

# Intro to Mechanical Engineering

# Mech. Eng. Top 10: ASME Survey

**Automobile:** High-power lightweight engines, efficient mass-manufacturing

**Apollo:** Saturn V launch vehicle (7.5 million pound thrust), command and service module, lunar excursion module

**Power generation:** Conversion of stored energy into electricity, manipulation of chemical-, kinetic, potential-, and nuclear-energy, large-scale power production

**Agriculture mechanization:** Powered tractors, mechanized harvesting, high-capacity irrigation pumps, computerized crops management

**Airplane:** Propulsion (jet engines), lightweight materials, electromechanical control systems

# Mech. Eng. Top 10: ASME Survey

**Integrated circuit mass production:** IC manufacturing machines, alignment systems, temperature- and vibration control, motors, bearings

**Air-conditioning and refrigeration:** Compressors, refrigerants, heat exchangers

**Computer-aided engineering technology:** Computer-aided design, analysis, manufacturing, virtual collaboratives

**Bioengineering:** Imaging, prosthetics, minimally invasive surgery, tissue engineering

**Codes and standards:** Interchangeability, interoperability, interconnectivity

# Mech. Eng.: Typical Program

**Thermo-Fluids:** Heat transfer, Energy Systems, HVAC, IC Engines

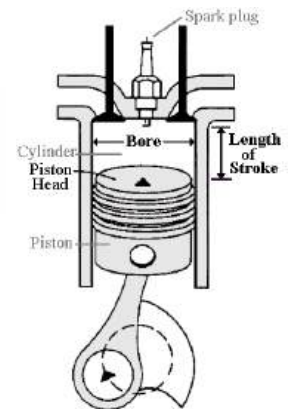
**Mechanical Systems:** Vibrations, Feedback control, Mechatronics, MEMS

**Design:** Composites, Machine Design, FEM

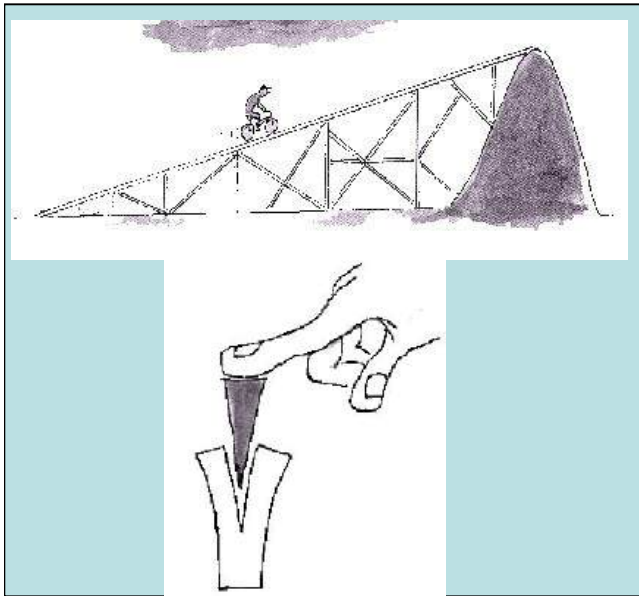
**Core:** Statics, Dynamics, Thermodynamics, Fluid mechanics, Solid mechanics

# Types of Motion

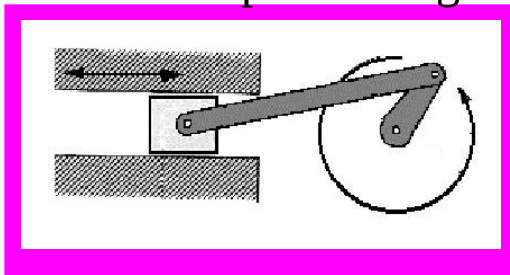
- Linear motion
  - motion in a straight line (example: train on a track)
- Reciprocating motion
  - linear motion that goes back and forth (example: pushing a slider-crank back and forth, such as the piston in an internal combustion engine)
- Rotary motion
  - circular motion (example: the hands of a clock moving, or a wheel on an axle)
- Oscillating motion
  - circular or arc-motion back and forth (example: the swing of a pendulum or the turning and release of a doorknob)



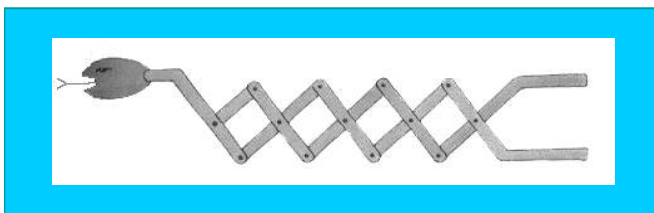
# Machine Components: Basic Elements



Inclined plane wedge

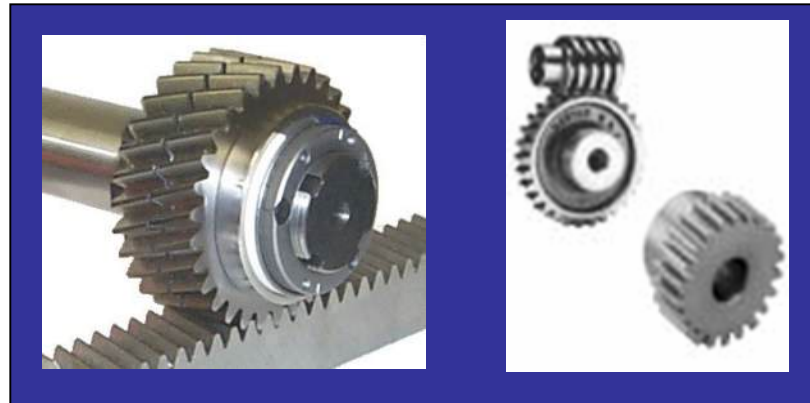


Slider-Crank

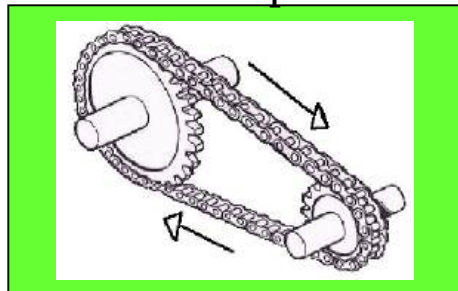


Linkage

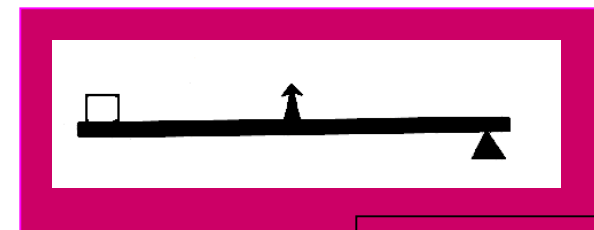
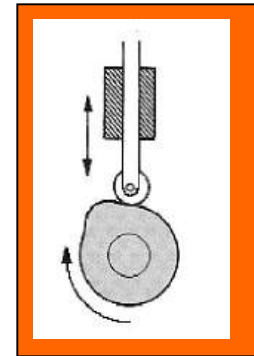
Gear, rack, pinion, etc.



Chain and sprocket



Cam and Follower



Lever



Wheel/Axle



Springs

# Inclined Plane



**Wedge**



**Worm Gear**

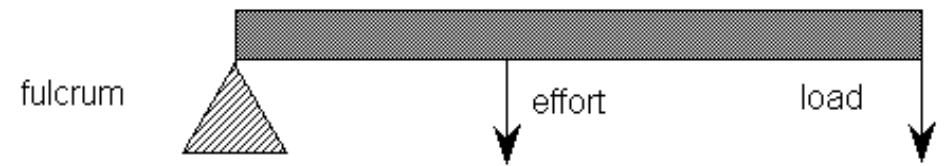
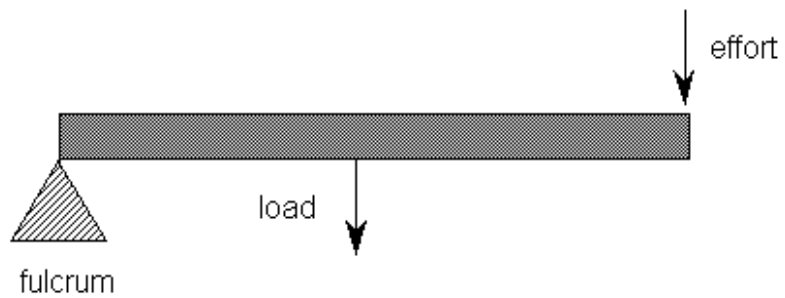
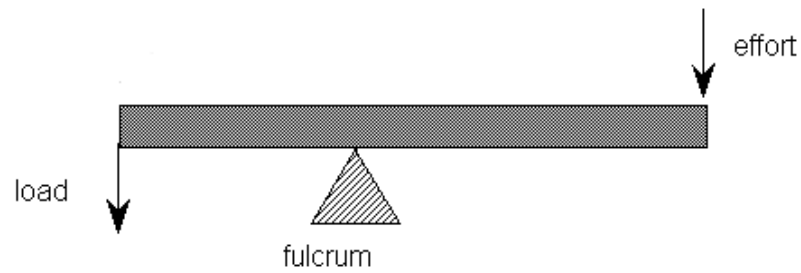


**Wood Plane**



**Screw**

# Lever



**Weighing Scale**

**Excavator**

**Scissors**

**Piano**

# Wheel and Axle



**Waterwheel**



**Turbine**



**Windmill**

# Belt and Pulley



**Chain Hoist**



**Crane**



**Elevator**

# Gears



**Bevel Gear**



**Spur Gear**

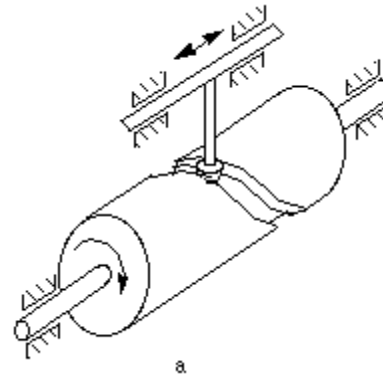


**Helical Gear**

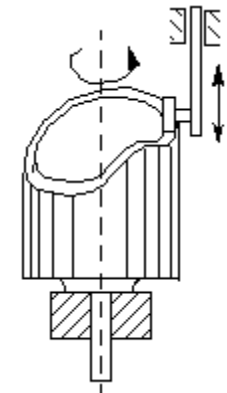


**Rack and Pinion**

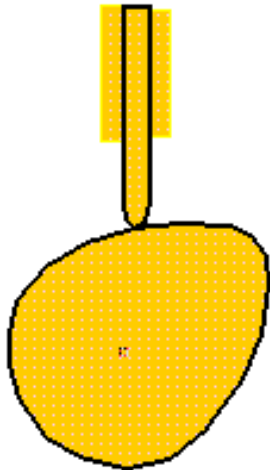
# Cams



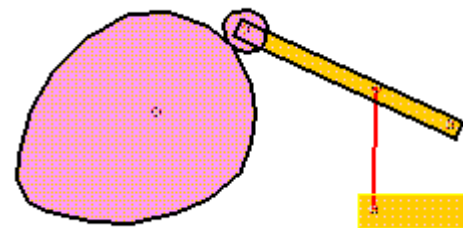
**Cylindrical cam**



**End Cam**



**Translating Cam**



**Oscillating Cam**

# **Springs**



**Leaf Spring**



**Washer Spring**

# Friction



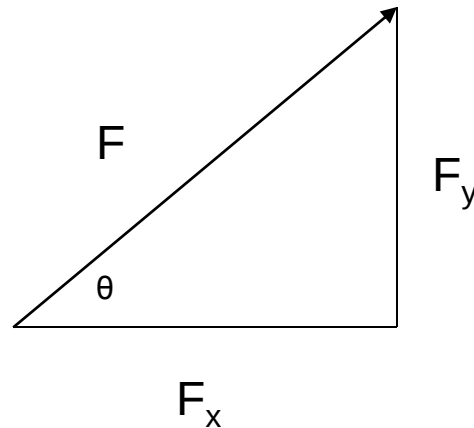
**Brake System**



**Bearing**

# Forces in Structures

## Forces and Resultants



Rectangular Form:  $F = F_x \mathbf{i} + F_y \mathbf{j}$

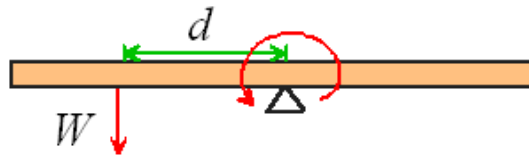
Polar Form:  $F = |F| \angle \theta$

$F_x = F \cos(\theta)$ ,  $F_y = F \sin(\theta)$

$|F| = \sqrt{F_x^2 + F_y^2}$ ,  $\theta = \tan^{-1}(F_y/F_x)$

# Moment of a Force—I

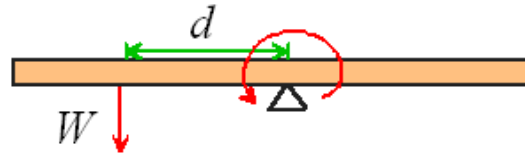
The moment of a force is a measure of its tendency to rotate an object about some point



A force applied to a pivoted beam causes the beam to rotate

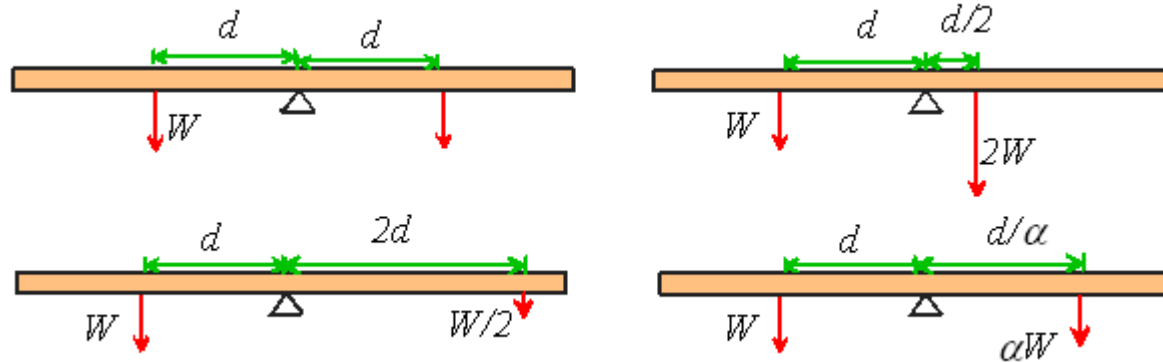
Moment of force  $W$  about pivot point:  $W \times d$

# Moment of a Force—II



A force applied to a pivoted beam causes the beam to rotate

## Balancing Beams using moment of forces



# Equilibrium of Forces & Moments

Object in equilibrium

$$\sum F_x = 0$$

$$\sum F_y = 0$$

$$\sum M_o = 0$$

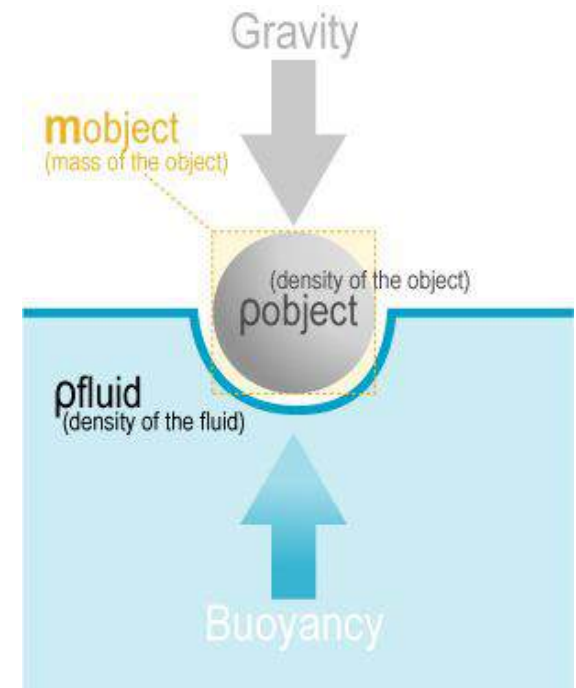
# Buoyancy

Force produced by fluid pressure

When an object is fully or partially immersed in a fluid, due to the pressure difference of the fluid between the top and bottom of the object, buoyant force acts on the object causing it to float

The net upward buoyancy force is equal to the magnitude of the weight of fluid displaced by the body

Buoyancy is important for boats, ships, balloons, and airships

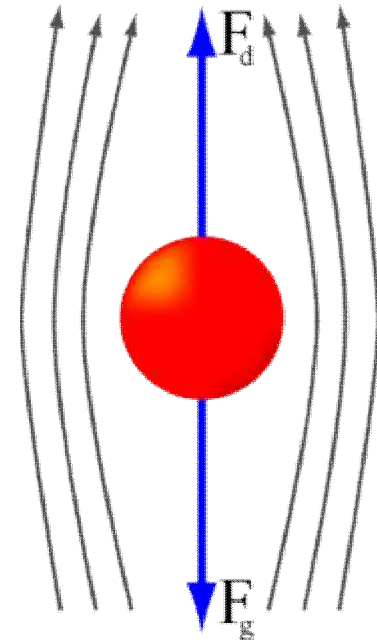


# Drag Force

Force that resists the motion of an object through a fluid

Drag force arises from the motion of an object through fluid

Drag force arises from the flow of fluid past an object



An object moving through a fluid experiences a force in direction opposite to its motion. Terminal velocity is achieved when the drag force is equal in magnitude but opposite in direction to the force propelling the object.

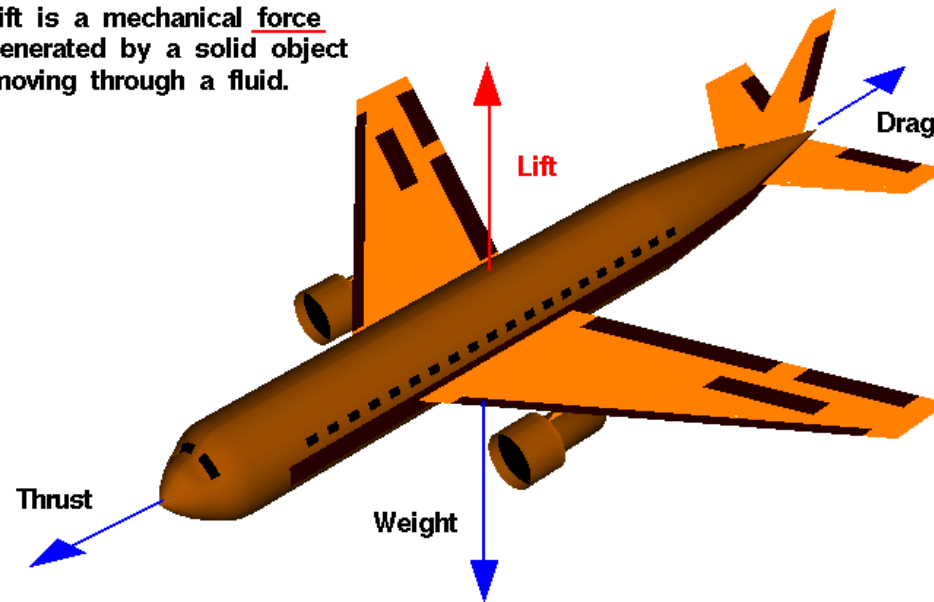
# Lift



## What is Lift ?

Glenn  
Research  
Center

Lift is a mechanical force  
generated by a solid object  
moving through a fluid.



Lift forces arises as a fluid flows around a structure  
Lift force acts perpendicular to the direction of flow

# Mechanical Energy

Gravitational Potential Energy: Energy stored by an object as it gains elevation within a gravitational field

$$\Delta U = mgh, \quad m: \text{mass of object}, g = \text{gravitational constant}, \\ h: \text{elevation of object}$$

Elastic Potential Energy: Energy stored by an object when it is stretched or bent.

$$\Delta U = \frac{1}{2}kx^2, \quad k: \text{spring constant}, x = \text{spring stretch/compression}$$

Kinetic Energy: Energy associated with an object's motion.

$$\Delta U = \frac{1}{2}mv^2, \quad m: \text{mass of object}, v = \text{speed of object}$$

# Work & Power

When a force  $F$  acting on an object displaces it by distance  $d$ , the force  $F$  is said to have done work  $W$

$$W = f \times d$$

Power is the rate at which work is performed

$$P = \frac{\Delta W}{\Delta t}$$

# Newton's Laws of Motion

1<sup>st</sup> Law: Every body continues in its state of rest or of uniform motion in a straight line unless it is compelled to change that state by an external force

2<sup>nd</sup> Law: The rate of change of momentum of an object is proportional to the force acting on the object and is in the same direction as that force

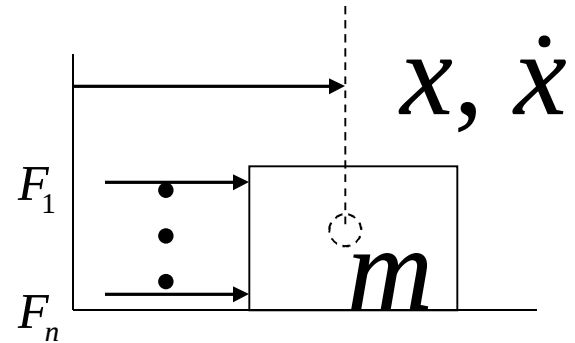
$$F = m \times a$$

3<sup>rd</sup> Law: To every action there is an equal and opposite reaction

# Equations of Motion

Translational motion

$$m\ddot{x} = \sum F$$



Rotational motion

$$I\ddot{\theta} = \sum M$$

