

PHYSICS CONTENT FACTS

The following is a list of facts related to the course of Physics. A deep foundation of factual knowledge is important; however, students need to understand facts and ideas in the context of the conceptual framework. This list is not intended to provide a comprehensive review for State and National Assessments. Its purpose is to provide a highlight of the factual material covered in Physics. This list is not all inclusive, be sure to check Nevada State Standards and your district syllabi.

MECHANICS

- Scalars are quantities which are fully described by a magnitude only
- Speed, Distance, Time, Mass, Charge, and Energy (joules) are examples of scalar quantities
- Vectors are quantities which are fully described by a magnitude and a direction
- Velocity, Displacement, Momentum, Force, and Acceleration are examples of vector quantities
- The resultant is a vector representing the sum of two or more vectors
 - At 0° , two vectors have a resultant equal to the sum of their magnitudes
 - At 180° , two vectors have a resultant equal to the difference of their magnitudes
 - From the difference to the sum, the total range of possible resultant magnitudes is determined
- The magnitude of two vectors, at right angles, can be calculated using the Pythagorean theorem ($a^2 = b^2 + c^2$)
- For two vectors at right angles, the direction of a resultant can be found using the tangent function
$$\tan \theta = \frac{\text{Opposite}}{\text{Adjacent}}$$
- The equilibrant is a vector that is equal in magnitude, but opposite in direction to the resultant vector
- Displacement is a change in position in a certain direction (not the total distance traveled)
- The velocity of an object is its speed in a given direction
- The average velocity of an object during some time interval is equal to the displacement of the object divided by the time interval
$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$
- The slope of a **position-time** graph is velocity
- The average acceleration of an object during a certain time interval is equal to the change in the object's velocity divided by the time interval
$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$
- The slope of the **velocity-time** graph is acceleration
- Objects in free-fall experience constant acceleration directed toward the center of Earth
- Free-fall acceleration is the same for all objects at the earth's surface, regardless of mass ($a=g= 9.8\text{m/s}^2$)
- Projectiles follow parabolic trajectories
- Ignoring air resistance, a launch angle of 45° produces the greatest range for a projectile

- At the top of a projectile's path, the vertical velocity is zero, and the acceleration is -9.8 m/s^2
- Projectiles have constant horizontal velocity (ignoring air resistance)
- Projectiles have constant downward free-fall acceleration (vertical velocity)
- Mass is the quantity of inertia – the greater the mass of an object, the greater its inertia (resistance to change)
- Net forces cause accelerations (constant velocity means the net force is zero and acceleration is zero)
- The acceleration of an object is directly proportional to the net external force acting on the object and inversely proportional to the object's mass. $a = \frac{\Sigma F}{m}$ or more commonly expressed $\Sigma F = ma$
- Forces ALWAYS exist in pairs
- Mass is not weight!
- Weight of an object is the force on the object due to gravity and is equal to the mass of the object times the acceleration due to gravity $w = mg$
- Weight (the gravitational attraction of the Earth) decreases rapidly as you move away from the earth by distance (r) squared $F = G \frac{m_1 m_2}{r^2}$
- Centripetal force and centripetal acceleration vectors are directed toward the center of the circle (or curve), while the velocity vector is tangent to the circle $F_c = \frac{mv^2}{r}$ $a_c = \frac{v^2}{r}$
- Friction is the resistive force that opposes the relative motion of two surfaces in contact
- The force of friction is proportional to the normal force, and depends on the surfaces in contact $F_{friction} = \mu F_{normal}$

ENERGY

- Mechanical energy is the sum of the potential and kinetic energy
- Gravitational potential energy (due to an object's vertical position) increases as height increases $PE = mgh$
- Kinetic energy (energy of motion) changes when velocity changes $KE = \frac{1}{2}mv^2$
- Mechanical energy (sum of PE + KE) does not change for a free falling mass or a swinging pendulum (ignoring air resistance/friction)
- Work occurs when a force causes something to move or change $W = Fd$
- The net work done by a force acting on an object is equal to the change in the total energy of the object

- Power is the rate at which energy is transferred $P = \frac{W}{\Delta t}$
- Momentum is a vector quantity defined as the product of an object's mass and velocity $p = mv$
- Impulse (for a constant external force) is the product of the force and the time interval over which it acts on an object $j = F\Delta t$
- Impulse = Change in momentum $F\Delta t = \Delta p$ or $F\Delta t = m\Delta v$
- Momentum is conserved in all collision systems – “The total of all objects interacting with one another remains constant regardless of the nature of the forces between the objects”

INTERNAL ENERGY

- Temperature is a measure of the average kinetic energy of the molecules of a substance
- Internal energy is the sum of kinetic and potential energies within the substance
- Specific heat capacity is the quantity of energy needed to raise the temperature of 1kg of a substance by 1°C at constant pressure $Q = mc\Delta t$
- Phase changes are due to internal potential energy changes $Q_f = mH_f$ $Q_v = mH_v$
- Thermal equilibrium is the condition in which the temperature of two objects in physical contact with each other is the same
- Internal energy always flows, in nature, from an object of higher temperature to one of lower temperature. This flow of internal energy is called heat
- When heat flows into a system, it leads to an increase in internal energy plus external work done by the system $\Delta E = \Delta Q + \Delta W$
- Entropy is a measure of the disorder of a system (increasing disorder reduces the energy available for work)
- The total entropy (disorder) of the universe is always increasing

FLUIDS

- Pressure is the magnitude of the force on a surface per unit area $P = \frac{F}{A}$
- Pressure within a fluid increases with depth $P = \rho gh$
- Pascal's Principle states that pressure applied to a fluid in a closed container is transmitted equally to every point of the fluid and to the walls of the container $P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$

- Archimedes' Principle states that any object completely or partially submerged in a fluid experiences an upward buoyant force equal to the magnitude of the weight of the fluid displaced by the object

$$F_b = F_g(\text{displaced fluid}) = m_f g \quad \text{or} \quad F_{net} = (\rho_f V_f - \rho_o V_o) g$$

- Bernoulli's Principle states that the pressure within a fluid decreases as the fluid's velocity increases

WAVES

- The period of a simple pendulum depends only on the string length and the free-fall acceleration

$$T = 2\pi \sqrt{\frac{L}{|g|}}$$

- Period is the time to complete one cycle, measured in seconds
- Frequency is the number of cycles per second, measured in hertz
- Frequency is the inverse of period $f = \frac{1}{T}$ $T = \frac{1}{f}$
- Waves transfer energy only (wave particles vibrate around equilibrium position as the wave travels)
- Transverse waves; vibrations are perpendicular to the direction of wave motion
- Longitudinal waves; vibrations are parallel to the direction of wave motion
- Wave speed equals frequency times wavelength $v = f\lambda$
- Sound waves are longitudinal, mechanical waves
- The speed of sound depends on properties of the medium through which sound travels
- The frequency of a sound wave determines its pitch
- The amplitude and frequency of a sound wave determines its intensity (greater amplitude and frequency = greater intensity)
- For a uniform medium, as the frequency of a wave increases its wavelength decreases
- The Doppler effect is an apparent frequency shift that results from relative motion between the source of the waves and an observer (higher pitch = approaching, lower pitch = receding)
- The electromagnetic spectrum (lowest to highest frequency; radio, microwave, infrared, visible light, ultraviolet, x-ray, and gamma ray) consists of oscillating electric and magnetic fields of different wavelengths
- The speed (**c**) of all types of electromagnetic waves is 3.0×10^8 m/s in a vacuum (speed of radio waves = speed of visible light = speed of gamma rays)
- Light slows down, bends toward the normal and has a shorter wavelength when it enters a higher (n) value medium
- Blue light has a shorter wavelength and a higher frequency than red light – R O Y G B I V

- A prism produces a rainbow from white light by dispersion (red bends the least because it slows the least)
- Electromagnetic waves are transverse, and can be polarized
- Constructive interference occurs when two waves are zero degrees (0°) out of phase or a whole number of wavelengths (360°) out of phase
- Wave behavior is proven by diffraction, interference and the polarization of light
- Coherent light waves have the same phase, frequency, and direction
- Light intensity (and sound) decreases by the square of the distance from the source $E = \frac{P}{4\pi r^2}$

OPTICS

- The index of refraction for a transparent substance is the ratio of the speed of light in a vacuum to the speed of light in that substance $n_s = \frac{c}{v_s}$
- Snell's Law (Law of Refraction) is used to determine how much refraction occurs when a ray of light passes from one medium to another $n_1 \sin \theta_1 = n_2 \sin \theta_2$
- Diffuse reflection occurs from dull/irregular surfaces while regular reflection occurs from mirror type surfaces
- Real images are always inverted
- Virtual images are always upright
- Converging devices are convex lenses and concave mirrors
- Diverging devices are concave lenses and convex mirrors
- Diverging lens (concave) produce only small virtual images
- Flat mirrors form virtual images that are the same distance from the mirror's surface as the object is
- The mirror equation relates object distance, image distance, and focal length $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$
- The magnification equation relates image height or distance to object height or distance $M = \frac{h_i}{h_o}$
- Light rays bend away from the normal as they gain speed and a longer wavelength by entering a slower index of refraction (n) medium {frequency remains constant}
- The focal length of a converging lens (convex) is shorter with a higher index of refraction (n) value lens or if blue light replaces red

ELECTRICITY

- A coulomb is a unit of charge ($1\text{C} = 6.3 \times 10^{18}$ electrons), an amp is a unit of current [coulomb/sec] and a volt is a unit of potential difference [joule/coulomb]
- The electric force between two objects depends directly on the object's charge and decreases rapidly as the charges separate $F = k \frac{q_1 q_2}{r^2}$
- Short fat cold wires make the best conductors
- An electron has a negative elementary charge. A proton has a positive elementary charge. One elementary charge = 1.6×10^{-19} coulombs
- Adding a resistor in series increases the total resistance of a circuit
- Adding a resistor in parallel decreases the total resistance of a circuit
- All resistors in series have equal current (I)
- All resistors in parallel have equal voltage (V)
- The current in a circuit is directly proportional to the voltage across the circuit and inversely proportional to the resistance of the circuit $I = \frac{V}{R}$
- If two charged spheres touch each other, then add the charges and divide by two to find the final charge on each sphere (charge flows until there is no difference in charge)
- Insulators do not contain free electrons
- Ionized gases conduct electric current using positive ions, negative ions, and electrons
- Electric fields all point in the direction of the force on a positive test charge
- Electric fields between two parallel plates are uniform in strength (except at the edges)
- Millikan determined the charge on a single electron using his famous oil-drop experiment
- All charge changes result from the **movement of electrons** not protons (an object becomes positive by losing electrons)

MAGNETISM

- The direction of a magnetic field is defined by the direction a compass needle points
- Magnetic fields point from the north to the south outside the magnet and south to north inside the magnet
- Magnetic flux is measured in webers
- Left hands are for negative charges and right hands are for positive charges

- The first hand rule deals with the B-field around a current bearing wire, the third hand rule looks at the force on charges moving in a B-field, and the second hand rule is redundant
- Solenoids are stronger with more current or more wire turns or adding a soft iron core
- A wire moving through a magnetic field induces an electric current through the wire

$$emf = -N \frac{\Delta[AB(\cos \theta)]}{\Delta t}$$

- A charged particle moving through a magnetic field experiences a deflecting force

$$F_{magnetic} = qVB$$

MODERN PHYSICS

- Light behaves both like a wave and as a particle
- The particle behavior of light is proven by the photoelectric effect
- A photon is a particle of light {energy packet}
- Large objects have very short wavelengths when moving and thus can not be observed behaving as a wave (DeBroglie Waves)
- All electromagnetic waves originate from accelerating charged particles
- The frequency of a light wave determines its energy $E = hf$
- The lowest energy state of a atom is called the ground state
- Increasing light frequency increases the kinetic energy of the emitted photo-electrons
- As the threshold frequency increase for a photo-cell (photo emissive material) the work function also increases
- Increasing light intensity increases the number of emitted photo-electrons but not their KE
- All nuclei weigh less than their parts. This mass defect is converted into binding energy ($E=mc^2$)
- Geiger counters, photographic plates, cloud and bubble chambers are all used to detect or observe radiation
- Rutherford discovered the positive nucleus using his famous gold-foil experiment
- Nuclear fusion occurs when smaller atomic nuclei unite to make a larger atom
- Nuclear fission occurs when a neutron causes a large atomic nuclei to be split into smaller size atoms, producing extra neutrons
- Radioactive half-lives can not be changed by heat or pressure