DOCUMENT

A LESSON NOTE ON THE PRINCIPLES AND TERMS RELATING TO SIMPLE MACHINES INCLUDING QUESTIONS AND ANSWERS

There are many technical terms used in describing the parts, conditions and functions of engines and equipment. The following basic principles can be applied to all machines, equipment and mechanical applications:

1. **LEVER**
   The lever is probably the first mechanical application and simplest mechanical device discovered by man. The lever is a simple method of increasing the amount of force that can be exerted on an object. A lever consists of a beam or stick or rod. It must have something on which to pivot, which is called a fulcrum. When using this principle a very heavy load can be lifted or moved with very little effort. It may be impossible for a person to lift a thousand pounds but, with the help of a lever the proper length and fulcrum properly placed, this work could be easily accomplished.
   There are three classes of a lever, known as follows:
   - **First Class Levers**
     They have the fulcrum placed between the load and the effort. Examples are the seesaw, crowbar and balance scale. If the two arms of the lever are of equal length like the balance scale, the effort must be equal to the load. If the effort arm is longer than the load arm like the crowbar, the efforts travels farther than the load and is less than the load.

   - **SECOND CLASS LEVERS**
     They have the load between the effort and the fulcrum. An example is a wheelbarrow. The wheel's axle is the fulcrum, the handles take the effort and the load is placed between them. The effort always travels a greater distance and is less than the load.

   - **Third Class Levers**
     They have the effort placed between the load and the fulcrum. The effort always travels a shorter distance and must be greater than the load. A hammer acts as a third class lever when it is used to drive a nail: the fulcrum is the wrist, the effort is applied through the hand, and the load is the resistance of the wood.

2. **SCREW**

A screw is considered to be an inclined plane that has been wrapped around some central axis. Screw can be used in two major ways. First, they can be used to hold things together. Some examples are wood and metal screws, the screws on jars and bottles and their tops. Second, screws can be used to apply force on objects. Examples are screws found in vices, presses, clamps, monkey wrenches, brace bits and corkscrews.

The screws acts as a simple machine when an effort force is applied to the larger circumference of the screw. For example, a person might apply the effort force to a wood screw by turning a screwdriver. That force is then transmitted down the spiral part of the screw called the thread to the tip of the screw. The movement of the screw tip into the wood is the resistance force in the machine. Each complete turn of the screwdriver produces a movement of only one thread of the screw tip into the wood. This distance between two adjacent threads is called the pitch.

3. **WHEEL AND AXLE**

The wheel and axle is generally considered to be a wheel attached to a axle so that these two parts can rotate together in which a force is transferred from one to the other. In this configuration a **hinge** or **bearing** supports the rotation of the axle**.** It transmit weight or load into rotary motion. A greater amount of weight can be applied to the end point of an axle and an object can easily be moved. The weight of the axle is transmitted to the wheel and converted into rotary motion for movement.

4. **PULLEY**

A pulley is a wheel on an axle or shaft that is designed to support movement and change of direction of a taut cable or belt along its circumference. Pulley is used in a variety of ways to lift loads apply forces and transmit power.

A pulley can also be called a sheave or drum and may have a groove between two flanges around its circumference. The drive element of a pulley system can be a rope, cable, belt or chain that runs over the pulley inside the groove.

A common example of this principle is the block and tackle used to lift heavy loads. Most automotive repair shop have a block and tackle they use for lifting engines from automobiles.

5. **INCLINED PLANE**

An inclined plane, also known as a ramp is a flat supporting surface tilted at an angle, with one end higher than the other, used as an aid for raising or lowering a load.

Moving an object up an inclined plane requires less force than lifting it straight up, at a cost of an increase in the distance moved. The mechanical advantage of an inclined plane, the factor by which the force is reduced, is equal to the ratio of the length of the sloped surface to the height it spans. Due to mechanical energy, the same amount of mechanical

energy (work) is required to lift a given object by a given vertical distance, disregarding losses from friction, but the inclined plane allows the same work to be done with a smaller force exerted over a greater distance.

6. **WEDGE**
   A wedge is a triangular shaped tool and is a portable inclined plane, and one of the six classical simple machines. It can be used to separate two objects or portions of an object in place. It functions by converting a force applied to its blunt end into forces perpendicular to its inclined surface. The mechanical advantage of a wedge is given by the ratio of the length of its slope to its width. Although the short wedge with a wide angle may do a job faster, it requires more force than a long wedge with a narrow angle.

MECHANICAL ADVANTAGE

The five basic principles of a lever – inclined plane, screw, pulley and the wheel and axle are the basic actions that allow us to multiply an applied force**.** This basic principle allows us to determine the least amount of force needed to lift a load or move an object from one position to the other, using the fulcrum and the distance between the fulcrum and the load. The amount of **force** applied at the long end of the lever is determined by the location of the fulcrum.

FORCE

A force is a push or pull exerted on an object in an attempt to change its conditions. When a gas or air is heated it expands and occupies more space. Gravity has a pull to bring things closer to the center of the earth. Magnetic poles attract or repels each other. These are all forces. They all ten to change the state or condition of an object from its present state to another.

NEWTON'S FIRST LAW OF MOTION AKA LAW OF INERTIA

What's inertia? Inertia is the tendency all material has to take the low route and not change its state. If something is moving it will do so in a straight line and never stop unless something gets in the way. That's an **outside force – could be a push, pull, obstacle, friction, air resistance, gravity, etc.**

In short:

No external force = no acceleration = no change velocity = no change in direction.

External force = acceleration = change in velocity (higher or lower), or a change in direction.

NEWTON'S SECOND LAW OF MOTION

Newton found out that when an external force acts on an object, then that object accelerates – and the rate of acceleration is proportional to the mass of the object.

$$F = m * a$$

If the force is in line with current motion then the object goes faster.

If the force is in opposite direction, then the object slows down.

Zero external force means no acceleration. That could mean constant velocity or it stays at rest.

WORK

Work is the movement of an object or weight through a distance. Moving an object from one place to another requires work.

$$\text{WORK} = \text{FORCE} * \text{DISTANCE}$$

When the movement is inclined at an angle, the formula for work changes and this brings in some interesting concepts:

- When the angle equals zero, the cosine equals one. This happens when the force and displacement are in the same direction, thus we have our original formula, $W = F.d$
- When the angle equals 90 degrees. The cosine equals zero which in turn makes work zero. This happens when the force and displacement are perpendicular to each other. Thus, when a force is applied to an object in a direction that is perpendicular to the object's displacement, that force does no work.
- When the angle is between 90 and 180 degrees, the cosine is less than zero which makes work less than zero. This gives us the concept of negative work, which can be illustrated by adding friction.

ENERGY

Energy is the ability to do work. The energy can be held in reserve or in action. Potential energy is contained and not in action. A person at rest contains potential energy and when he begins to move this energy is then changed into kinetic energy.

Energy is another physical quantity, certain types of which are closely related to work. The first type we will discus is kinetic energy, which is the energy an object has simply by being in motion. We can calculate an object's kinetic energy with the following formula:

$$K = 1/2mv^2$$

Where, K is kinetic energy, m is mass, and v is velocity, (You can use this equation to verify that the units of energy are the same as those of work: joules.)

Another type of energy is potential energy, which is defined in the context of certain types of forces we call conservative forces. Conservative forces like gravity and elastic forces have associated potential energies and non-conservative forces like friction, air resistance, pull and push of a person don't.

In general, the change in potential energy associated with conservative force in the negative of the work done by that force.

GRAVITY

Gravity is one of the four outside forces that have an effect on all simple machines. Gravity is the force that draws all bodies toward the center of the earth. The force of gravity gives us weight, it causes objects to fall from the sky or roll down a hill.

INERTIA

Static inertia is the tendency of an object to remain at rest. Without some outside force the body tends to remain at rest and not move.

Dynamic inertia is the tendency of an object to continue moving once it has been set in motion.

MOMENTUM

Momentum is the amount of motion of a moving object. There is the linear momentum and the angular momentum.

Angular momentum is also known as moment of momentum and rotational momentum. Often referred as rotational equivalent of linear momentum. It is a vector quantity. For an object rotating about an axis, angular momentum (L) is represented by the product of the object's rotational inertial (I) and its angular velocity (w).

$$L = I.w \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The definition could be extended to a point mass (an object whose radius is much smaller as compared to its distance from the axis of rotation). Angular momentum in this case is equal to the cross product of an object's linear momentum (mv) and its distance from the axis of rotation (r).

$$L = r.x.mv \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Where, m and v are mass and velocity of the object.

The unit of angular momentum is $Kg*m^2 /s^2$

If all the external torques acting on an object is negligible, then the angular momentum acting on an object is always conserved/constant.

$$Iiwi = Ifwf \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

Where, Ii and wi are the initial momentum of inertia and angular velocity while If and wf are the final moment of inertia and angular velocity respectively.

RESISTANCE

Resistance is an opposing or retarding force. Two forces pulling away or pushing against each other is resistance. It is also present when two forces oppose each other, such as two rough surfaces rubbing together. Resistance will often create friction. Various forms of resistance are often used in electrical components to retard the flow of electricity. Resistance is found in all engines caused by friction of the moving parts. Résistance is also present when an object is moving and has momentum.