

Students' Alternate Conceptions in Introductory Physics

The following is a list of preconceptions and misconceptions that high school physics teachers and college professors have recognized in their students.

0. OVERALL/KINEMATICS

- History has no place in science.
- Two objects side by side must have the same speed.
- Acceleration and velocity are always in the same direction.
- Velocity is a force.
- If velocity is zero, then acceleration must be zero too.

1. FALLING BODIES

- Heavier objects fall faster than light ones.
- Acceleration is the same as velocity.
- The acceleration of a falling object depends upon its mass.
- Freely falling bodies can only move downward.
- There is no gravity in a vacuum.
- Gravity only acts on things when they are falling.

2. INERTIA

- Forces are required for motion with constant velocity.
- Inertia deals with the state of motion (at rest or in motion).
- All objects can be moved with equal ease in the absence of gravity.
- All objects eventually stop moving when the force is removed.
- Inertia is the force that keeps objects in motion.
If two objects are both at rest, they have the same amount of inertia.
- Velocity is absolute and not dependent on the frame of reference.

3. NEWTON'S LAWS

- Action-reaction forces act on the same body.
- There is no connection between Newton's Laws and kinematics.
- The product of mass and acceleration, ma , is a force.
- Friction can't act in the direction of motion.
- The normal force on an object is equal to the weight of the object by the 3rd law.

- The normal force on an object always equals the weight of the object.
- Equilibrium means that all the forces on an object are equal.
- Equilibrium is a consequence of the 3rd law.
- Only animate things (people, animals) exert forces; passive ones (tables, floors) do not exert forces.
- Once an object is moving, heavier objects push more than lighter ones.
- Newton's 3rd law can be overcome by motion (such as by a jerking motion).
- A force applied by, say a hand, still acts on an object after the object leaves the hand.

4. GRAVITATION

- The Moon is not falling.
- The Moon is not in free fall.
- The force that acts on apple is not the same as the force that acts on the Moon.
- The gravitational force is the same on all falling bodies.
- There are no gravitational forces in space.
- The gravitational force acting on the Space Shuttle is nearly zero.
- The gravitational force acts on one mass at a time.
- Moon stays in orbit because the gravitational force on it is balanced by the centrifugal force acting on it.
- Weightlessness means there is no gravity.
- The Earth's spinning motion causes gravity.

5. CONSERVATION OF ENERGY

- Energy gets used up or runs out.
- Something not moving can't have any energy.
- A force acting on an object does work even if the object does not move.
- Energy is destroyed in transformations from one type to another.
- Energy can be recycled.
- Gravitational potential energy is the only type of potential energy.
- When an object is released to fall, the gravitational potential energy immediately becomes all kinetic energy.
- Energy is not related to Newton's laws.
- Energy is a force.

6. CONSERVATION OF MOMENTUM

- Momentum is not a vector.
- Conservation of momentum applies only to collisions.
- Momentum is the same as force.
- Moving masses in the absence of gravity do not have momentum.
- The center of mass of an object must be inside the object.
- Center of mass is always the same as the center of gravity.
- Momentum is not conserved in collisions with "immovable" objects
- Momentum and kinetic energy are the same.

7. CIRCULAR MOTION

- Circular motion does not require a force.
- Centrifugal forces are real.
- An object moving in circle with constant speed has no acceleration.
- An object moving in a circle will continue in circular motion when released.
- An object in circular motion will fly out radially when released.

8. ANGULAR MOMENTUM

- Any force acting on an object will produce a torque.
- Objects moving in a straight line can not have angular momentum.
- Torque is the same as force and is in same direction.
- Angular momentum is not a vector.
- The direction of angular momentum is in direction of linear momentum.

9. KEPLER'S LAWS

- Planetary orbits are circles.
- The speed of a planet in orbit never changes.
- An object must be at both foci of an elliptical orbit.
- All the planets move in their orbits with the same speed.
- No work is done on orbiting planets by the sun.
- The orbits of the planets lie precisely in the same plane.
- All the planets revolve about sun with the same period.
- Revolution is the same as rotation.

10. NAVIGATING IN SPACE

- Spacecraft travel in straight lines from one planet to another.
- Spacecraft can be launched anytime to travel from one planet to another.
- Spacecraft are not affected by the sun.
- Motion relative to Earth is same as motion relative to the sun.
- Jets can fly in space.
- Spacecraft in orbit about Earth don't follow a sinusoidal path relative to the sun.
- Rockets need something (air) to push against.

11. CURVED SPACE & BLACK HOLES

- Space is not something.
- Black holes are big.
- Light always travels in straight lines.
- Black holes exert a greater gravitational force on distant objects than the star from which it was formed.
- Observations made in a gravitational field are different than those made in a system undergoing constant acceleration.
- Things in space make sounds.
- If the Sun were to become a black hole, the Earth would get sucked into it.

12. TEMPERATURE AND GAS LAWS

- A cold body contains no heat.
- There is no limit on the lowest temperature.
- At absolute zero motion of every part of an object stops.
- An object has no mass at absolute zero.
- Sweaters will make you warmer.
- Cold can flow.
- Gases can be compressed to zero volume.
- Heat and temperature are the same thing.
- Heat and cold flow like liquids.
- Pressure is the same as force.
- Skin is a good thermometer.

13. HARMONIC MOTION

- The period of oscillation depends on the amplitude.
- The restoring force is constant at all points in the oscillation.
- The heavier a pendulum bob, the shorter its period.
- All pendulum motion is perfect simple harmonic motion, for any initial angle.
- Harmonic oscillators go forever.
- A pendulum accelerates through lowest point of its swing.
- Amplitude of oscillations is measured peak-to-peak.
- The acceleration is zero at the end points of the motion of a pendulum.

14. WAVES

- Waves transport matter.
- There must be a medium for a wave to travel through.
- Waves do not have energy.
- All waves travel the same way.
- Frequency is connected to loudness for all amplitudes.
- Big waves travel faster than small waves in the same medium.
- Different colours of light are different types of waves.
- Pitch is related to intensity.

15. WAVE NATURE OF LIGHT

- Light just is and has no origin.
- Light is a particle.
- Light is a mixture of particles and waves.
- Light waves and radio waves are not the same thing.
- In refraction, the characteristics of light change.
- The speed of light never changes.
- Rays and wave fronts are the same thing.
- There is no interaction between light and matter.
- The addition of all colours of light yields black.
- Double slit interference shows light wave crest and troughs.
- Light exits in the crest of a wave and dark in the trough.
- In refraction, the frequency (colour) of light changes.
- Refraction is the bending of waves.

16. MICHELSON-MORLEY EXPERIMENT

- A null result means experiment was a failure.
- The aether exists because something must transmit light.
- Relativistic effects (length contraction) is the reason why no difference in the speed of light was observed.

17. SPECIAL RELATIVITY

- Velocities for light are additive like for particles.
- Postulates cannot be used to develop a theory.
- Length, mass, and time changes are just apparent.
- Time is absolute.
- Length and time only change for one observer.
- Time dilation refers to 2 clocks in 2 different frames.
- Time dilation and length contractions have not been proven in experiments.
- There exists a preferred frame of reference in the universe.
- A mass moving at the speed of light becomes energy.
- Mass is absolute, that is, it has the same value in all reference frames.

18. FUNDAMENTAL FORCES

- All forces have to be contact forces.
- The gravitational force is the only natural force.
- All forces are unique, so none are fundamental.
- The gravitational force is the strongest force.
- The gravitational and electromagnetic forces are more fundamental than the strong and weak nuclear forces.
- Electricity and magnetism are two different forces.
- The weak and strong nuclear forces are really the same force.
- All forces are equally effective over all ranges.
- None of the fundamental forces have been proven to exist.
- The electrical force is the same as the gravitational force.

19. ELECTRIC FIELDS AND FORCES

- A moving charge will always follow a field line as it accelerates.
- If a charge is not on a field line, it feels no force.
- Field lines are real.
- Coulomb's law applies to charge systems consisting of something other than point charges.
- A charged body has only one type of charge.
- The electric field and force are the same thing and in the same direction.
- Field lines can begin/end anywhere.
- There are a finite number of field lines.
- Fields don't exist unless there is something to detect them.
- Forces at a point exist without a charge there.
- Field lines are paths of a charges motion.
- The electric force is the same as the gravitational force.
- Field lines actually radiate from positive to negative charges and convey motion.
- Field lines exist only in two dimensions.

20. MILLIKAN EXPERIMENT

- Charge is continuous and can occur any amount.
- An electron is pure negative charge with no mass.
- Oil drops are electrons.
- The scientific method is pure and absolute.
- Scientists always stumble on discoveries.
- Millikan measured the mass of the electron.

21. EQUIPOTENTIALS AND FIELDS

- Voltage flows through a circuit.
- There is no connection between voltage and electric field.
- Voltage is energy.
- Equipotential means equal field or uniform field.
- High voltage by itself is dangerous.
- It takes work to move a real charge on an equipotential.
- Charges move by themselves.
- Sparks occur when an electric field pulls charges apart.

22. POTENTIAL DIFFERENCE AND CAPACITANCE

- A capacitor and a battery operate on the same principle.
- A potential difference is only on plates of a capacitor and not in region between.

- Charge flows through a dielectric, such as glass.
- Designations of (+) and (-) are absolute.
- $Q = CV$ is a basic conceptual law.
- No work is required to charge a capacitor.
- A capacitor requires two separate pieces.
- There is a net charge on a capacitor.
- The capacitance of a capacitor depends on the amount of charge.
- A positive charged capacitor plate only has positive charges on it.
- Charges flow through a capacitor.

23. SIMPLE DC CIRCUITS

- Resistors consume charge.
- Electrons move quickly (near the speed of light) through a circuit.
- Charges slow down as they go through a resistor.
- Current is the same thing as voltage.
- There is no current between the terminals of a battery.
- The bigger the container, the larger the resistance.
- A circuit does not have form a closed loop for current to flow.
- Current gets "used up" as it flows through a circuit.
- A conductor has no resistance.
- The resistance of a parallel combination is larger than the largest resistance.
- Current is an excess charge.
- Charges that flow in circuit are from the battery.
- The bigger the battery, the more voltage.
- Power and energy are the same thing.
- Batteries create energy out of nothing.

24. MAGNETIC FIELDS

- North and south magnetic poles are the same as positive and negative charges.
- Magnetic field lines start at one pole and end at the other.
- Poles can be isolated.
- Flux is the same as field lines.
- Flux is actually the flow of the magnetic field.
- Magnetic fields are the same as electric fields.
- Charges at rest can experience magnetic forces.
- Magnetic fields from magnets are not caused by moving charges.
- Magnetic fields are not 3-dimensional.
- Magnetic field lines hold you on the Earth.
- Charges, when released, will move toward the poles of a magnet.

25. ELECTROMAGNETIC INDUCTION

- Generating electricity requires no work.
- When generating electricity only the magnet can move.
- Voltage can only be induced in a closed circuit.
- Magnetic flux, rather than change of magnetic flux, causes an induced emf.
- All electric fields must start on (+) and end on (-) charges.
- Water in dams causes electricity.

26. ALTERNATING CURRENT

- Charges move all the way around a circuit and all the way back.
- Voltage and current remain constant as in DC circuits.
- Energy is not lost in a transformer.
- A step-up transformer gives you something more for less input.
- Transformers can be used to change DC voltages.
- Electrical companies supply the electrons for your household current.

27. WAVE-PARTICLE DUALITY

- Light is one or the other--a particle or a wave—only.
- Light can be a particle at one point in time and a wave at another point in time.
- Particles can't have wave properties.
- Waves can't have particle properties.
- The position of a particle always can be exactly known.
- A photon is a particle with a wave inside.
- Photons of higher frequency are bigger than photons of lower frequency.
- All photons have the same energy.
- Intensity means that the amplitude of a photon is bigger.
- The Uncertainty Principle results from the limits of measuring devices.
- Laser beams are always visible by themselves.
- Sometimes you feel like a wave, sometimes you don't.

28. MODELS OF THE ATOM

- There is only one correct model of the atom.
- Electrons in an atom orbit nuclei like planets orbit the sun.
- Electron clouds are pictures of orbits.
- Electrons can be in any orbit they wish.
- Hydrogen is a typical atom.
- The wave function describes the trajectory of an electron.
- Electrons are physically larger than protons.
- Electrons and protons are the only fundamental particles.
- Physicists currently have the "right" model of the atom.
- Atoms can disappear (decay).