

Annotations to Automotive Technology/Science Concepts Chart

The "Science Principles/Concepts" matrix on the previous pages was developed by Dennis Mattoon, a high school automotive technology teacher. At his school, students received four elective credits for completing the auto curriculum. However, Dennis believed that based on the science information he included in his lessons, his students deserved to receive one science credit after completing the auto curriculum (at the student's option), plus three elective credits. He was successful in making his case.

Please note that at this time, not all automotive technology courses incorporate "hard science" in the lessons, and few physics and chemistry teachers strive to put automotive examples into their lessons. Ultimately, as "contextual learning" takes hold, such an integrated approach will become common. Even today, the fact is: There's real science in automotive technology, and in automotive service, as well.

BERNOULLI'S PRINCIPLE, also known as the venturi effect, describes the changes in speed and pressure to a fluid as it passes through an hour glass-shaped passage. This principle causes "lift" as air passes over an aircraft wing and causes fuel to flow into the venturi of a carburetor, where it mixes with air.

MOLECULAR THEORY describes the structure of the molecule and its component parts: atoms and their protons, neutrons, and electrons. This is illustrated by the power enhancing gas called nitrous oxide which is used in many off-road and racing vehicles. This gas carries additional oxygen atoms into the combustion chamber which can then react with additional fuel thus providing more heat and, ultimately, more horsepower.

STATES OF MATTER describe the relationship between solids, liquids, and gases. These "states" and the temperatures at which substances change "state" are illustrated well by engine coolant. We add "antifreeze" to purposely alter the temperatures at which water freezes as well as boils. Improper ratios of antifreeze to water can cause "boilovers" and "frozen blocks". Gasoline must also transition

from the liquid state to the vapor state to burn efficiently in the piston engine.

BOYLE'S LAW describes the relationship between the pressure and volume of a given amount of a gaseous substance. It is exemplified by the pressure rise in a sealed cooling system as the liquid coolant expands with heat and creates a decreasing air space above the coolant. It is also illustrated by the pressure increase and volume decrease of the air/fuel mixture during the compression stroke of the engine.

HEAT OF FUSION is the energy required to melt a solid substance. This energy comes into play with the "welding" of metals. An example of this is the melting and fusion of aluminum pistons to piston rings or the engine block in an automobile engine. This can occur if engine temperatures rise uncontrollably due to a faulty cooling system or loss of engine oil.

CAPILLARY ACTION describes the ability of liquids to flow or move due to surface tension. Commonly referred to as "wicking", it can be illustrated with the action of lubricating oil in the engine and its ability to flow between engine parts without external force or pressure.

HYDRODYNAMICS describe the action or motion of fluid substances in motion. Waves on a beach or the wake behind a boat are examples of hydrodynamic action. This principal can also be illustrated as lubricating oil is forced between the engine crankshaft and the main crankshaft bearing shells. This oil, reacting to both lube system pressure and the rotational and radial forces of the crankshaft journal, forms a "wedge" that is designed to prevent all metal to metal contact.

CHARLES'S LAW, closely related to Boyle's Law, also describes the relationships between pressure, temperature, and volume of gaseous substances. Charles's Law can be exemplified by the various pressure, volume, and temperature changes encountered by automotive refrigerant as it is pumped through the air conditioning system.

DEALERSHIP TOUR: EDUCATOR'S HANDOUT

INCANDESCENCE describes the ability of some substances to be heated to the point at which they begin to give off light. This can be illustrated by the glow of a tungsten filament in a light bulb as current is forced through the filament. It can also be seen clearly as racing engine turbochargers are heated, by exhaust, to a red glow.

GALVANIC ACTION describes the movement of electrons or the flow of electricity as a result of chemical action or chemical potential. This movement of electrons, (for instance, among the lead plate, the lead peroxide plate and the sulfuric acid/electrolyte of a lead acid battery) is the primary source of electrical current on vehicles. In some cases galvanic action (also known as electrolysis) is an unintended and harmful side effect as is the case with various metals in contact with engine coolant and the metals' resultant corrosion.

INCLINED PLANE is one of the "simple machines" that form the foundation of our technological society. When a refrigerator is moved up a ramp, over a door threshold, or a car is driven up an overpass ramp and down the other side, an inclined plane is being used. The inclined plane is also useful when wrapped around a cylinder to form a spiral. This is the basic concept of a screw thread—probably the single most important fastening concept known to man.

CONDENSATION describes the change of state from gas to liquid. One of the best examples is when liquid gasoline that has been changed to gasoline vapor in the carburetor begins to condense, or change back into a liquid, as the gasoline vapor comes into contact with the cold surfaces of the intake manifold. This problem, encountered with not yet warmed-up engines, is the principal cause for the addition of a choke system to the carburetor.

COHESION OF LIQUIDS describes the attractive properties that a liquid's molecules exert on one another. This phenomenon is extremely important in the formation of engine lubricating oils and other liquid lubricants. Most of these lubricants must create an unbroken barrier or layer of oil between moving metal parts. It is the liquid's cohesive properties, often enhanced through the addition of chemical additives, that is chiefly responsible for maintaining the integrity of this layer.

ADHESION OF LIQUIDS describes a liquid's ability to adhere or "cling" to the parts it is designed to lubricate. Many of these parts are moving or rotating at high speeds. Simple lubricants with low adhesive qualities would be thrown off the moving part. Chemical additives are often mixed with the base lubricant to increase its adhesive qualities. Engine oil must adhere well to the camshaft of an engine or, for instance, the chain of a chainsaw, in order to not be thrown off these "high speed" parts.

INDUCTIVE REACTANCE is a measure of the opposition to the flow of an Alternating Current by an electrical inductor. Alternating current (AC) is used in selected situations in the automobile such as the alternator and certain engine and speed sensors. When AC current passes through coils of wire called a winding or coil, the changing current causes a reverse or counter electromotive force (CEMF) which "fights" or "bucks" the initial current flow. This "back pressure" creates opposition to AC current flow and must be considered when designing AC electrical systems.

ELECTRICAL RESISTANCE is the property of all materials to resist, to a greater or lesser extent, the flow of electrons (current). Resistance is usually measured in Ohms (Ω) and is responsible for the conversion of electricity into heat and light. Resistance is one of the three main factors of all electrical circuits. Bigger electrical conductors have less resistance and therefore can flow more current. One look at the battery cables on a vehicle exemplify this rule.

VOLUMETRIC EFFICIENCY is a measure of an engine's ability to intake and exhaust or "breathe". By measuring the dimensions of the piston cylinders and the speed of the pistons one could determine, theoretically, the total intake and exhaust flow of any engine. Volumetric efficiency is seldom 100% because there are often restrictions to air flow on the intake or exhaust "sides" of the engine. The design of an air cleaner, or an exhaust muffler, have a definite effect on volumetric efficiency.

ELASTICITY refers to the ability of material to "give" or flex under stress, but still be able to return to its original shape. The springs on a vehicle's suspension are a prime example of elasticity. They flex repeatedly to absorb road shock and will continue to do so until they are "overloaded". If a vehicle is overloaded, the springs may be stressed to their "yield

point" and a permanent distortion or bend may become apparent or they may simply fracture due to the overload condition.

INERTIA / MOMENTUM is the tendency of an object at rest to remain at rest or an object in motion to remain in motion. Automobiles provide countless countless examples of this "Newton's First Law of Motion". Two examples would be the use of torque multiplication (first gear in a manual transmission) to accelerate the parked car (mass at rest) to road speed (mass in motion). Once the vehicle is moving, much less power or torque is required to maintain this motion. To bring the moving vehicle to a stop a tremendous amount of kinetic energy must be converted to some other form of energy. The braking system accomplishes this using friction to convert the kinetic energy into large amounts of heat energy.

ELECTROMAGNETIC INDUCTION describes the ability of a magnetic field to induce or generate electrical current in an adjacent conductor. This principle is used to generate most of the electrical power we use today, both in our homes and businesses, as well as in our automobiles. The alternator uses this principle to create significant amounts of electrical energy for use in the car using a tiny amount of battery current and rotational energy provided by the engine crankshaft.

ELECTROMAGNETIC FORCE / VOLTAGE is another of the three main factors in all electrical circuits. It is the pressure or "push" that causes current to flow through conductors. Voltage is caused by an imbalance in the number of electrons in two or more locations. The automotive battery, for instance, generates approximately 12.8 volts through chemical action. This voltage forces current to flow through automotive circuits which can then be used to make heat, light, sound, or motion.

EVAPORATION / HEAT OF EVAPORATION describes the process of a liquid changing state into a gas. The simple act of evaporation is well understood by most, but many people do not understand that this process requires large amounts of heat energy. This process is the key step in creating chilled air for air conditioners and refrigerators. As liquid refrigerant is evaporated into a gas it extracts huge amounts of heat from the air around it and this air "without heat" is cold air.

FREQUENCY / HERTZ describes the speed at which something vibrates or moves. It is often measured in "cycles per second" or "Hertz". The frequency of AC current changes in a sensor circuit, for example, is used by on-board computers to determine how fast something is occurring. The frequency could tell the computer about the speed of the engine, the wheels, and the vehicle.

CONSERVATION OF ENERGY is the fundamental fact that within any system the total amount of energy will remain the same although conversions of one form of energy to another are commonplace. A good example of this principle is the deceleration and stopping of a moving vehicle. The total kinetic energy of the moving car at certain speed would be converted completely into heat energy generated through friction at the brakes and the tire road interface, and motion of the car body during deceleration (brake dive).

FRICTION, one of the simplest and most common principles, is a factor in most of the vehicle systems. Friction and its "side effects", namely heat and wear, account for the need for periodic replacement of brake pads and tires. Certain parts in engines, bearing shells, for instance, are designed to be "sacrificial", undergoing significantly greater wear than more complex and expensive adjacent parts. An entire field of expertise, Lubrication Engineering, has evolved specifically to deal with the challenge of managing friction and wear.

LEFT / RIGHT HAND RULES are mnemonic devices designed to aid in the understanding and recall of the relationship between magnetic lines of flux and current flow through adjacent conductors. Magnetic fields and electricity are closely related and these two "handy" rules illustrate the direction of current flow and flux line direction in both motor windings and generator windings.

LENZ'S LAW states that the direction of an induced current is always such that its own magnetic field opposes the change in flux responsible for producing it. Although this law is not easily simplified into layman's terms, it helps explain the behavior of current flow and magnetic fields in various inductors throughout the automobile.

MASS / VELOCITY LAWS are closely allied with inertia or momentum. They help the student to understand the relationship between moving masses and the forces required to set them to motion as

DEALERSHIP TOUR: EDUCATOR'S HANDOUT

well as the forces created when they are halted. These are illustrated well by the piston starting, accelerating, decelerating, stopping, and reversing direction in the cylinder many times per second.

NEWTON'S LAWS OF MOTION are actually three (3) separate laws that explain the interaction of masses, force, motion, inertia, and velocity. A good example of the application of Newton's work in the automobile is the use of a heavy flywheel attached to the engine crankshaft to "smooth out" and sustain the power impulses delivered by the piston.

OHM'S LAW details the interaction and relationship between the three main factors in Direct Current (DC) electrical circuits: Voltage, Amperage, and resistance. This simple law is used to determine the third factor when any two of the factors are already known. For example, it can be used to determine the current flow (in Amps) of a given circuit and, therefore, allow the selection of adequate wire size to carry this current.

PARALLAX is an optical or visual condition which can result in distortion or inaccuracy when viewing certain objects by eye. It is exemplified by the misreading of analog meter faces. If the viewer is not positioned to read the needle and scale or face of a meter at right angles to the meter face then parallax error will result and the viewer will not interpret the meter indication correctly. Meters are commonly used in automotive service and repair.

PASCAL'S PRINCIPLE states that an external pressure exerted on a fluid is transmitted uniformly throughout the volume of the fluid. This simple concept forms the basis for all hydraulic systems. Hydraulic systems are widely used in our world to accomplish various tasks. Examples include excavating the earth with backhoes, operating the control surfaces on the wings of an aircraft, slowing the closing of the screen door on your house, or applying the brakes on your car.

PHOTOVOLTAIC ACTION describes the unique ability of certain metals to convert light energy directly into electrical energy. This phenomenon is used in "solar" calculators, photographic light meters, and solar panels that commonly provide power to orbiting satellites. This form of power generation has been successfully employed in experimental, electrically powered automobiles. As electric cars become more commonplace, photoelectric panels may provide an environmentally friendly source of electrical power.

PIEZOELECTRIC ACTION describes the unusual ability of certain materials to generate an electrical output when subjected to pressure. This principle is used in many applications. Two applications in the automotive field are 1) "Piezo" sensors used in product and materials testing procedures when measuring shock or vibration and 2) on-board engine sensors designed to detect the vibration resulting from spark knock or "ping" due to improper combustion in the cylinder.

THERMODYNAMICS is the science that deals with the transformations of energy from one form to another. A basic concept of thermodynamics is that energy can be neither created nor destroyed, but only transformed. A fine example of this is the progression of chemical energy in the form of gasoline, to heat energy in the cylinder, to kinetic energy of expanding gasses against the piston, to rotational kinetic energy or torque turning the crankshaft, and ultimately the wheels, to provide forward motion.

SERIES / PARALLEL CIRCUITS are the basic configuration of electrical components in a circuit or system. All electrical systems are either one of these designs or a combination of both series or parallel designs. Each type of circuit has its own advantages and disadvantages and applying the correct circuit in a particular application is the key to effective electrical system operation.

SIMPLE MACHINES is a term that encompasses the lever, the inclined plane, and the hydraulic press. Many of the simple and complex mechanisms on today's automobile can be seen as extensions or adaptations of these three basic machines. Examples would be the threads on nuts and bolts (inclined plane), valve train rocker arms (lever), and the automotive hydraulic brake system (hydraulic press).

SURFACE TENSION is the property of liquids to maintain a membrane-like surface. This causes liquids to behave in a fashion that might seem unusual or strange. An example of this action in the automobile would be the meniscus that is formed at the surface of the pool of battery electrolyte in each battery cell. When the electrolyte forms a meniscus against the split rings near the top of the cell reservoir we know the electrolyte is at the proper level.

THERMAL EXPANSION / CONTRACTION describes the basic action of most solids to increase their size in proportion to temperature. A decrease in temperature usually brings on a contraction

DEALERSHIP TOUR: EDUCATOR'S HANDOUT

in size. These two actions must be reckoned with when designing, manufacturing, and repairing automobiles. Since vehicles often experience very broad temperature ranges, significant expansion and contraction dimensional changes occur. These dimensional changes would play havoc with the tight clearances that many precision automotive parts are assembled with. In some cases parts are intentionally heated or cooled to expand or shrink them and then assembled and allowed to normalize.

TRANSFORMER ACTION is a term that describes the ability of electrical transformers to alter voltage in a circuit. They may be used to decrease voltage, as is the case with the "step down" transformers found on neighborhood power poles, or they may be used to "step up" the voltage in a circuit, as is the case with automotive battery voltage (12 volts) being boosted to spark plug firing voltages of thirty thousand volts or more.

VISCOSITY is a term used to describe a fluid's resistance to flow. Viscosity is usually affected by temperature. This occurrence is important to engine lubrication. During cold startups the oil is thicker and flows less easily to vital engine parts. Oil is specially blended with additives designed to improve cold viscosity. Cold temperature viscosity can be determined by the first number in the familiar numerical rating on oil containers (e.g. SAE 10-30).

VOLATILITY describes a material's tendency to change from a liquid to a gas. Heat usually accelerates this process. Volatility must be controlled in most liquids used in automobiles because of the extreme temperatures found in many locations on the car. Lubrication engineers usually try to reduce the volatility of lubricants so they do not vaporize with heat while fuel engineers must closely control gasoline volatility to cause proper vaporization without excessive vaporization during hot weather creating "vapor lock" conditions.

ELECTRONICS /SEMICONDUCTORS describe the low voltage, low current circuitry usually used to sense the operation, position, pressure, or temperature of various components and then calculate proper responses and control various actuators to achieve the desired results. The automobile is loaded with electronic circuitry from bumper to bumper. It now pervades every system of the car from air bags, to radios, to cruise control, to anti-lock brakes.

REFRIGERATION is the term used to describe the process used in cooling air or liquids. This process, involving compressing and then evaporating a liquid while it absorbs and then releases heat, is the heart of the automotive air conditioning system. The same system is used in icemakers, refrigerators, freezers, and heat pumps.

METALLURGY is the study of the properties of metal. Metals have widely varied characteristics and, therefore, certain metals may be far superior to others in certain applications. Selecting the best metal for a job, determining the optimum method or process to shape or form the metal, and then using metallurgical knowledge to examine product failures are all common applications of metallurgy.

POWER TRANSMISSION is a term that describes the process of transferring power in the form of rotational motion or torque from one location or component to another. This process is used extensively on vehicles to transfer torque from the engine flywheel to the drive wheels of the vehicle. Bearings, shafts, couplings, universal joints, chains and sprockets, belts and pulleys, and gear trains all play important roles in power transmission.

LUBRICATION THEORY and friction theory go hand in hand. Sliding friction, rolling friction, and viscous friction all are present in the automobile and each demands its own form of lubricant and application method. Bushing bearings, roller bearings, ball bearings, and pressure fed crankshaft bearings are examples of components that rely on lubrication theory to survive.

CHEMISTRY is a term that describes the basic construction of all elements in our world and how these elements combine and break apart constantly. A prime example of chemistry in action in the automobile is the battery. Batteries cause electrons to flow from one pole to another, through a path or circuit, by the chemical reaction that takes place between an electrolyte (Sulfuric acid) and two dissimilar metals (lead and lead peroxide).

CATALYTIC ACTION describes the ability of certain materials to initiate or speed up reactions. Automotive catalytic converters are prime examples of devices using this technology. Catalytic converters alter harmful exhaust pollutants to form harmless emissions. Catalysts (Platinum, Palladium, Rhodium) are used to reduce certain pollutants and oxidize others.

DEALERSHIP TOUR: EDUCATOR'S HANDOUT

OXIDATION / REDUCTION REACTIONS refer to a type of chemical reaction involving a loss of electrons by one molecule (oxidation) and absorption of electrons by another (reduction). Typically, the oxygen molecule is involved as the molecule which absorbs the electrons and hence the other molecule involved in the reaction is "oxidized." These reactions occur in catalytic converters as oxygen combines with carbon monoxide to form carbon dioxide. Reduction reactions occur when molecules split apart. Catalytic converters promote the reduction of oxides of nitrogen – a pollutant – into oxygen and nitrogen, harmless components of our atmosphere.

TYPES OF ENERGY describes the basic forms of energy in our world and the methods used to convert them from one form to another. Kinetic, electrical, magnetic, chemical, heat, light, sound, and nuclear energy are all examples of these various forms. Energy can be traced from one form to another in the automobile and efficiencies and waste can be examined.

CENTRIFUGAL FORCE describes the force encountered when mass begins to rotate on, or around, an axis. These forces multiply with increases in mass and velocity (or RPM). The degree to which the rotating mass is counterbalanced affects vibration and, typically,

wear. These forces are evident in tire and wheel assemblies, drive shafts and axles, flywheels, and engine crankshafts.

GLOBAL WARMING, also known as the greenhouse effect, is caused, in part, by the increase in the amount of combustion gasses, mainly carbon dioxide, that modern man has produced through combustion driven engines. "Zero Emission Vehicles", electric cars to name one, produce no exhaust emissions, and therefore, do not contribute to global warming while operating.

TORQUE / LEVERAGE describes the relationship of increased or decreased turning force with increased or decreased leverage through the use of larger or smaller gear diameter. Transmissions provide the operator with a selection of gears to properly match speed, load, and torque to the job at hand.

GRAVITY plays a greater role than simply keeping the car planted on the pavement. Gravity is used to counter the "pulling" of fuel up a discharge tube in the automotive carburetor. A proper balance between gravity, fuel level in the reservoir (or float bowl) and venturi effect in the barrel will cause proper fuel delivery under most operating conditions.