similarly, an aircraft accelerates because it applies a backward force on the air (via a propeller or turbine), and the air applies a forward force on the aircraft. In space, where there is no air, a rocket are typically used - it applies a backwards force on its exhaust material and the exhaust material applies a forward force on the rocket.

Often there are multiple forces involved. When a person shoots a rifle, a force is obviously applied to the bullet. It is the hot gunpowder gases that push on the bullet, and the bullet pushes back on the gases. The gases push back on the gun and the gun pushes forward on the gases. The gun pushes back on the person holding it, and the person pushes forward on the gun. You could continue this to the person pushing back on the Earth and the Earth pushing forward on the gun.

Action/Reaction Pairs

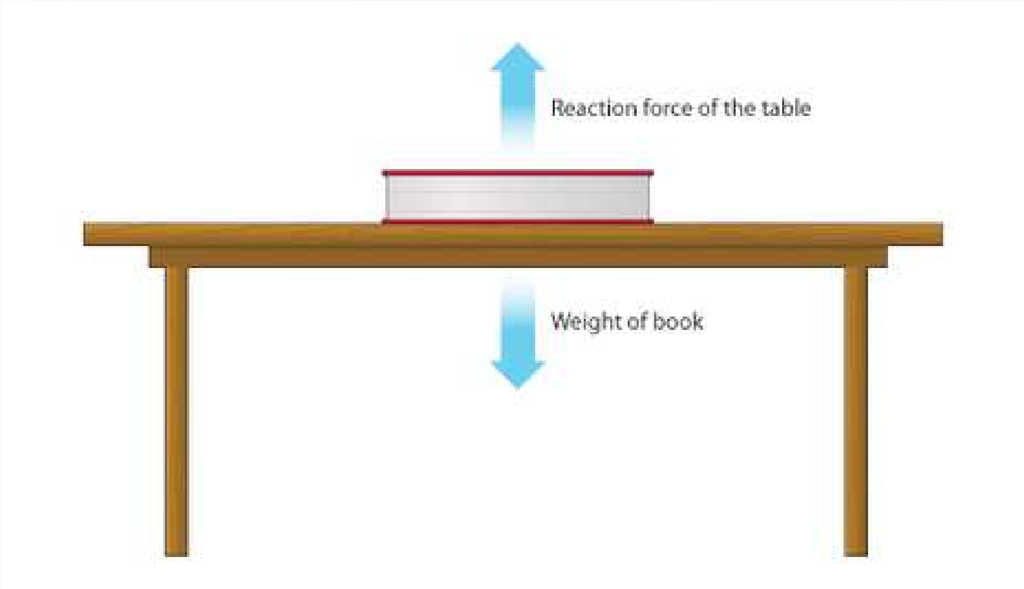
Consider the Earth and a ball. The force from the Earth on the ball, and the force from the ball on the Earth are of equal magnitude, but opposite directions.



The Earth and a ball in the air exert equal and opposite forces on each other. The Earth and ball in this situation are said to be "Action/Reaction" pairs.

Action/Reaction Pairs

Consider now a book sitting at rest on a table. There is a force downwards from its mass on the table (weight) and a force upwards from the table on the book (normal force). However, weight and normal force are not Action/Reaction Pairs, as the weight is not created by the normal force. The true normal force in this example are the mass and the Earth, as the Earth is applying a gravitational force on the mass (weight) and the mass is applying the same magnitude force in a opposite direction.



Example 1

Although people would surely avoid getting into the elevator with you, suppose that you weigh yourself while on an elevator that is moving. Would you weigh more than, less than, or the same as when the scale is on a stationary floor?

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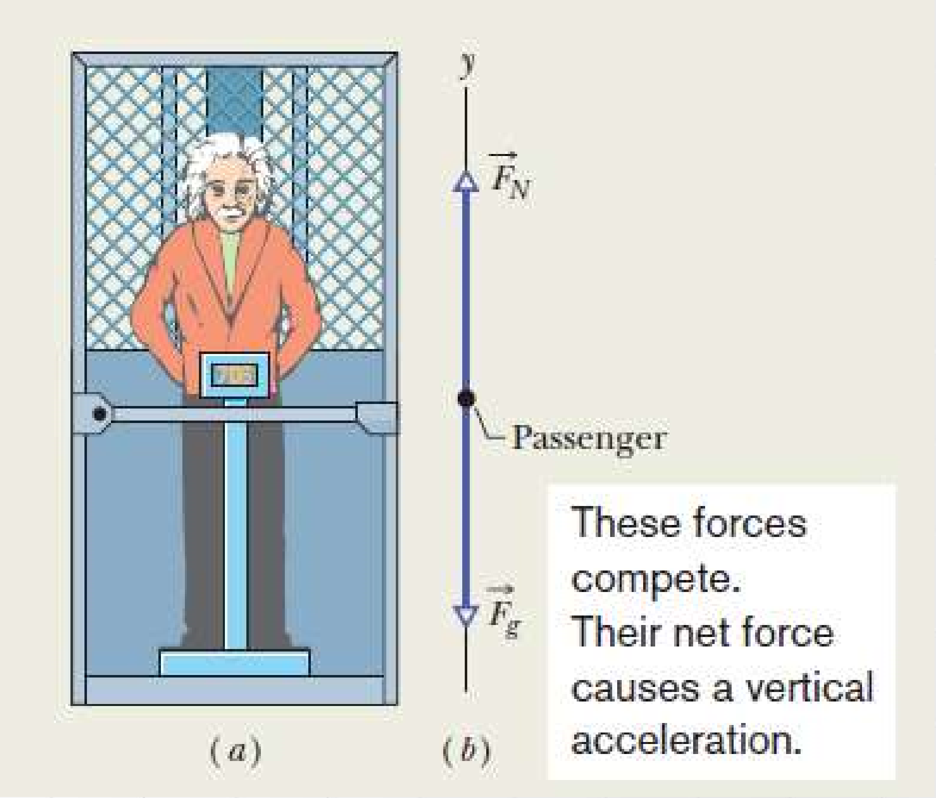

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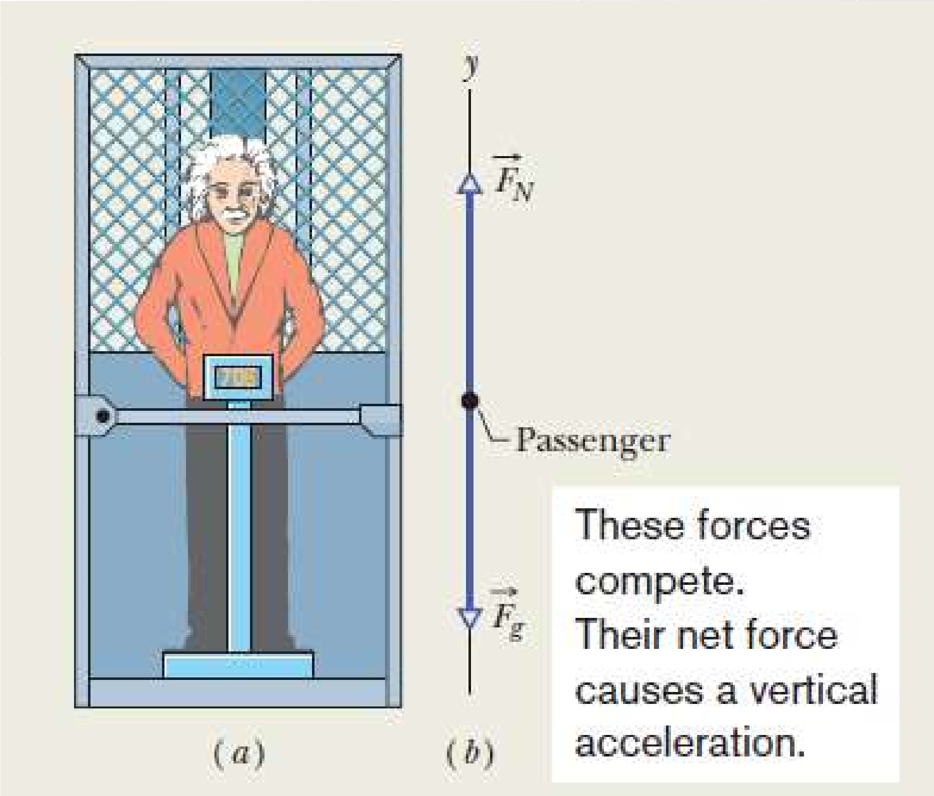

$$F_N - F_g = ma$$
$$F_N = F_g + ma.$$

$$F_N = m(g + a)$$

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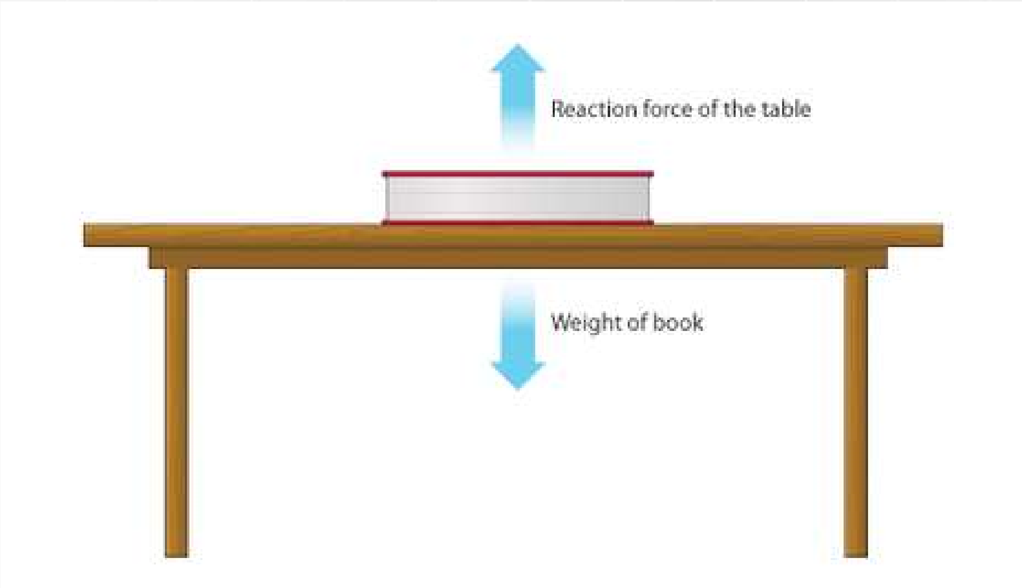

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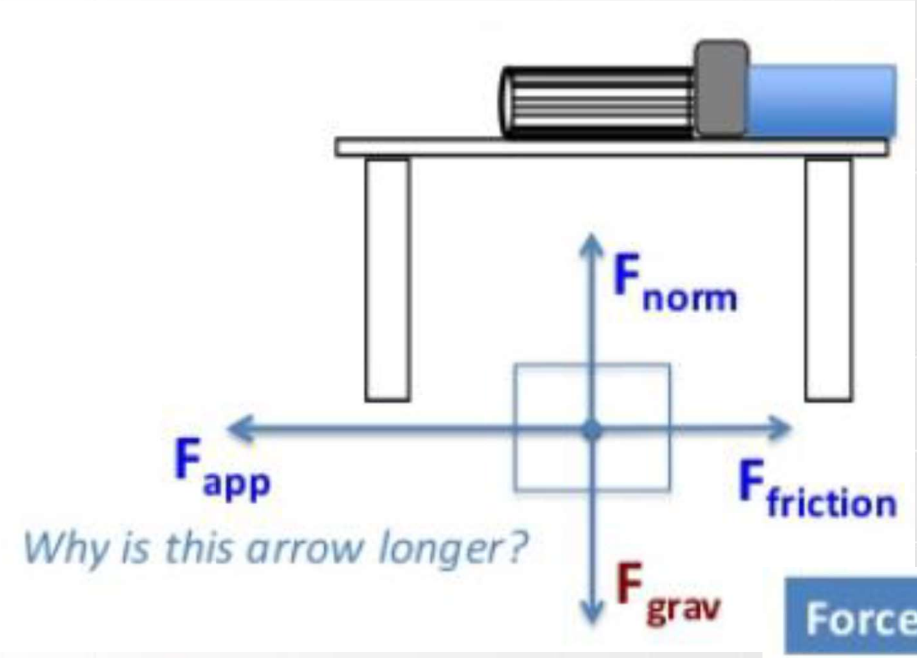
Action/Reaction Pairs



Force	Agent	Direction
Weight (gravity)	Earth	Down
Normal	Table	Up
Applied (finished)	MrT	Left
Friction	Tabletop	Right

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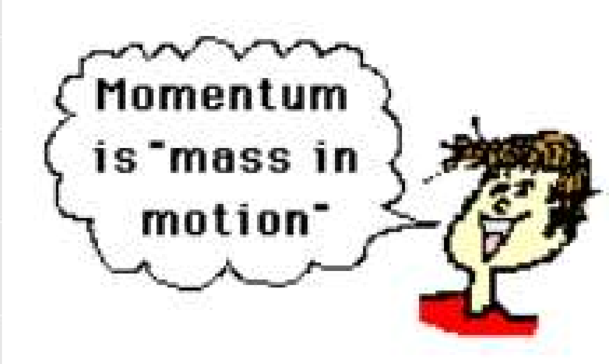
Momentum

Momentum is a commonly used term in sports. A team that has the momentum is on *the move* and is going to take some effort to stop. A team that has a lot of momentum is really *on the move* and is going to be *hard to stop*. Momentum is a physics term; it refers to the quantity of motion that an object has. A sports team that is *on the move* has the momentum. If an object is in motion (*on the move*) then it has momentum.



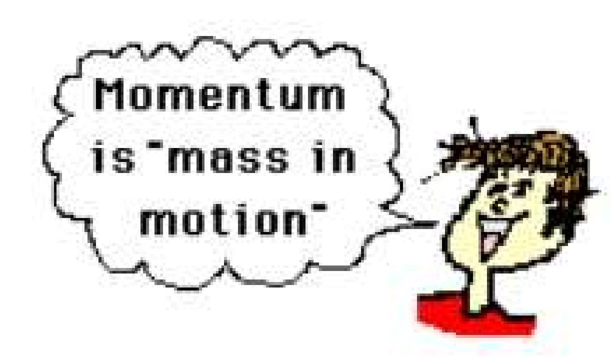
Momentum = mass • velocity

$p = m \bullet v$

Example 1

Determine the momentum of a ...

a) 60-kg halfback moving eastward at 9 m/s.
b) 1000-kg car moving northward at 20 m/s.
c) 40-kg freshman moving southward at 2 m/s.



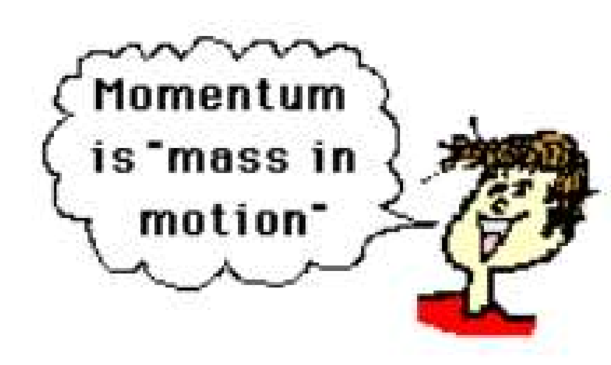
Example 1

Determine the momentum of a ...

a) 60-kg halfback moving eastward at 9 m/s.
   p = 540 kg•m/s, east

b) 1000-kg car moving northward at 20 m/s.
   p = 20 000 kg•m/s, north

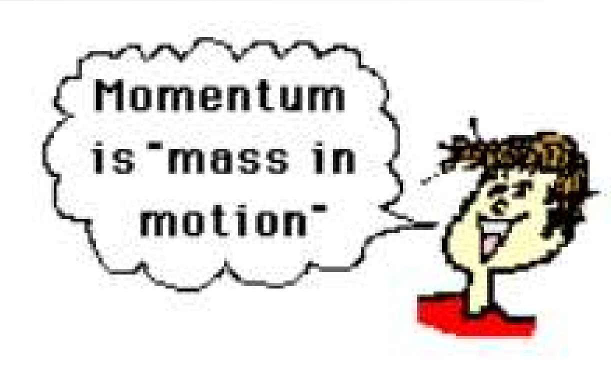
c) 40-kg freshman moving southward at 2 m/s.
   p = 80 kg•m/s, south



Example 1

A car possesses 20 000 units of momentum. What would be the car's new momentum if ...

a) its velocity was doubled.
b) its velocity was tripled.
c) its mass was doubled (by adding more passengers and a greater load)
d) both its velocity was doubled and its mass was doubled.



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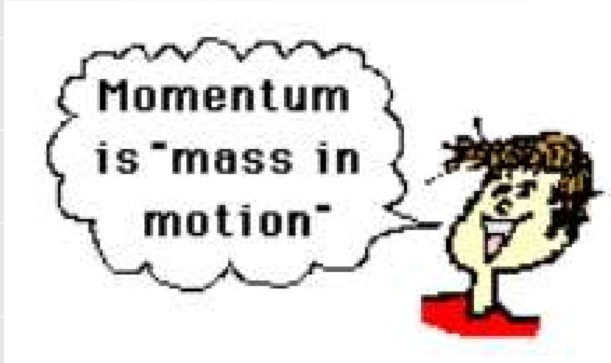
Example 1

A. **p = 40 000 units** (doubling the velocity will double the momentum)
B. **p = 60 000 units** (tripling the velocity will triple the momentum)
C. **p = 40 000 units** (doubling the mass will double the momentum)
D. **p = 80 000 units** (doubling the velocity will double the momentum and doubling the mass will also double the momentum; the combined result is that the momentum is doubled twice -quadrupled)



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Momentum Conservation Principle

Total system momentum is conserved for collisions between objects in an isolated system.

$$F_1 = - F_2$$

The forces are equal in magnitude and opposite in direction.

$$t_1 = t_2$$

$$F_1 * t_1 = - F_2 * t_2$$

The impulses are equal in magnitude and opposite in direction.

$$m_1 * \Delta v_1 = - m_2 * \Delta v_2$$

The momentum changes are equal in magnitude and opposite in direction.

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Example 1

A 120 kg lineman moving west at 2 m/s tackles an 80 kg football fullback moving east at 8 m/s. After the collision, both players move east at 2 m/s. Draw a vector diagram in which the before- and after-collision momenta of each player is represented by a momentum vector. Label the magnitude of each momentum vector.

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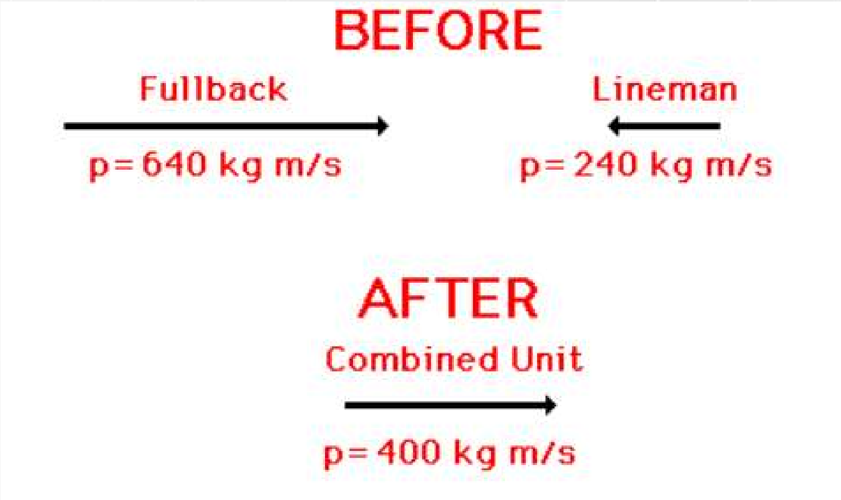

Example 2

A 62.1 kg male ice skater is facing a 42.8 kg female ice skater. They are at rest on the ice. They push off each other and move in opposite directions. The female skater moves backwards with a speed of 3.11 m/s. Determine the post-impulse speed of the male skater.

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Example 2

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Answer: **2.14 m/s**

	Momentum Before Explosion	Momentum After Explosion
Male Skater	0	(62.1 kg) • **v**
Female Skater	0	(42.8 kg) • (-3.11 m/s) = -133.11 kg•m/s
Total	0	0

$$(62.1\text{ kg}) \bullet \mathbf{v} + (-133.11\text{ kg}\bullet\text{m/s}) = 0$$

$$\mathbf{v} = (133.11\text{ kg}\bullet\text{m/s}) / (62.1\text{ kg})$$

$$\mathbf{v = 2.14\text{ m/s}}$$

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Work

In physics, work is related to the amount of energy transferred in or from a system by a force. It is a scalar-valued quantity with SI units of Joule.

Work can be represented in a number of ways. For the case where a body is moving in a steady direction, the work done by a constant force **F** acting parallel to the displacement Δx is defined as

$$W_F = F \cdot \Delta x.$$

the dot product of force and displacement is known as work.

When the force is not acting parallel to the body's direction of movement, the work done is defined as a dot product of the force and the displacement,

$$W_F = \vec{F} \cdot \Delta\vec{x} = ||\vec{F}|| \cdot ||\Delta\vec{x}|| \cdot \cos\phi.$$

Examples

1) A wagon displaces by a distance of 2 m while under the influence of an 80 N force directed parallel to the motion. How much work is performed by the force exerted on the wagon?

2) Suppose the same displacement of 2 m for the wagon while under the influence of an 80 N force 60o to the axis of the motion. How work is performed by the force exerted on the wagon in this case?

Examples

1) A wagon displaces by a distance of 2 m while under the influence of an 80 N force directed parallel to the motion. How much work is performed by the force exerted on the wagon?

$$W_F = F\Delta x = 80\ \mathrm{N} \cdot 2\ \mathrm{m} = 160\ \mathrm{N} \cdot \mathrm{m} = 160\ \mathrm{Joules}.$$

2) Suppose the same displacement of 2 m for the wagon while under the influence of an 80 N force 60^{o} to the axis of the motion. How work is performed by the force exerted on the wagon in this case?

$$W_F = F\Delta x\cos(60^\circ) = 80\ \mathrm{N} \cdot 2\ \mathrm{m} \cdot 0.5 = 80\ \mathrm{N} \cdot \mathrm{m} = 80\ \mathrm{Joules}$$

Power

Power is defined to be the rate at which work is performed, or the derivative of work over time. The SI unit for power is the watt. OR: Rate of doing work with respect to time is called power.

$$P = \frac{\mathrm{d}E}{\mathrm{d}t} = \frac{\mathrm{d}W}{\mathrm{d}t}$$

Example: A garage hoist steadily lifts a car up 2 meters in 15 seconds. Calculate the power delivered to the car. Use 1000 kg for the mass of the car.

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Example: A garage hoist steadily lifts a car up 2 meters in 15 seconds. Calculate the power delivered to the car. Use 1000 kg for the mass of the car.

First we need the work done, which requires the force necessary to lift the car against gravity:
F = mg = 1000 x 9.81 = 9810 N.
W = Fd = 9810N x 2m = 19620 Nm = 19620 J.
The power is P = W/t = 19620J / 15s = 1308 J/s = 1308 W.

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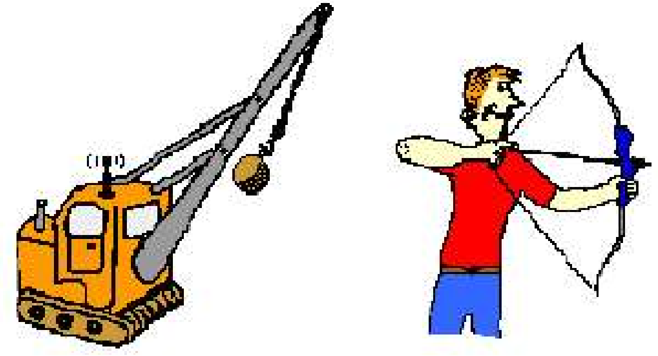
Potential energy

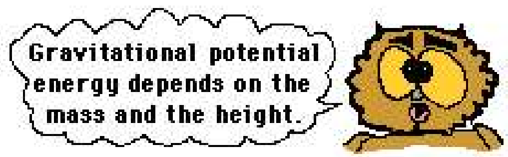
An object can store energy as the result of its position. **Potential energy** is the stored energy of position possessed by an object.



The massive ball of a demolition machine and the stretched bow possesses stored energy of position - potential energy.

PE_{grav} = mass • g • height

PE_{grav} = m *• g • h



Elastic potential energy is the energy stored in elastic materials as the result of their stretching or compressing.

$PE_{spring} = 0.5 \bullet k \bullet x^2$

where k = spring constant

x = amount of compression (relative to equilibrium position)

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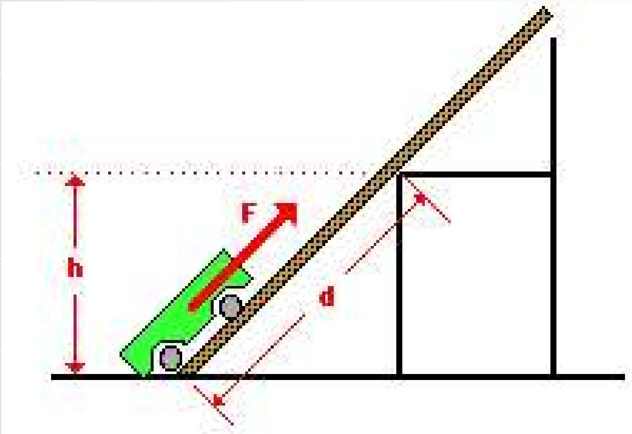
Example 1

A cart is loaded with a brick and pulled at constant speed along an inclined plane to the height of a seat-top. If the mass of the loaded cart is 3.0 kg and the height of the seat top is 0.45 meters, then what is the potential energy of the loaded cart at the height of the seat-top?



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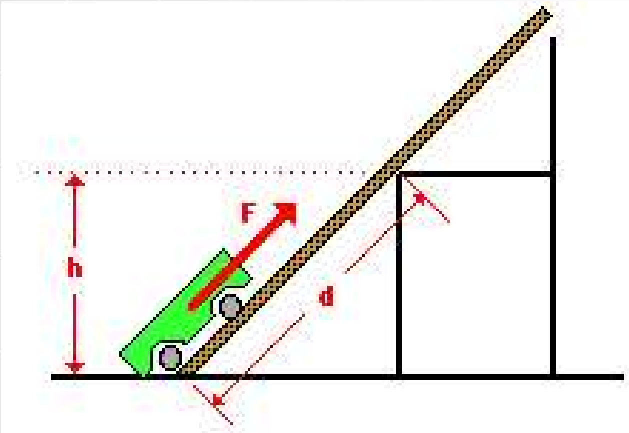

PE = m*g*h
PE = (3 kg) * (9.8 m/s/s) * (0.45 m)
PE = 13.2 J

Kinetic energy

Kinetic energy is the energy of motion. An object that has motion - whether it is vertical or horizontal motion - has kinetic energy.

$$KE = 0.5 \bullet m \bullet v^2$$

where m = mass of object

v = speed of object

Like work and potential energy, the standard metric unit of measurement for kinetic energy is the Joule. As might be implied by the above equation, 1 Joule is equivalent to 1 kg*(m/s)^2.

$$1\ \text{Joule} = 1\ \text{kg} \bullet m^2/s^2$$

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Example 1

1. Determine the kinetic energy of a 625-kg roller coaster car that is moving with a speed of 18.3 m/s.
2. If the roller coaster car in the above problem were moving with twice the speed, then what would be its new kinetic energy?
3. Missy Diwater, the former platform diver for the Ringling Brother's Circus, had a kinetic energy of 12 000 J just prior to hitting the bucket of water. If Missy's mass is 40 kg, then what is her speed?
4. A 900-kg compact car moving at 60 mi/hr has approximately 320 000 Joules of kinetic energy. Estimate its new kinetic energy if it is moving at 30 mi/hr.

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Example 1

1. Determine the kinetic energy of a 625-kg roller coaster car that is moving with a speed of 18.3 m/s.

$$KE = 0.5*m*v^2$$

$$KE = (0.5) * (625\ kg) * (18.3\ m/s)^2$$

$$\mathbf{KE = 1.05\ x10^5\ Joules}$$

2. If the roller coaster car in the above problem were moving with twice the speed, then what would be its new kinetic energy?

$$KE = 4 * (1.04653 \times 10^5\ J) = 4.19 \times 10^5\ Joules$$

3. Missy Diwater, the former platform diver for the Ringling Brother's Circus, had a kinetic energy of 12 000 J just prior to hitting the bucket of water. If Missy's mass is 40 kg, then what is her speed?

$$KE = 0.5*m*v^2$$

$$12\ 000\ J = (0.5) * (40\ kg) * v^2$$

$$300\ J = (0.5) * v^2$$

$$600\ J = v^2$$

$$\mathbf{v = 24.5\ m/s}$$

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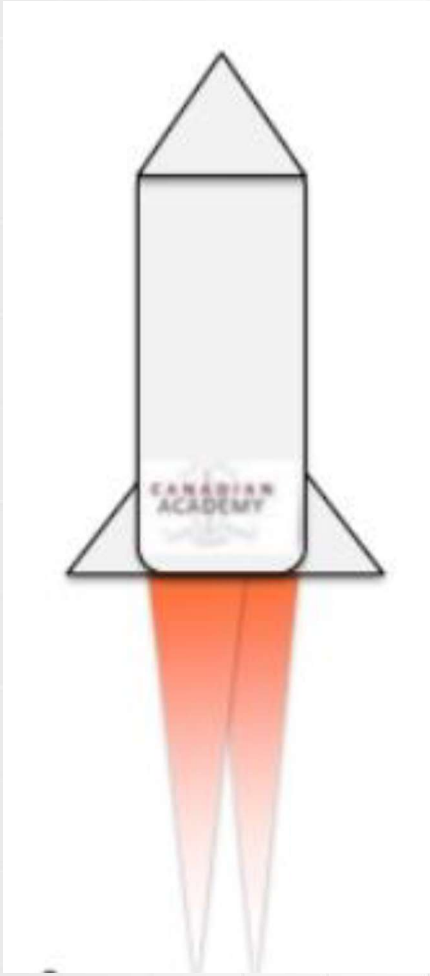
Motion phenomena - Dynamics

All right. So if you go to our website today, you will find I've assigned some problems and you should try to do them. They apply to this chapter. Then next week we'll do anothers problems connected with motion phenomena.



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Closer look at calendar

	FEBRUARY	MARCH					APRIL				MAY					JUNE			JULY	
MON	22	1	8	15	22	29	5	12 Mon O	19	26	3	10	17	24	31	7	14	21	28	5
TUE	23	2	9	16	23	30 Fri E	6	13	20	27	4	11	18	25	1	8	15	22	29	6
WED	24	3	10	17	24	31	7	14	21	28	5	12	19	26	2 Thu E	9	16	23	30	7
THU	25	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8
FRI	26	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9
SAT	27	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	3	10
SUN	28	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27	4	11
E - EVEN O - ODD	O	E	O	E	O	E	O	E	O	E	O	E	O	E	O	E	O	E	O	E

Lecture
Exercise
Revision/exam

Wednesday, 18:20 - 19:50
Friday, 18:20 - 19:50

Office hours:
Monday, 20:30 - 21:30
virtual room

Quizz

Kahoot link:
https://kahoot.it/challenge/04307658?challenge-id=459c69ba-0699-474d-ae7d-12916780bd23_1615325575325

Deadline: 17th March 2021, 18:00

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