Unit for thermal energy and efficiency

- 1 calorie (cal) = 0.001 Kcal = 4.187 J

  or 1 J = 0.239 cal

  - P = 100 J/s = _____ cal/s = _____ Kcal/min
- Efficiency
  - The percentile ratio of work output to energy input
- Usually human body has 25% efficiency in converting metabolic energy into mechanical energy ➔ the metabolic energy cost of the task would be four times greater than mechanical power generated.

Impact and Coefficients of restitution

KIN 335 Srping 2005

Impact

- Many sporting activities in which one object collides with another (e.g., baseball bat and a pitched ball, tennis racquet and ball, golf club and ball, bowling ball and pins) ➔ Impact
- Impacts
  - Generally occur over a very short period of time
  - Involve contact forces of high magnitude
  - Result in rapid changes in momentum of one or both colliding objects
  - During the brief time of impact the two colliding objects typically will undergo a period of deformation (i.e., change in shape) and a period of restitution (return to the original shape).

Quality of Impact

- The velocities of the two colliding objects following the impact depend on their velocities before impact and the nature or "quality" of the impact.
- Perfectly elastic impact
  - the relative velocities of the two objects after impact (separation velocities) are the same as their relative velocities before impact (approach velocities).
  - the total energy of motion is not changed.
- Perfectly plastic impact
  - the relative velocities of the colliding objects after impact are less than those before impact
  - some of the total energy of motion is lost (e.g., some may be transformed into heat associated with the deformation and restitution processes).

Coefficient of restitution

- Impacts which are neither perfectly elastic nor perfectly plastic, but somewhere between the two ➔ Coefficient of restitution describes the relative elasticity of an impact
- The relationship between the relative velocities of two bodies before and after an impact

$$e = -\frac{(v_1 - v_2)}{(u_1 - u_2)} = -\frac{(\textit{relative velocity after impact})}{(\textit{relative velocity before impact})}$$

- An e equal to 1 reflects a perfectly elastic collision, whereas e equal to 0 reflects a perfectly plastic collision.

Q. A baseball is coming to strike zone. A batter hit the ball exactly. If the coming ball velocity right before collision was 25 m/s and became 29 m/s right after collision to opposite direction. A bat swing speed right before collision was 30 m/s and reduced at 25 m/s right after collision (same direction). Then what would be the coefficient of restitution between bat and baseball during impact?

Another form of Coefficient of restitution

- When a object drops on the ground, the coefficient restitution is

$$e = - \frac{v_1}{u_1}$$

- Since the velocity of the floor before and after impact is zero ($v_2 = u_2 = 0$)
- Other expression of coefficient of restitution (using projectile motion equations)

$$e = \sqrt{\frac{h_b}{h_d}}$$

- h_d : the height of drop & h_b : the height of bounced

Q. A basketball is dropped from a height of 2 m onto a gymnasium floor. If the coefficient of restitution between ball and floor is 0.9, how high will the ball bounce?

Q. The 0.45-kg soccer ball is 1 m above the ground when it is kicked upward at 12 m/s. If the coefficient of restitution between the ball and the ground is $e = 0.6$, what maximum height above the ground does the ball reach on its first bounce?

Impact & Friction

- Top spin

- Under spin