Energy – Work – Power

Terms

- Speed
- Endurance
- Strength
- Work
- Energy
- Power

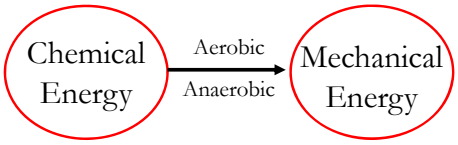
Speed

- Speed
  - The ability to achieve high velocity.
- Speed-strength
  - Force developed rapidly or at high velocities.
- Speed-endurance
  - Maintenance of maximal velocity over a period of time or in multiple bouts.

Endurance

- The ability to withstand extraordinary mental or physical stress for a prolonged period. *Taber's Medical Dictionary*
- The ability to continue
  - Despite pain, fatigue, stress

Human Performance



- Development of useful Mechanical Energy
  - Neuromuscular coordination
    - Generation of appropriate forces (direction, magnitude)
  - Transforming energy

Energy

- Energy
  - The capacity to do work.
  - Units: Joule
  - Formula depends on the type of energy
    - Nuclear
    - Heat
    - Mechanical
    - Chemical
    - Light
    - Electrical

Energy Concepts

- Energy is needed to get an object moving.
  - Work needs to be done on the object.
- Energy needs to be dissipated to slow an object down.
  - Work is done by the object on to something else (which is causing it to slow down).
- Example
  - Shot-put: The athlete performs work on the shot.
  - Catching a shot-put: The shot performs work on the catcher (the catcher 'absorbs' energy).

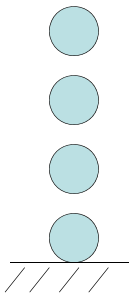
Conservation of Energy

- Energy cannot be created or destroyed.
- Energy can change from one form to another.
  - 'Transformation of energy from one form to another'
- $E_1 = E_2$
- More general form:
  $E_1 = E_2 + Q$

Projectile Motion

PE = mgh

KE = ½ mv^2



Potential energy high

Kinetic energy low

Kinetic energy high

Potential energy low

The total amount of energy remains the same

Summary: Energy

- Conservation of Energy
- Forms of Energy
- Units of Energy
- Terms
  - Speed
  - Endurance
  - Strength

Work

- Work
  - A force acting on an object that causes that object to move through some displacement.
  - $W = Fd\cos\theta$
    - F = force magnitude
    - d = displacement
    - θ = angle between force and displacement
  - Units: Nm or Joule

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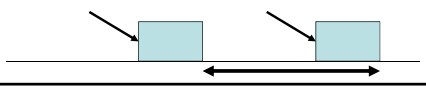

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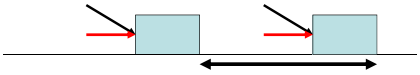
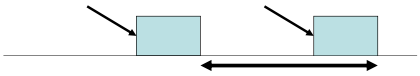


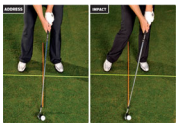
Work

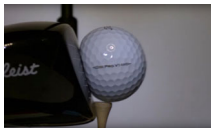
- When work is done 'on an object' energy is transferred to that object from the object causing the force.
- Work describes energy transfer.



Example

- The golfer does work on the club
  - Energy in the golfer is transferred to the club.
  - The golfer applies a force to the club to move it.
- The club does work on the golf ball.
  - Energy in the club is transferred to the ball.
  - The club applies a force to the ball to move it.





Summary Work

- Work
  - Application of a force over a distance.

    W = Fd

    where F & d are parallel

    $W = Fd\cos\theta$

    Units: Joule

Work-Energy Theorem

- Energy
  - The capacity to do work.
- Work
  - Application of force over displacement.

(both have units of Joules)

Mechanical Energy

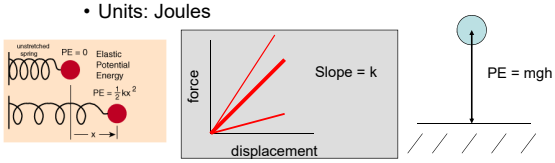
- Energy related to the motion of an object.
  - Potential Energy
    - Due to position
    - Elastic
  - Kinetic Energy

Energy is the capacity to do work.

Energy is the capacity to apply a force to move an object.

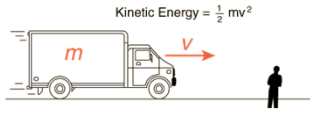
Mechanical Energy

- Potential Energy (PE)
  - The energy due to position of an object.
    - PE = mgh
    - Units: Joules
  - The energy stored in a spring
    - PE = ½ kx^2
    - Units: Joules



Mechanical Energy

- Kinetic Energy (KE)
  - The capacity to do work due to movement.
  - Translational: KE_T = ½ mv^2
  - Rotational: KE_R = ½ $I\omega^2$
  - Units: Joules

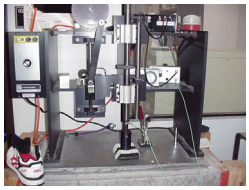


Work-Energy Theorem

- The amount of work done **on** an object **by** a net force is equal to the change in kinetic energy.

  $W = KE_f - KE_i$

- Impact test determines how much energy is 'absorbed' by the shoe.
  - KE at impact
  - KE = zero at t_f



Work-Energy Theorem

- The net work done on an object is equal to the change in Kinetic Energy

$$W = KE_f - KE_i$$

- If $KE_f > KE_i$
  - the object's speed increases
  - the work done on the body is positive
  - Word on the street: Energy is *generated* by the 'system'
- If $KE_f < KE_i$
  - the object's speed decreases
  - The work done on the object is negative.
  - Word on the street: Energy is *absorbed* by the 'system'
- Total energy (e.g., mechanical + heat + …) is always the same (i.e., conserved).

Summary Mechanical Energy

- Mechanical Energy
  - Potential Energy
  - Kinetic Energy
- Work-Energy Theorem
  - The amount of work done **on** an object by a force is equal to the **change** in Kinetic Energy.
- Energy and Work have the same set of units (Joule).

Power

- Power
  - The rate at which work is done.
  - The rate at which energy is transferred from one object to another.

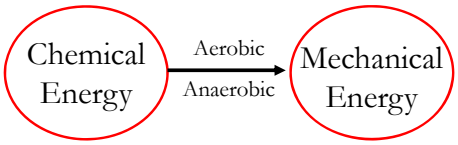
$P = W/\Delta t$

Linear: $P = Fd/\Delta t = Fv$

Angular: $P = T\omega$

Units: Watts

Human Performance

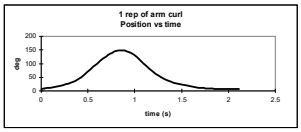


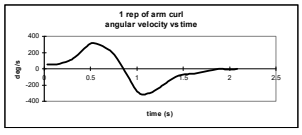
What a person can do is not limited only by the total amount of energy required but also by the **rate** at which energy can be transformed from one form to another (e.g., chemical to mechanical).

Work, Power, Energy

- We often use the phrases 'energy absorption' or 'energy generated'
  - Conservation of Energy
    - energy can not be created or destroyed.
- When work is positive (Fd)
  - Force and displacement are in the same direction.
  - power will be positive (W/Δt)
  - we say energy is 'generated.'
- When work is negative
  - Force and displacement are in different directions.
  - power is negative
  - we say energy is 'absorbed'.

Example

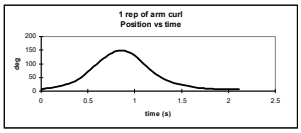


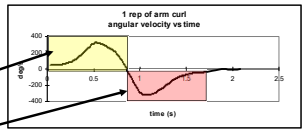


Given: the torque about the elbow is always positive during this movement.

The biceps brachii are always active trying to cause flexion.

Example





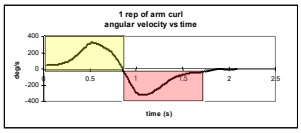
Power will be positive

$P = T\omega$

Power will be negative

The joint moment will be positive throughout the movement.

Example



Eccentric contractions will have a negative power since the joint moment is in a different direction than joint velocity.

Concentric contractions will have positive power.

Power

- Maximum power is accomplished by optimizing force and velocity.
  - P = Fv
  - Force is not maximized.
  - *Contraction* Velocity is not minimized or maximized.

Cycling Power

- (Fp)(v) = (Fs + Fair + Fr + Fb)(v)
- (Fp)(v) = The power the biker generates

$$\text{Velocity} = \frac{Power}{Resistance\ Forces}$$

- We can measure power using a variety of tools
  - Hub based system
  - Crank based system

Summary: Power

- Power
  - Rate of work done
  - Rate of transformation of Energy from one form to another

P = Fv

P = Work/time

Units: Watt