IB phy Part 5

Work, Energy, and Power

https://scienceknowledge.webador.com/

Work

- A measure of energy transfer that occurs when an object is moved over a distance by an external force at least part of which is applied in the direction of the displacement.

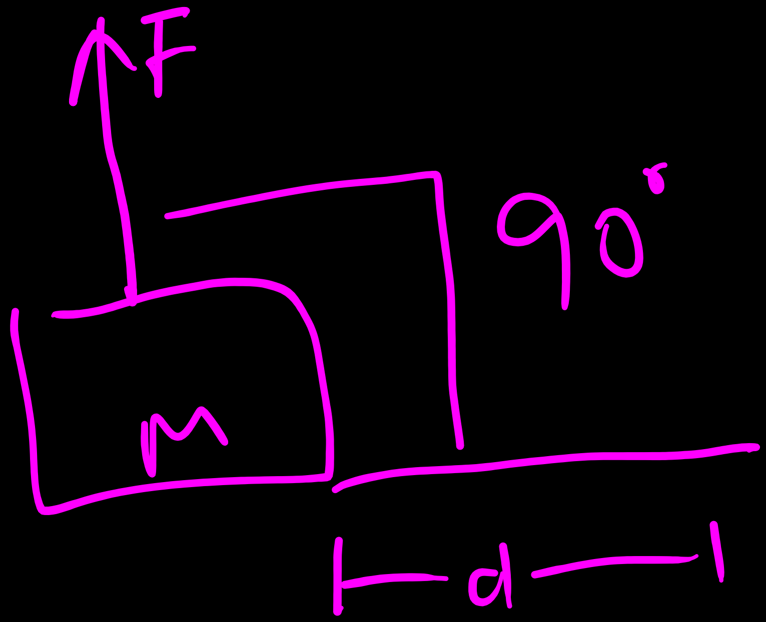
- Scalar quantity (dot product)

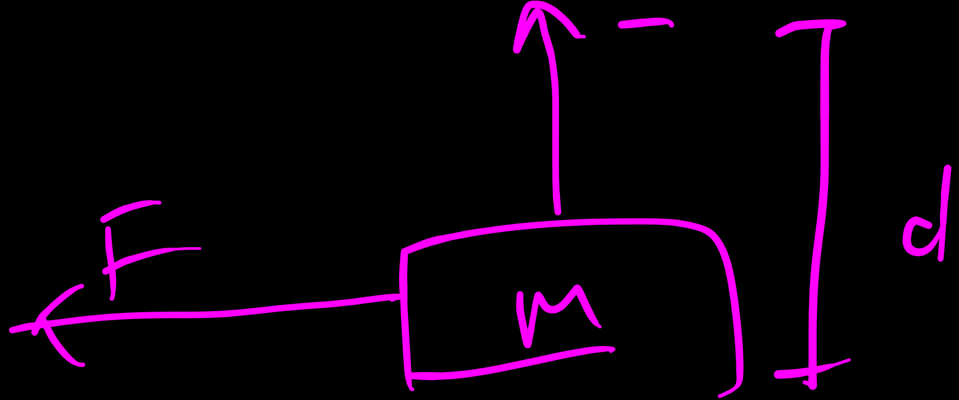
- $W = Fd\cos\theta$ ← The angle between F & d

Force applied

displacement

- [Joule] = $kg \cdot m^2 \cdot s^{-2} = \frac{kg \cdot m^2}{s^2}$



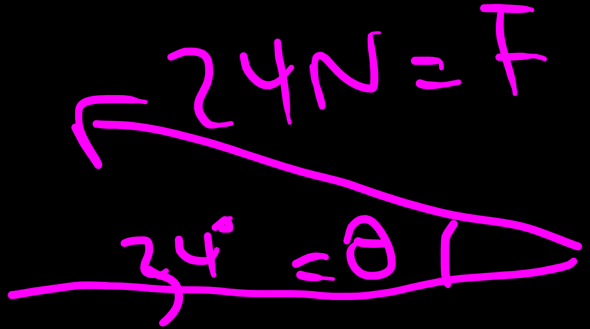


$W = 0\,J$

$$W = Fd\cos 90^\circ$$
$$= Fd\,0$$
$$W = 0\,J$$

$$Fd\cos\theta$$
$$1$$
$$Fd$$

A mass is being pulled along a level road by a rope attached to it in such a way that the ~~rope~~ Force makes an angle of 34 degree with the horizontal. The force in the rope is 24N. Calculate the work done by this force in moving the mass a distance of 8.0 m along the level road.



$$W = Fd\cos\theta$$

$$= (24)(8)\cos(34^\circ)$$

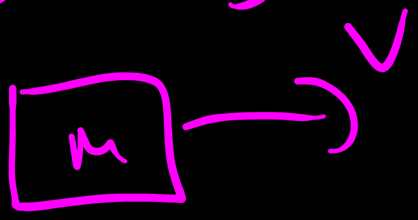
$$= 159.1755\ J$$

(Approximation)

Kinetic Energy (Energy)

- Kinetic energy is the energy an object has because of its motion

- Energy E is also a scalar quantity
- Joule = $kg \cdot m^2 \cdot s^{-2}$



$$\Delta \cancel{K} = \frac{1}{2} m \cancel{\Delta} v^2$$

$$\Delta v^2 = v_f^2 - v_i^2$$

- $K = \frac{1}{2} m v^2$

$$\rightarrow \Delta K = K_f - K_i = \frac{1}{2} m v_f^2 - \frac{1}{2} m v_i^2$$

$$= \frac{1}{2} m (v_f^2 - v_i^2)$$

(a) What is the kinetic energy of an 80-kg athlete, running at 10 m/s? (b) The Chicxulub crater in Yucatan, one of the largest existing impact craters on Earth, is thought to have been created by an asteroid, traveling at 22 km/s and releasing 4.2×10^23J of kinetic energy upon impact. What was its mass? (c) In nuclear reactors, thermal neutrons, traveling at about 2.2 km/s, play an important role. What is the kinetic energy of such a particle?

(a) $K = \frac{1}{2} m v^2 = \left(\frac{1}{\cancel{2}}\right)(\cancel{80}^{40})(10^2)^{100} = 4000\ \text{J}$

(b) $m = \frac{2K}{v^2} = \frac{(2)(4.2 \times 10^{23})}{22 \times 10^{+3}}$ 1 km = 1000 m

$m = 3.82 \times 10^{+19}$ kg

(c) $K = \frac{1}{2} m v^2 = (1)\left(\frac{1}{2}\right)(2.2 \times 10^{+3}) = 1.1 \times 10^{3}\ \text{J}$

Work-Energy Theorem

$$W = \frac{1}{2}m(v_f^2 - v_i^2)$$

Proof:

$$v_f^2 - v_i^2 = 2as$$

$$v_f^2 - v_i^2 = 2\frac{F}{m}s$$

$$\frac{1}{2}v_f^2 - \frac{1}{2}v_i^2 = \frac{F}{m}s$$

$$F = ma, \; a = \frac{F}{m}$$

$$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = Fs$$

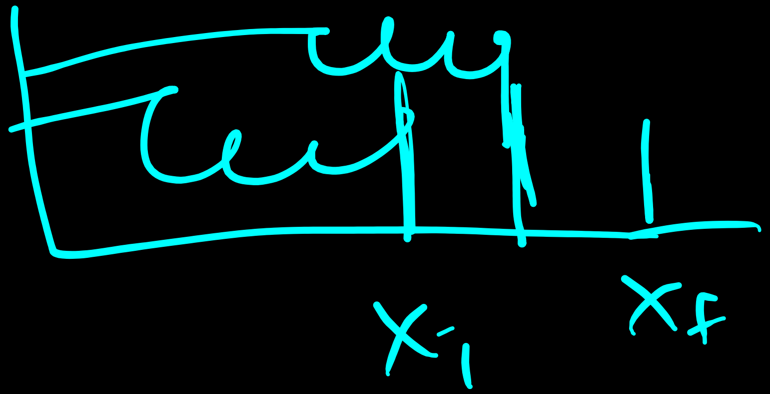
$$\frac{1}{2}m(v_f^2 - v_i^2) = W$$

Potential Energy

- Potential energy is defined as mechanical energy, stored energy, or energy caused by its position

$$U_g = mgh$$

$$\frac{1}{2}kx^2 = U_s$$



Spring/Elastic Potential Energy

- Elastic potential energy is Potential energy stored as a result of deformation of an elastic object, such as the stretching of a spring

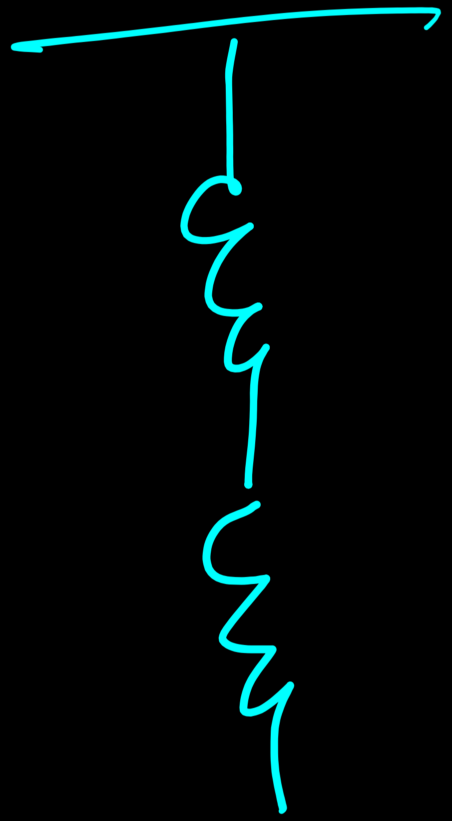
$$W = \int \vec{F} \cdot dx = \int kx \cdot dx = k \int x \cdot dx$$

$$W = k\frac{1}{2}x^2 = \frac{1}{2}kx^2$$

$$\Delta W = \Delta \underline{K}$$

Change in energy = work done by an force

Spring in Series and Parallel

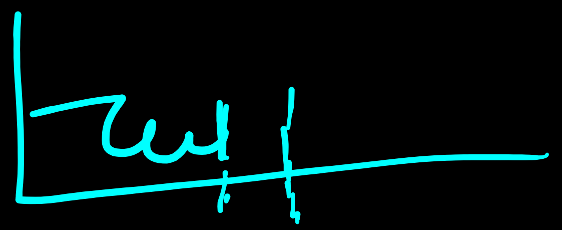


$$K_{sum} = K_1 + K_2 + \dots + K_n$$

$$\frac{1}{K_{sum}} = \frac{1}{K_1} + \frac{1}{K_2} + \dots + \frac{1}{K_n}$$

A mass of 8.4kg rests on the top of a vertical spring. The spring compresses by 5.2 cm. a) calculate the spring constant b)determine the energy stored in the spring

a) $K = 1584.69 \frac{N}{m}$



b) $U_s = \frac{1}{2} K X^2$

$$= \left(\frac{1}{2}\right)(1584.69)(0.052)^2$$

$U_s = 2.1425 N$

Gravitational Potential Energy

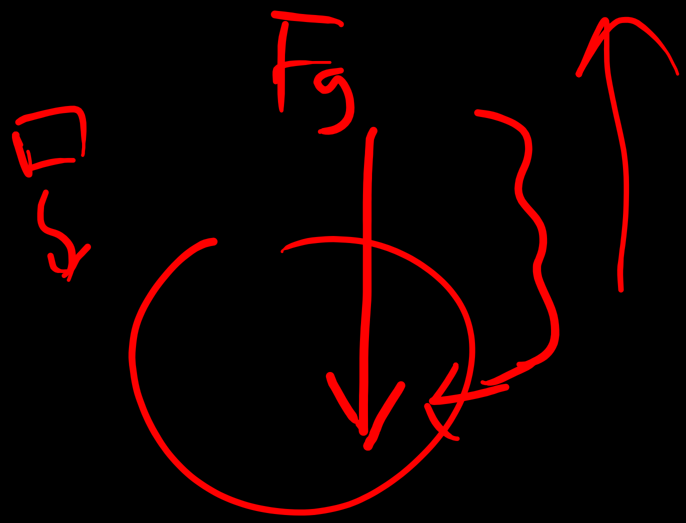
- Gravitational potential energy is energy an object possesses because of its position in a gravitational field.

- $U_g = m g h$ ← Vertical position

mass

9.81

- Conservation force F_g



$$\frac{Gm_1m_2}{r^2}$$

$U_g<0$

$U_g>0$

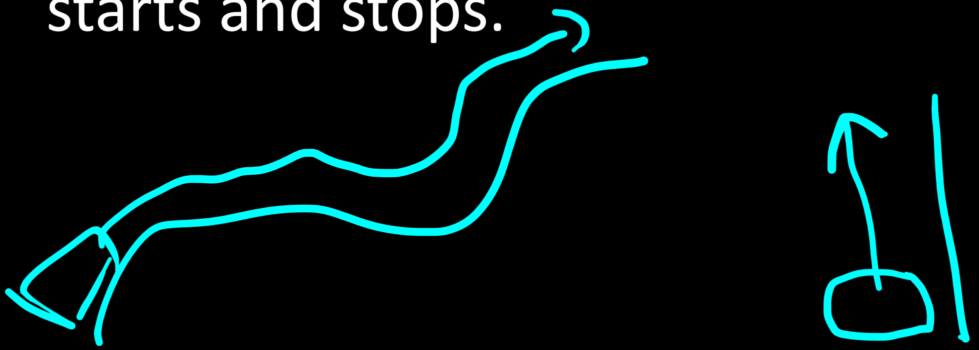
Conservative and Non-Conservative Force

- The work done by a conservative force is independent of the path
- A force is conservative if the work it does around any closed path is zero:

$$mgh_i = mgh_i$$

thermal energy

- **Non-conservative forces** are dissipative forces such as friction or air resistance.
- These forces take energy away from the system as the system progresses, energy that you can't get back.
- These forces are path dependent; therefore it matters where the object starts and stops.



Power

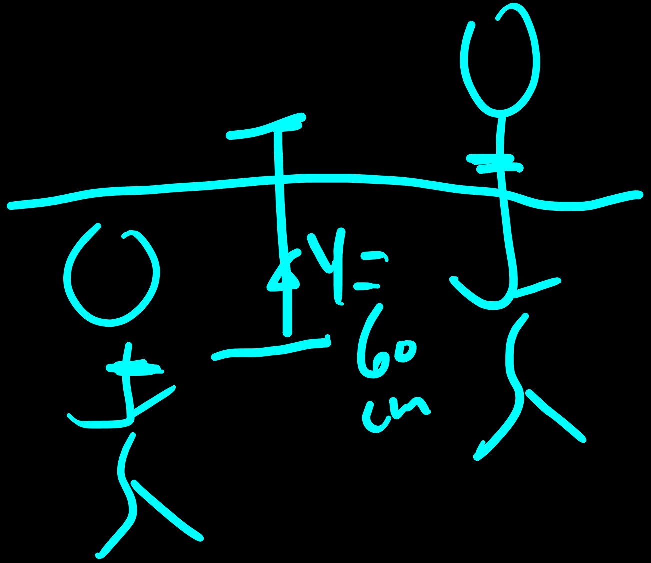
- Power is the amount of energy transferred or converted per unit time

$$P = \frac{W}{t} = \frac{E}{t} = \frac{F \cdot d}{t} = F \cdot \frac{d}{t} = Fv$$

$$P = \left[\frac{\text{Joul}}{s}\right] = [\text{watt}]$$

$$= \left[\frac{\frac{kg \cdot m^2}{s^2}}{s}\right] = \left[\frac{kg \cdot m^2}{s}\right]$$

An 80-kg army trainee does pull-ups on a horizontal bar. It takes the trainee 0.8 seconds to raise the body from a lower position to where the chin is above the bar. The trainee moves for 60cm. How much power do the trainee's muscles supply moving his body from the lower position to where the chin is above the bar?



$$P = \frac{E}{t} = \frac{W}{t} = \frac{F \cdot d\cos\theta}{t}$$

$$= \frac{mgh}{t}$$

$$= \frac{(80)(9.81)(0.6)}{0.8}$$

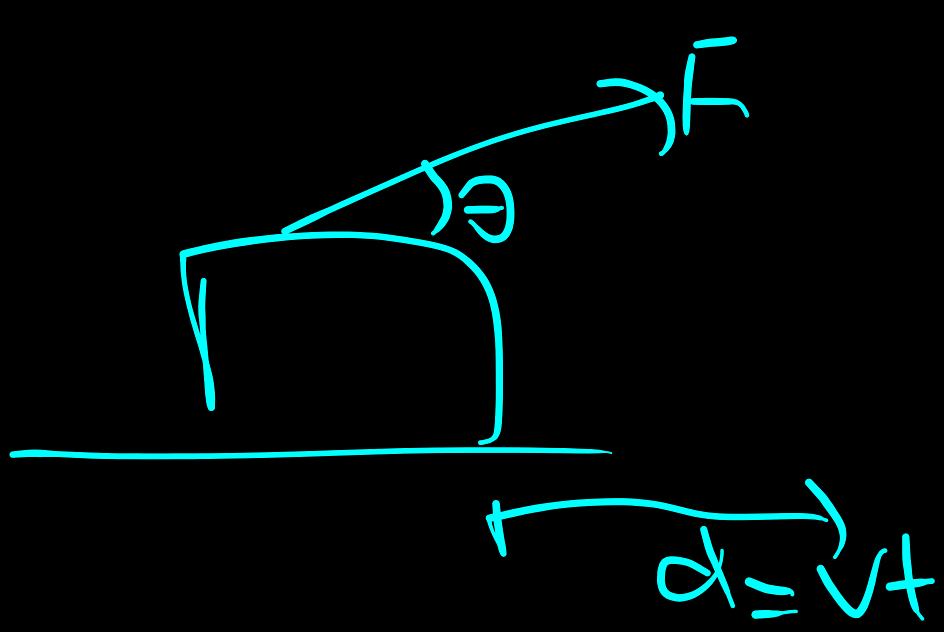
$$= 529\ W$$

$$U_g = mgh$$

$$60\,cm = 0.6\,m$$

An 80-kg army trainee does pull-ups on a horizontal bar. The trainee moves up at a velocity of 5 cm per second, and he moves for 2 second. How much energy does the trainee gain?

$$P = \frac{W}{t} = \frac{E}{t} = Fv$$



$$E = mgh = mgvt$$

displacement = Average velocity × time

$K = \frac{1}{2}mv^2$

$U_s = \frac{1}{2}kx^2$

$U_g = mgh$

$\left.\begin{array}{l} \left.\begin{array}{l} U_s = \frac{1}{2}kx^2 \\ U_g = mgh \end{array}\right\} \text{potential energy} \end{array}\right.$

$\left.\begin{array}{l} K = \frac{1}{2}mv^2 \\ U_s = \frac{1}{2}kx^2 \\ U_g = mgh \end{array}\right\} \text{mechanical energy}$

Mechanical Energy = Kinetic energy + Potential energy

s

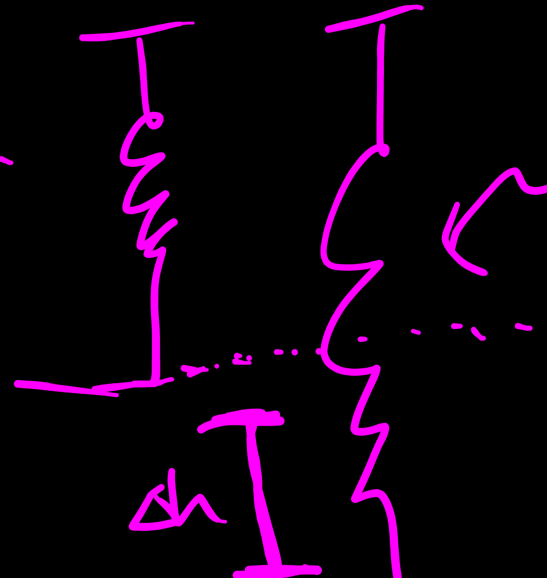
Conservation of Energy

The law of conservation of energy states that the total energy of an <u>isolated</u> system remains constant; it is said to be *conserved* over time

$$K_i + U_{si} + U_{gi} = K_f + U_{sf} + U_{gf} + E_{thermal}$$

$$\frac{1}{2}mv_i^2 + \frac{1}{2}kx_i^2 + mgh_i = \frac{1}{2}mv_f^2 + \frac{1}{2}kx_f^2 + mgh_f$$

Coment:

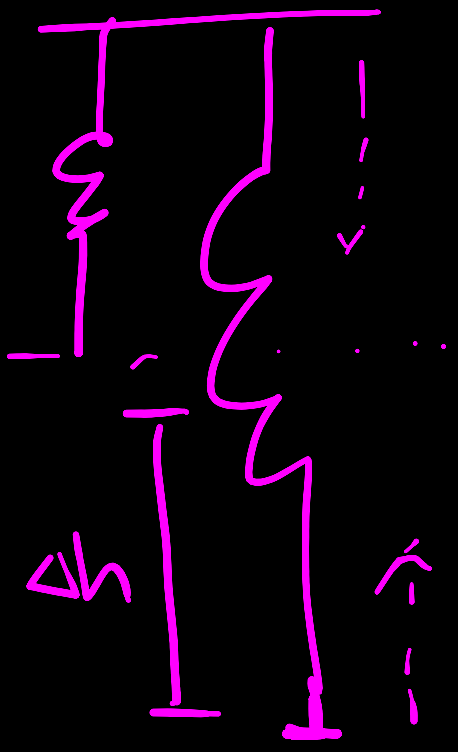


$$\frac{1}{2}k\underline{\Delta x}^2 = \frac{1}{2}k(x_f^2 - x_i^2)$$

$$mg\underline{\Delta h} = mg(h_f - h_i)$$

$$\Delta h = \Delta x$$

Spring's Maximum Stretch



spring is released

$$E_i = E_f$$

$$\cancel{K_i} + \cancel{U_{s_i}} + U_{g_i} = \overset{0}{\cancel{K_f}} + U_{sf} + U_{gf}$$

$$0 + 0 + mgh_i = 0 + \frac{1}{2}k\Delta h^2 + mgh_f$$

$$mgh_i - mgh_f = \frac{1}{2}k\Delta h^2$$

$$mg(h_i - h_f) = \frac{1}{2}k\Delta h^2$$

$$mg\cancel{\Delta h} = \frac{1}{2}k\Delta h^{\cancel{2}}$$

$$\frac{2mg}{k} = \Delta h$$

A block of mass 2.5kg slides on a rough horizontal surface. The initial speed of the block is 8.6m/s. It is brought to rest after travelling a distance of 16 m. Dtermine the magnitude of he frictional force.

Energy gaind = Energy lost = Work done

gains frictional energy

lost Kinetic energy

ΔK

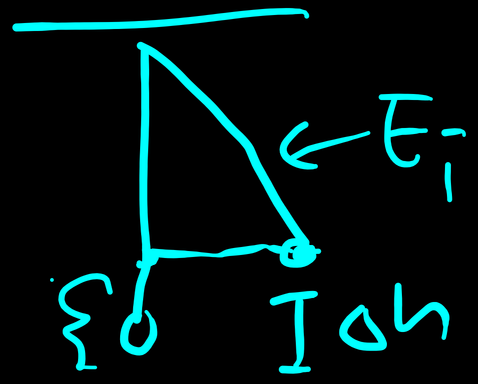
$$E_{thermal} = \Delta K$$

$$f \cdot d = \frac{1}{2} m v_i^2$$

$$-f = \frac{m v_i^2}{2d} = \frac{(2.5)(8.6)^2}{2(16)} = 5.778 \text{ N}$$

A pendulum of length 1.0m is released with the string at a angle of 10 degree to the vertical. Find the speed and mass of the pendulum when it passes the lowest position

$$\Delta h = 1 - 1\cos 10^\circ = 1(1 - \cos 10^\circ)$$



$$E_i = E_f$$

$$K_i + \cancel{U_{si}}^{0} + U_{gi} = K_f + \cancel{U_{sf}}^{0} + U_{gi}$$

$$U_{gi} - U_{gf} = K_f - \cancel{K_i}^{0}$$

$$\rightarrow \Delta U_g = \Delta K = K_f$$

$$\cancel{m} g \Delta h = \frac{1}{2} \cancel{m} V_i^2$$

$$g\Delta h = \frac{1}{2} V_i^2$$

$$\sqrt{2g\Delta h} = V_i$$

$$2(10)(1 - 1\cos 10^\circ) = V_i$$

$$V_i = 0.55 \frac{m}{s}$$