Week of Sept 28

Experiment 1:
Measurement of Length and Mass

Week of Oct 5

Tutorial and Test 2

WileyPLUS Assignment 1 now available
Due Monday, October 5 at 11:00 pm
Chapters 2 & 3
The hint for Q3.22 is for a question from edition 7!!
Dr. Gericke will correct scores

PHYS 1020 Midterm Exam

Thursday, October 22
7 - 9 pm
Location(s) to be announced

Chapters 1 - 5

20 multiple choice questions
(see back of lab manual for old exams)
Formula sheet provided

Chapter 4: Forces and Newton's Laws

- Force, mass and Newton's three laws of motion
- Newton's law of gravity
- Normal, friction and tension forces.
- Apparent weight, free fall
- Conditions for equilibrium

Force and Mass

Forces have a magnitude and direction – forces are vectors

Types of force –

- Contact – example, a bat hitting a ball
- Noncontact or "action at a distance" – eg, gravitational force

Mass: two types –

- Inertial mass – what is the acceleration when a force is applied?
- Gravitational mass – what gravitational force acts on the mass?

Inertial and gravitational masses are equal

Newton's Laws of Motion

(1) Velocity is constant if a zero net force acts

$$\vec{a} = 0 \text{ if } \vec{F} = 0$$

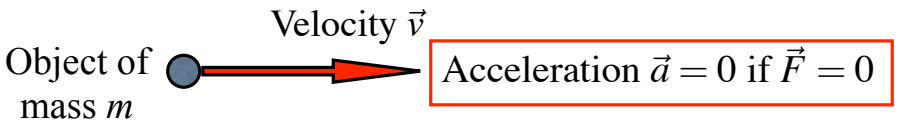
(2) Acceleration is proportional to the net force, inversely proportional to mass:

$$\vec{a} = \vec{F}/m, \quad \text{so } \vec{F} = m\vec{a}$$

The acceleration is in the same direction as the force.
Force in Newtons (N), mass in kg

(3) Action and reaction forces are equal in magnitude and opposite in direction

Newton's First Law (law of inertia)



The velocity is constant if a zero net force acts on the mass.

That is, if a number of forces act on the mass and their vector sum is zero:

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \ldots = 0$$

then the acceleration is zero and the mass remains at rest or has constant velocity

Newton's First Law

Was a revolutionary idea that objects continue to move if no force acts:

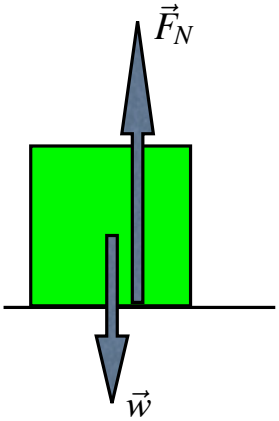
- experience shows that a force is needed to keep objects moving (friction)

- was believed that some cosmic force keeps the planets moving in their orbits, as they couldn't just keep moving by themselves.

In the absence of friction, objects continue to move at constant velocity if net force is otherwise zero.

If the net force, including the force due to friction, is zero, objects move at constant velocity.

Newton's First Law



A crate is at rest on the ground –

$\vec{v} = 0,\ \vec{a} = 0$

What forces act on the crate?

– the weight $\vec{w}$

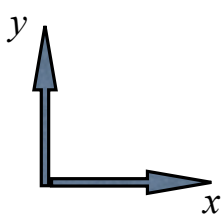
According to Newton's first law, there must be another force so the net force acting on the crate is zero –

–the normal force of the ground acting on the crate, $\vec{F}_N$

$\vec{F}_N + \vec{w} = 0 \quad \rightarrow \vec{F}_N = -\vec{w}$ so crate remains at rest

Inertial Reference Frame

Reference frame – a coordinate system, (*x, y, z*)



Can be defined anywhere –

- right here
- in your car...

An inertial reference frame is one that is **not** accelerated (moves at constant velocity, including zero velocity).

- the law of inertia (first law) applies in an inertial frame – objects at rest remain at rest if no net force acts on them.
- law of inertia does not apply in an accelerated (noninertial) frame.

Example: driving around a corner – velocity changes, force has to be applied *to keep objects from moving*. A noninertial frame.

Clicker Question: Focus on Concepts, Question 2

Which one of the following descriptions violates Newton's first law of motion?

A) A child is sitting in the back seat of a car and is not wearing a seat belt. The car is travelling forward, and the driver suddenly applies the brakes. The child flies forward against the rear side of the front seat.

B) A small suitcase is at the front of the overhead luggage compartment on an airplane. When the airplane begins its takeoff, the suitcase slides to the rear of the compartment.

C) A glass of water is sitting on a table in the dining car of a train. The train brakes as it nears the station, and the glass slides forward.

D) A rabbit's foot is hanging on a chain from the rearview mirror of a car. As the car accelerates, the rabbit's foot swings toward the windshield.

Newton's Second Law of Motion

Says what happens if the net force acting on a mass is not zero.

The mass accelerates:

Acceleration, $\vec{a} \propto \vec{F}_{net}$ ($\vec{F}_{net}$ = net force acting on the mass)

proportional to

Introduce the mass:

$$\vec{a} = \frac{\vec{F}_{net}}{m} \qquad \text{or } \vec{F}_{net} = m\vec{a}$$

Units: m in kilograms (kg) a in m/s^2 F_{net} in Newtons (N)

m is the "inertial mass", a measure of how difficult it is to accelerate an object.

Newton's Second Law of Motion

A catapult on an aircraft carrier accelerates a 13,300 kg plane from 0 to 56 m/s in 80 m. Find the net force acting on the plane.

$F_{net} = ma$ (acceleration along a straight line)

What is a?

$$v^2 = v_0^2 + 2ax$$

or, $56^2 = 0 + 2a \times 80$

So, $a = 56^2/160 = 19.6$ m/s^2

Therefore, $F_{net} = (13,300 \text{ kg}) \times (19.6 \text{ m/s}^2) = 261,000$ N

Clicker Question

All of the following, except one, cause the acceleration of an object to double. Which one is it?

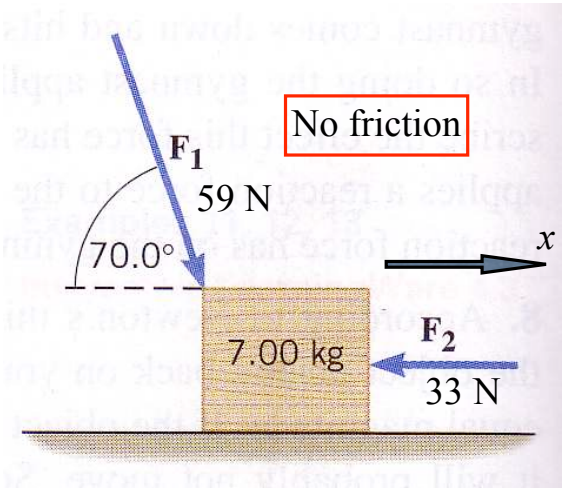
A) All forces acting on the object double

B) The net force acting on the object doubles

C) Both the net force acting on the object and the mass of the object double

D) The mass of the object is reduced by a factor of two

Newton's Second Law



4.11/11: What is the acceleration of the block in the horizontal direction?

Work out the components of forces in the x-direction.

$$F_x = F_{1x} + F_{2x}$$

$$= F_1 \cos 70^\circ - F_2 = -12.8 \text{ N}$$

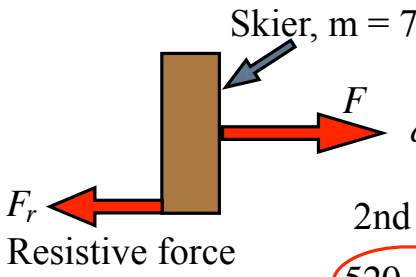
As $\vec{a} = \vec{F}/m$ then, $a_x = F_x/m = (-12.8 \text{ N})/(7 \text{ kg})$

$$= -1.83 \text{ m/s}^2$$

Newton's Second Law

A 75 kg water skier is pulled by a horizontal force of 520 N and has an acceleration of 2.4 m/s^2.

Assuming the resistive force from water and wind is constant, what force would be needed to pull the skier at constant velocity?



$a = 2.4$ m/s^2 when $F = 520$ N

2nd law: $F_{net} = ma$ (in horizontal direction)

$520 - F_r = 75 \times 2.4 = 180$ N So, $F_r = 340$ N

If the pulling force is reduced to 340 N, the net force acting on the skier will be zero and his/her speed will be constant.

Newton's Second Law

A special gun is used to launch objects into orbit around the earth.

It accelerates a 5 kg projectile to 4 × 10^3 m/s by applying a net force of 4.9 × 10^5 N.

How much time is needed to accelerate the projectile?

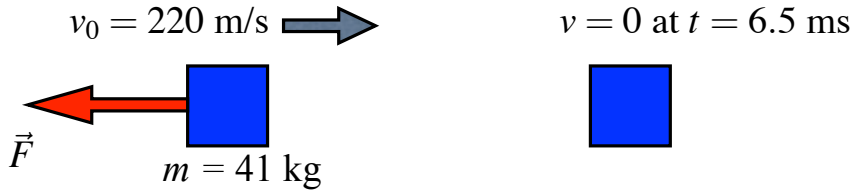
$$F = ma = m\Delta v/\Delta t$$

$$\text{So } \Delta t = m\Delta v/F = \frac{(5 \text{ kg}) \times (4 \times 10^3 \text{ m/s})}{4.9 \times 10^5 \text{ N}}$$

$$= 0.0408 \text{ s} = 41 \text{ ms}$$

Newton's Second Law

A 41 kg box is thrown at 220 m/s against a barrier. It is brought to a halt in 6.5 ms. What is the average net force that acts on the box?



$F = ma$, but what is a?

$v = v_0 + at$

$0 = (220 \text{ m/s}) + a \times (0.0065 \text{ s}) \rightarrow a = -220/0.0065 = -33,850 \text{ m/s}^2$

Then, $F = (41 \text{ kg}) \times (-33,850 \text{ m/s}^2) = -1.39 \times 10^6 \text{ N}$

Newton's Second Law

4:19/17: A 325 kg sailboat is sailing 15.0^0 north of east at 2.00 m/s. 30 s later, it is sailing 35^0 north of east at 4.00 m/s.

Three forces act on the boat:

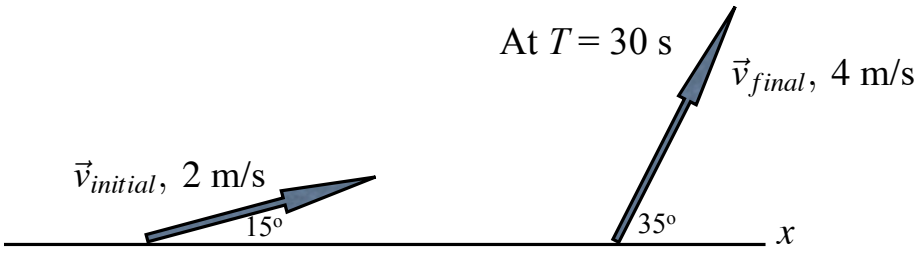
- 31 N at 15^o north of east $= \vec{F}_1$
- 23 N at 15^o south of west $= \vec{F}_2$
- $\vec{F}_w$, due to the wind $= \vec{F}_w$

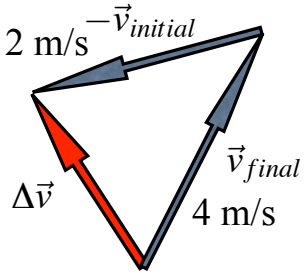
$$\vec{F}_1 + \vec{F}_2 + \vec{F}_w = m\vec{a}$$

Solve by working out the average acceleration, then calculate the missing force, F_w.

31 N at 15^0 north of east, 23 N at 15^0 south of west

Average acceleration, $\vec{a} = \dfrac{\vec{v}_{final} - \vec{v}_{initial}}{T} = \dfrac{\vec{v}_{final} + (-\vec{v}_{initial})}{T} = \dfrac{\Delta\vec{v}}{T}$





$\Delta v_x = 4\cos 35^\circ - 2\cos 15^\circ = +1.345$ m/s

$\Delta v_y = 4\sin 35^\circ - 2\sin 15^\circ = +1.777$ m/s

$a_x = (1.345 \text{ m/s})/(30 \text{ s}) = +0.0448 \text{ m/s}^2$

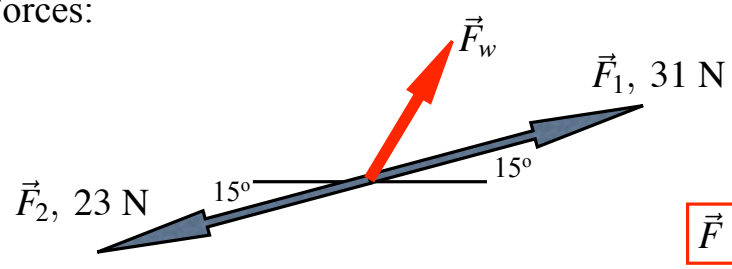
$a_y = (1.777 \text{ m/s})/(30 \text{ s}) = +0.0592 \text{ m/s}^2$

$a_x = +0.0448 \text{ m/s}^2,\ a_y = +0.0592 \text{ m/s}^2$

So, $F_x = ma_x = (325 \text{ kg}) \times (0.0448 \text{ m/s}^2) = 14.56$ N

$F_y = ma_y = (325 \text{ kg}) \times (0.0592 \text{ m/s}^2) = 19.24$ N

Forces:

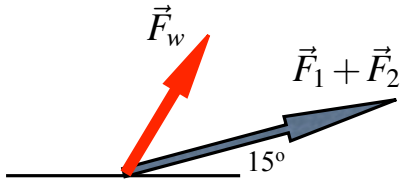


$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_w$

Simplification: $\vec{F}_2$ is directly opposite $\vec{F}_1$

So, $\vec{F}_1 + \vec{F}_2 = 31 - 23 = 8$ N at 15° north of east

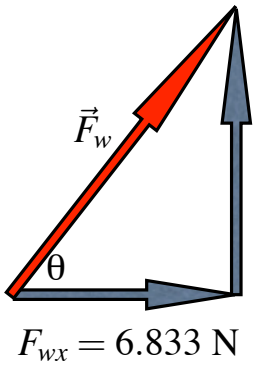
$F_x = 14.56$ N, $F_y = 19.24$ N



$\vec{F}_1 + \vec{F}_2$, 8 N, 15° north of east

$$F_x = (8\text{ N}) \times \cos 15^\circ + F_{wx} = 14.56\text{ N} \rightarrow F_{wx} = 6.833\text{ N}$$

$$F_y = (8\text{ N}) \times \sin 15^\circ + F_{wy} = 19.24\text{ N} \rightarrow F_{wy} = 17.169\text{ N}$$



$$F_w = \sqrt{F_{wx}^2 + F_{wy}^2} = 18.5\text{ N}$$

$$\tan\theta = 17.169/6.833$$

$$\rightarrow \theta = 68.3^\circ \text{ north of east}$$

Newton's Laws of Motion

(1) Velocity is constant if a zero net force acts

$$\vec{a} = 0 \text{ if } \vec{F} = 0$$

(2) Acceleration is proportional to the net force, inversely proportional to mass:

$$\vec{a} = \vec{F}/m, \quad \text{so } \vec{F} = m\vec{a}$$

The acceleration is in the same direction as the force

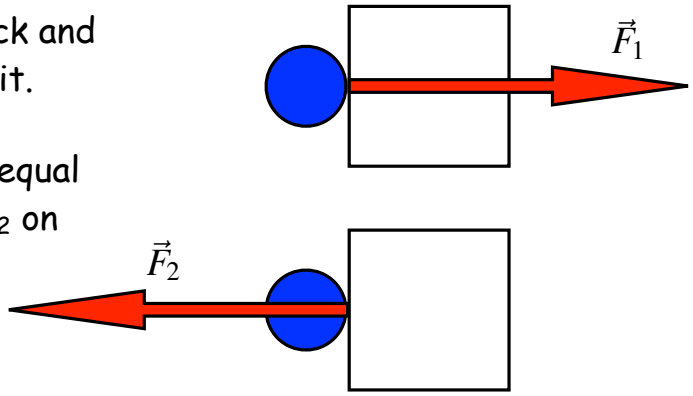
(3) Action and reaction forces are equal in magnitude and opposite in direction

Newton's Third Law of Motion

When you exert a force on an object, it exerts a force back on you (otherwise you fall over).

The ball hits the block and exerts a force F_1 on it.

The block exerts an equal and opposite force F_2 on the ball.

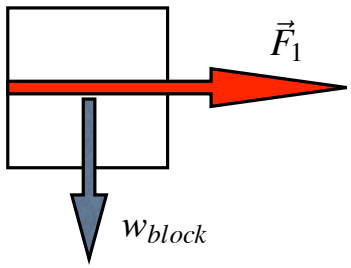


$$\vec{F}_2 = -\vec{F}_1$$

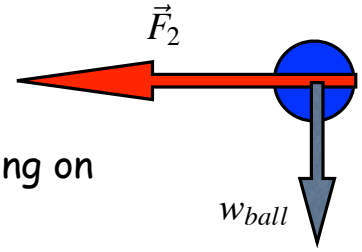
That is, action and reaction forces are equal and opposite

Action and reaction forces act on DIFFERENT OBJECTS!

All of the forces acting on the block



All of the forces acting on the ball



As action and reaction forces act on **different** objects, **the forces do not cancel**.

Clicker Question: Focus on Concepts, Question 8

Two ice skaters, Paul and Tom, are each holding on to opposite ends of the same rope. Each pulls the other toward him. The magnitude of Paul's acceleration is 1.25 times greater than the magnitude of Tom's acceleration. What is the ratio of Paul's mass to Tom's mass?

A) 0.25

B) 0.67

C) 0.50

D) 1.25

E) 0.80