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

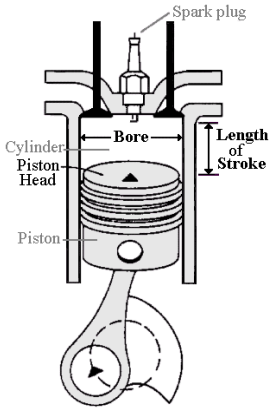
Thermo-Fluids: Heat transfer, Energy Systems, HVAC, IC Engines

Mechanical Systems: Vibrations, Feedback control, Mechatronics, MEMS

Design: Composites, Machine Design, FEM

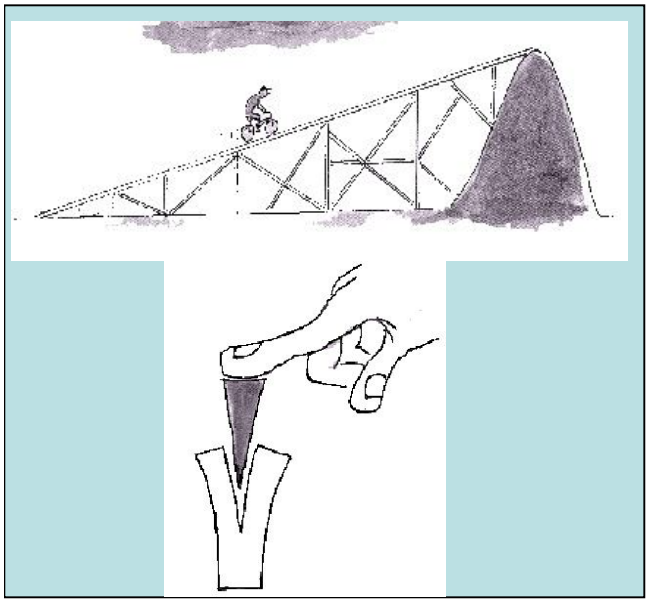
Core: Statics, Dynamics, Thermodynamics, Fluid mechanics, Solid mechanics

Types of Motion



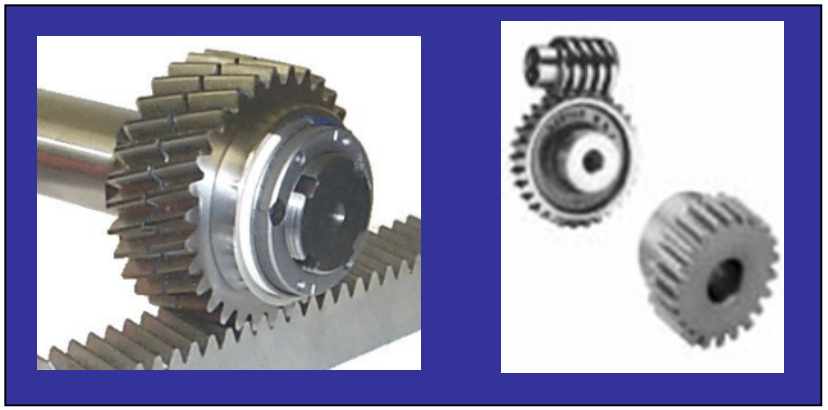
- Linear motion
  - motion in a straight line (example: train on a track)
- Reciprocating motion
  - linear motion that goes back and forth (example: pushing a slider-crank back and forth, such as the piston in an internal combustion engine)
- Rotary motion
  - circular motion (example: the hands of 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)

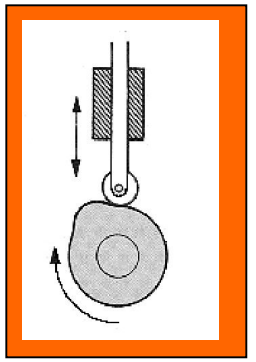
Machine Components: Basic Elements



Inclined plane wedge

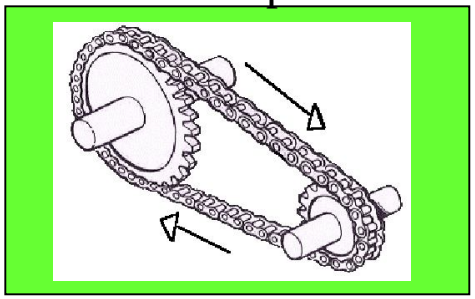
Gear, rack, pinion, etc.

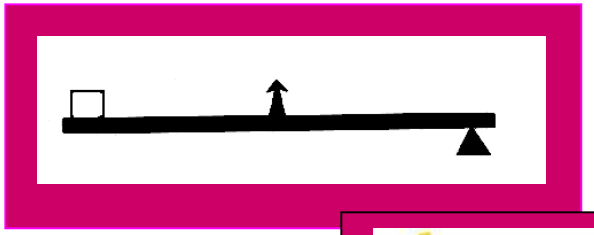




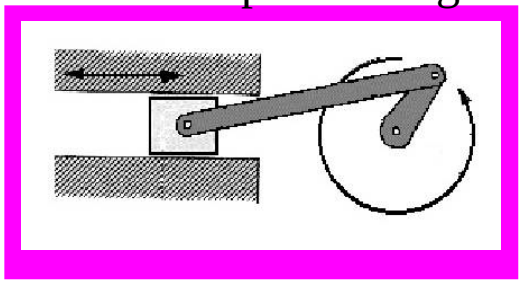
Cam and Follower

Chain and sprocket

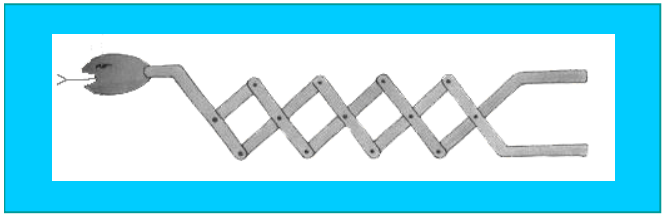




Lever



Slider-Crank



Linkage

Wheel/Axle

Springs

Inclined Plane

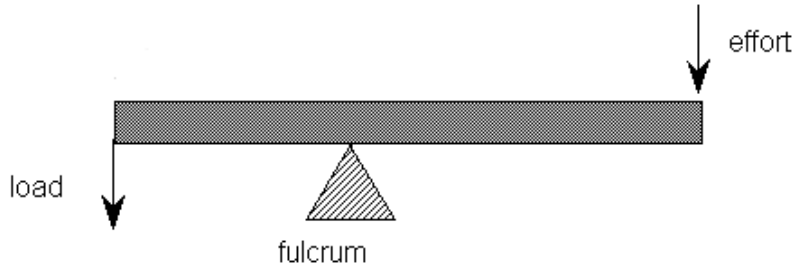
Wedge

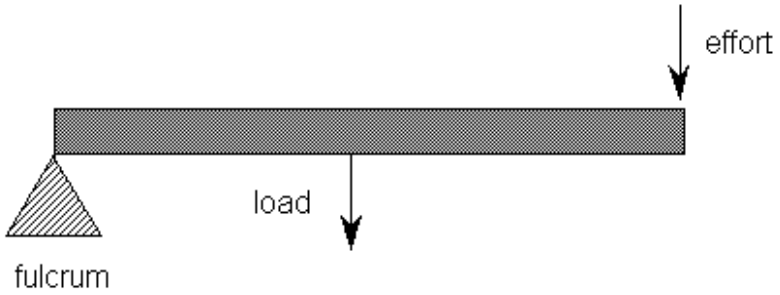
Worm Gear

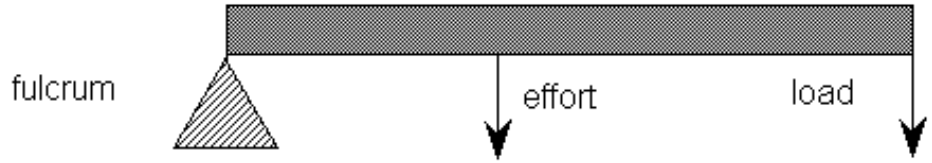
Wood Plane

Screw

Lever







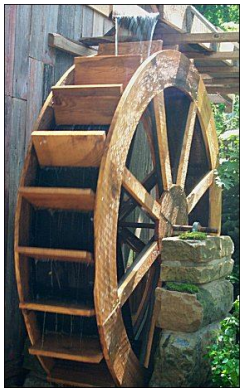
Weighing Scale

Excavator

Scissors

Piano

Wheel and Axle



Waterwheel

Turbine

Windmill

Belt and Pulley

Chain Hoist

Crane

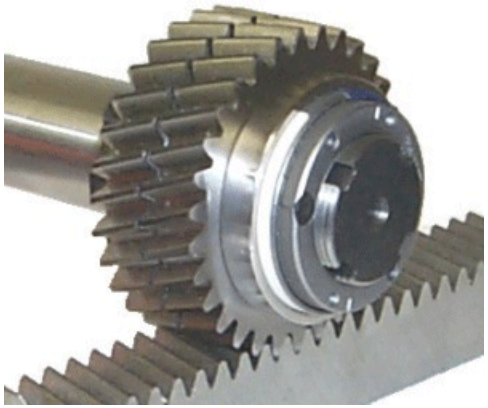
Elevator

Gears

Bevel Gear

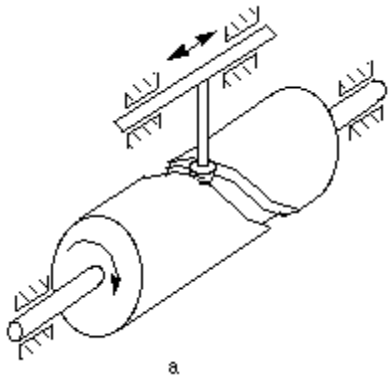
Spur Gear

Helical Gear

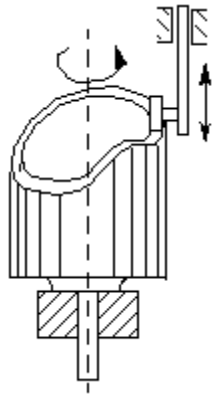


Rack and Pinion

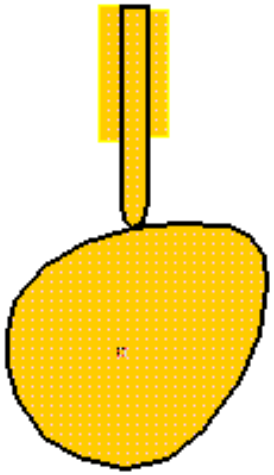
Cams



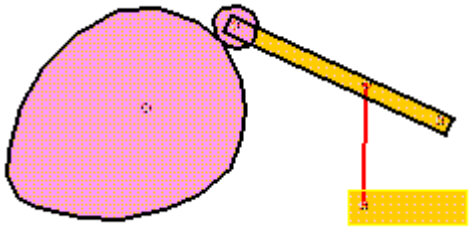
Cylindrical cam



End Cam



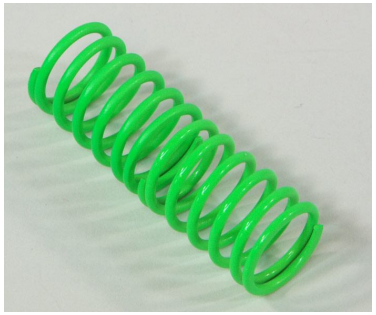
Translating Cam



Oscillating Cam

Springs

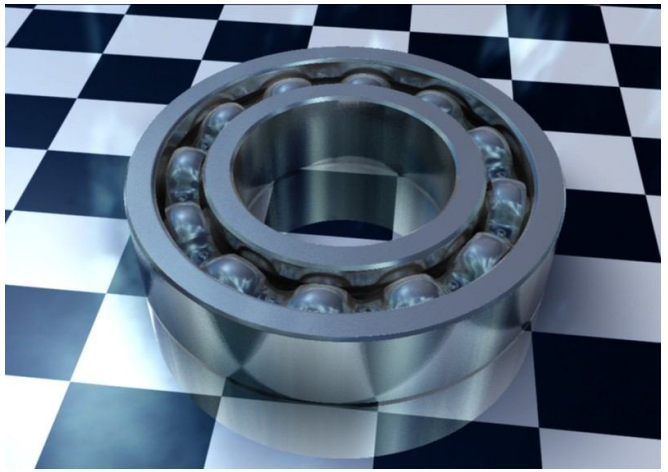
Leaf Spring



Washer Spring

Friction

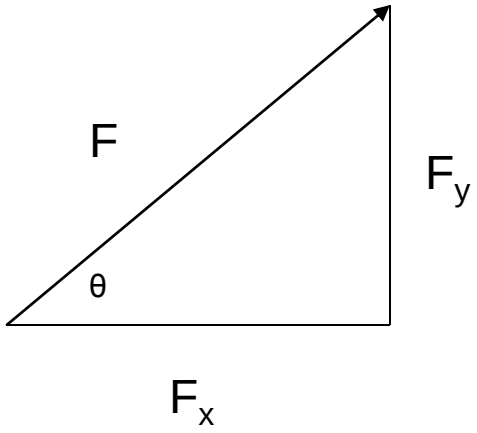
Brake System



Bearing

Forces in Structures

Forces and Resultants



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

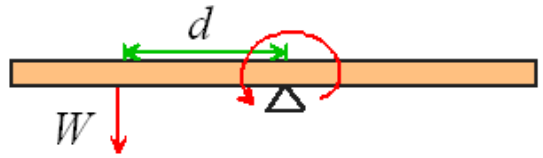
Polar Form: $F=|F|<\theta>$

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

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

Moment of a Force—I

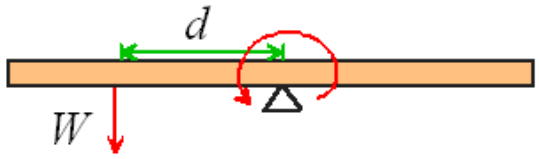
The moment of a force is a measure of its tendency to rotate an object about some point



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

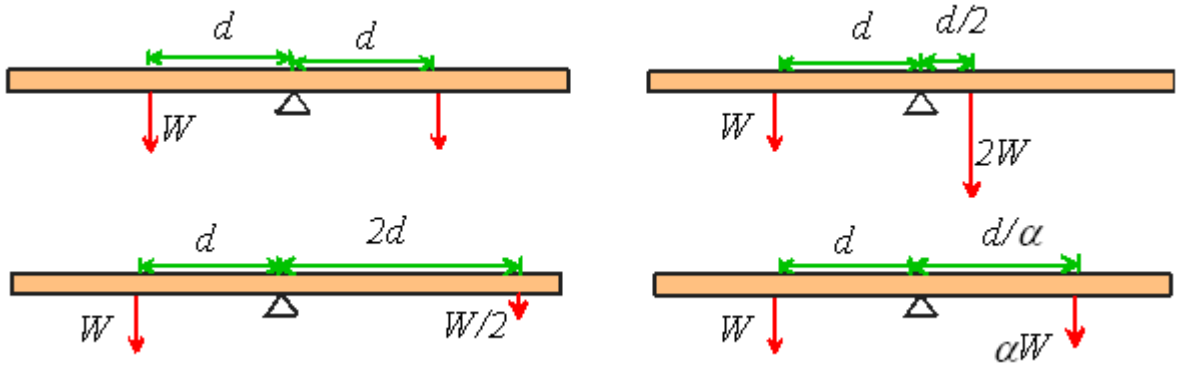
Moment of force W about pivot point: W×d

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

$$\sum F_x = 0$$

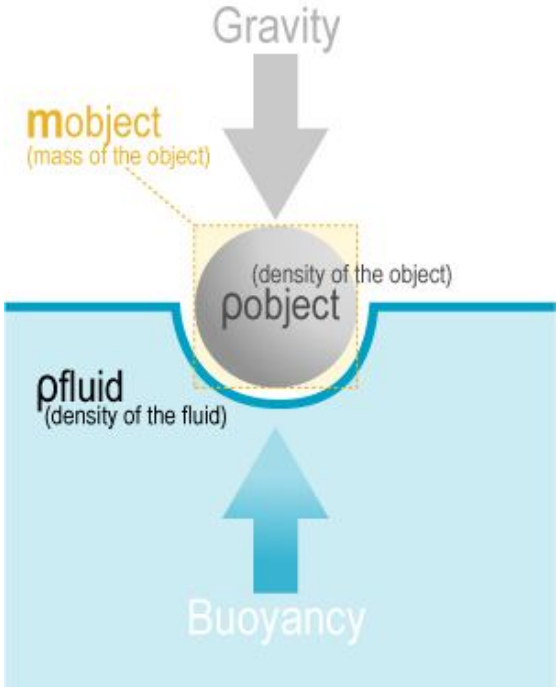
$$\sum F_y = 0$$

$$\sum M_o = 0$$

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

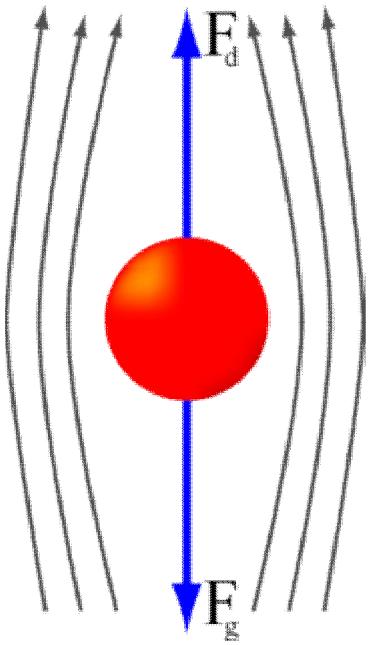
Buoyancy is important for boats, ships, balloons, and airships

Drag Force

Force that resists the motion of an object through a fluid

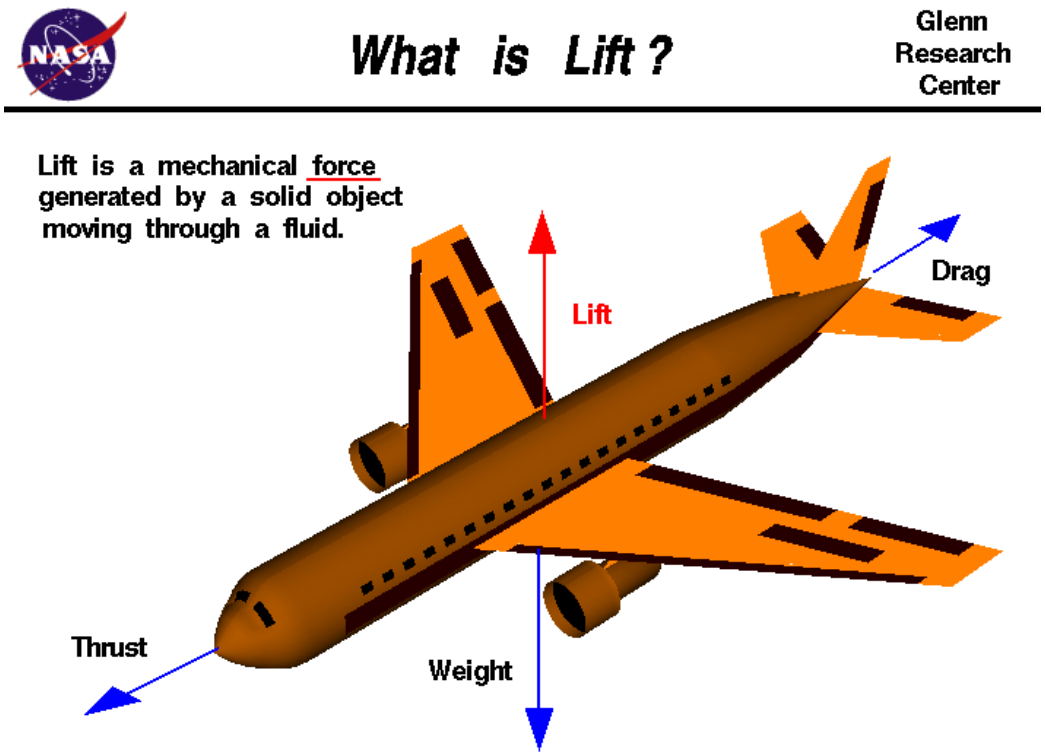
Drag force arises from the motion of an object through fluid

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



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

1st 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

2nd 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

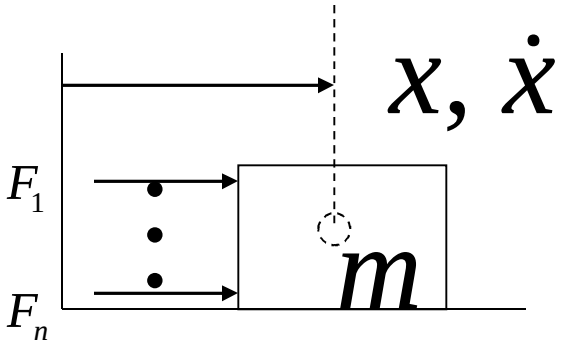
$$F = m \times a$$

3rd Law: To every action there is an equal and opposite reaction

Equations of Motion

Translational motion

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



Rotational motion

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