Energy

- **Ability to do work**
- **Measured in joules (J)**
- **One joule is the work done when a one newton force moves an object through one metre**
- **1 Calorie = 1000 cals = 4.186 kJ**
- **Can take many forms**

Forms of Energy

- **Mass ($E = mc^2$)**
- **Solar or Light (solar panels, photovoltaic battery)**
- **Electricity (electron flux, magnetic induction)**
- **Chemical (fossil fuels, ATP, food)**
- **Thermal or Heat**
- **Mechanical energy**

Types of Mechanical Energy

- **Translational Kinetic = $\frac{1}{2} m v^2$**
  - $v^2 = v_x^2 + v_y^2$ $(+ v_z^2)$
  - **this is usually the largest type in biomechanics**
- **Rotational Kinetic = ½ I ? ^{2}**
  - **this is usually the smallest type in biomechanics**
- **Gravitational Potential = $m g y$**
- **Elastic Potential = $\frac{1}{2} k (x_1^2 - x_2^2)$**
  - **Assumed to be zero for rigid bodies**

Laws of Thermodynamics

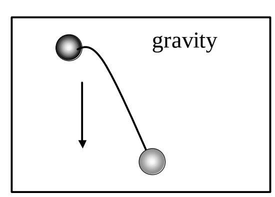
- **Zeroth law**
  - **When two quantities are in thermal balance to a third they are in thermal balance with each other. I.e., they have the same temperature.**
- **First Law (Law of Conservation of Energy)**
  - **Energy is conserved (remains constant) within a "closed system."**
  - **Energy cannot be created or destroyed.**
- **Second Law (Law of Entropy)**
  - **When energy is transformed from one form to another there is always a loss of usable energy.**
  - **All processes increase the entropy of the universe.**
- **Third Law**
  - **Absolute zero (absence of all atomic motion) cannot be achieved.**

Law of Conservation of Mechanical Energy

- **If the resultant force acting on a body is a conservative force then the body's total mechanical energy will be conserved.**
- **Resultant force will be conservative if all external forces are conservative.**
- **A force is conservative if it does no work around a closed path (motion cycle).**

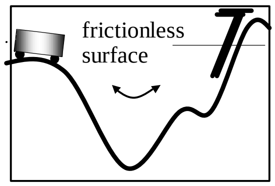
Examples of Conservative Forces

- **Gravitational forces**



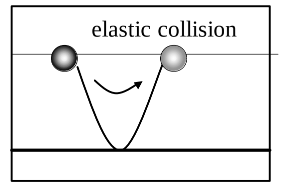
Examples of Conservative Forces

- Gravitational forces
- Normal force of a frictionless surface



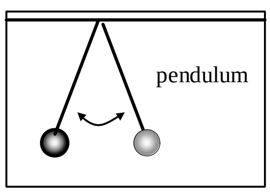
Examples of Conservative Forces

- Gravitational forces
- Normal force of a frictionless surface
- Elastic collisions



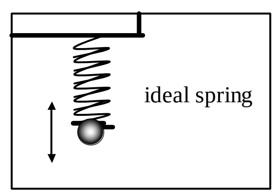
Examples of Conservative Forces

- Gravitational forces
- Normal force of a frictionless surface
- Elastic collisions
- Ideal pendulum



Examples of Conservative Forces

- Gravitational forces
- Normal force of a frictionless surface
- Elastic collisions
- Ideal pendulum
- Spring forces

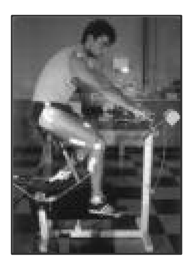


Direct Ergometry

- Treadmill ergometry
- External work = m g t v sin ?
- where, m = mass, g = 9.81, t = time, v = treadmill velocity, and ? = treadmill's angle of incline

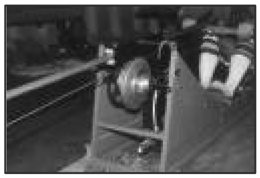
Direct Ergometry

- Cycle ergometry
- External work = 6 n L g
- where, n = number of pedal revolutions, L = load in kiloponds and g = 9.81
- Note, each pedal cycle is 6 metres motion of flywheel



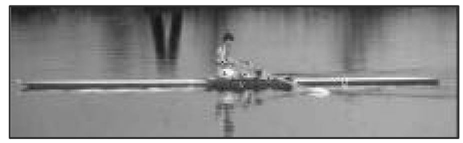
Direct Ergometry

- Gjessing rowing ergometry
- External work = n L g
- where, n = number of flywheel cycles, L = workload in kiloponds and g = 9.81



Biomechanical Methods

- Point mass method
  - Simplest, least accurate, ignores rotational energy
- External work = $m\,g\,y + \frac{1}{2}\,m\,v^2$

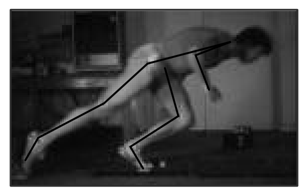


Biomechanical Methods

- Single rigid body method
  - Simple, usually planar, includes rotational energy
- External work = $mgy + \frac{1}{2}\,mv^2 + \frac{1}{2}\,I?^{2}$

Biomechanical Methods

- Multiple rigid body method
  - Difficult, usually planar, more accurate, accuracy increase with number of segments
- External work = $E_{final} - E_{initial}$
- E = sum of segmental total energies (kinetic plus potential energies)

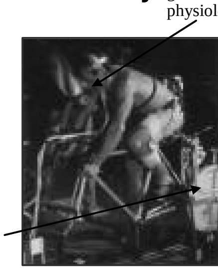


Physiological Methods

- Oxygen uptake
  - Difficult, accurate, expensive, invasive
- External work = $c\,(VO_2)$
- Where, *c* is the energy released by metabolizing O_2 and VO_2 is the volume of O_2 consumed

Mechanical Efficiency

- Measure both mechanical and physiological costs
- ME = mechanical cost divided by physiological cost times 100%



Mechanical Efficiency

Internal work + External work

ME = -- x 100 %

Physiological cost

Internal work is measured by adding up the work done by all the joint moments of force. Most researchers ignore the internal work done.

Work of a Force

Work of a force is product of force (F) and displacement (s) when F and s are in the same direction.

Work = F s (when F is parallel to s)

= F s cos ? (when F is not parallel to s and is ? angle between F and s)

= $\underline{F}$. $\underline{s}$ = $F_x s_x + F_y s_y$ (dot or scalar product)

= $E_f - E_i$ (change of energy)

= P t (power times time)

Work of a Moment of Force

Work of a moment of force is product of moment of force (M) and angular displacement (?).

Work = M ?

= r F (sin ?) ? ???is angle between r and F)

= P t (power times time)

Average Power

Power is the rate of doing work.

measured in watts (W), 1 watt = 1 joule per second (J/s)

Power = work / time (work rate)

= $(E_f - E_i)$ / time (change in energy over time)

= (F s) / t = F v (force times velocity)

= (M ?? / t = M ? (moment of force times angular velocity)

Instantaneous Power of a Force or Moment of Force

Power = F v (when F is parallel to v)

= F v cos ? (when F is not parallel to v and is ? angle between F and v)

= $\underline{F}$. $\underline{v}$ = $F_x v_x + F_y v_y$ (dot or scalar product)

= M ? (moment times angular velocity)

Isokinetic Dynamometers

- **Controls speed of motion therefore lever has constant angular velocity (?)**
- **Measures force against a lever arm**
- **Moment = force times lever arm**
- **Instantaneous power = moment time angular velocity**