In his Name

Physics Summary

SY: 2020 /2021

Al-Mahdi Schools

Chapter 1: Energy | **Grade 12** GS

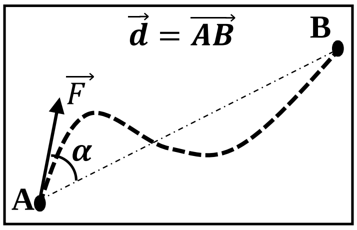
I- Prerequisites:

- Scalar or dot product $\vec{v}_1.\vec{v}_2 = v_1 \times v_2 \times \cos(\alpha)$
- Derivative :$(u^m)' = m\, u^{m-1}u'$
  e.g.: $(x^2)' = 2xx'$ for rectilinear motion $x' = v$ so: $(x^2)' = 2xv$
  $(v^2)' = 2vv'$ for rectilinear motion $v' = a$ so: $(v^2)' = 2va$
- Rectilinear motion:
  1. URM: $a = 0$, $v = constant$: $x = vt + x_0$
  2. URAM: $a.v > 0$,$|v| \nearrow$
  3. URDM: $a.v < 0$, $|v| \searrow$

  $$:\left\{\boxed{\begin{array}{l} x = \frac{1}{2}at^2 + v_0t + x_0\ ; \\ v = at + v_0\ ;\ v^2 - {v_0}^2 = 2a(x - x_0) \end{array}}\right.$$

II- Work done by a force:

- A force works if it participates in the motion of a system.
- The work done by a **constant force** $\vec{F}$ acting on a solid (S), whether (S) moves along a **rectilinear** displacement $\vec{d} = \overrightarrow{AB}$ or along a **curvilinear** trajectory from A to B (adjacent figure), is: $\boldsymbol{W_{\vec{F}} = \vec{F}.\vec{d} = F \times d \times \cos\alpha}$
- In SI units **F** is in Newton (**N**), **d** is in meter (**m**) and **W** is in Joules (**J**).

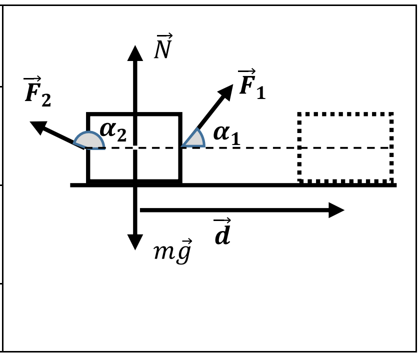


- A **constant force** is a force that keeps the **same direction** and **magnitude**
- The work done by a constant force is **independent** of the followed path.

Note 1

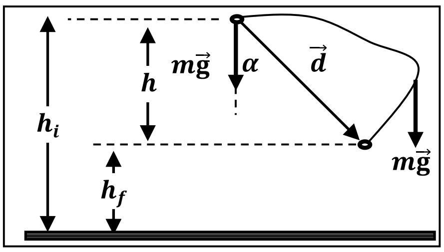
- Particular cases:

Angle α	Work of $\vec{F}$	Participation in motion
Acute	$W_{\vec{F}} > 0$	The work is motive, and the force tends to accelerate the motion (e.g.: work of $\vec{F}_1$)
Obtuse	$W_{\vec{F}} < 0$	The work is resistive, and the force tends to decelerate the motion (e.g.: work of $\vec{F}_2$)
90°	$W_{\vec{F}} = 0$	No participation in motion (e.g.: work of $m\vec{g}$ and $\vec{N}$)



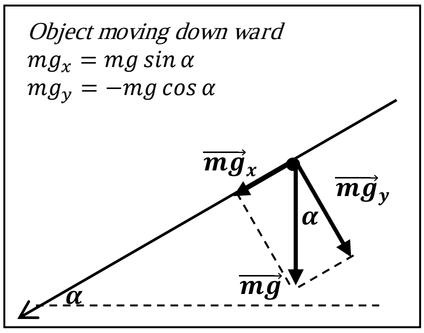
1. Work done by weight

- **Along any path:**
  When an object moves from an initial height h_i to a final height h_f, the work of the weight as a constant force is independent of the followed path



$$\boldsymbol{W_{m\vec{g}} = mgd\cos\alpha = mgh = mg(h_i - h_f)}$$

- If the body moves up: $h_i < h_f \Longrightarrow W_{\overrightarrow{mg}} = -mgh < 0$ then the weight resists the motion.
- If the body moves down: $h_i > h_f \Longrightarrow W_{\overrightarrow{mg}} = mgh > 0$ then the weight helps the motion.

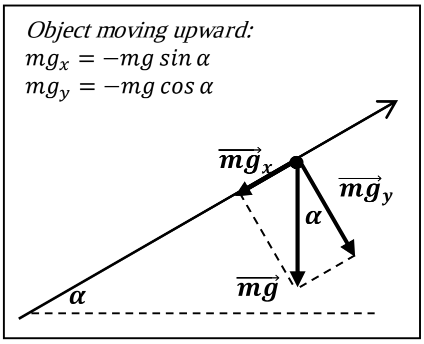


- **Along an inclined plane:**

$W_{\overrightarrow{mg}} = W_{\overrightarrow{mg}_x} + W_{\overrightarrow{mg}_y}$

$= \overrightarrow{mg}_x . \vec{d} + \overrightarrow{mg}_y . \vec{d}$

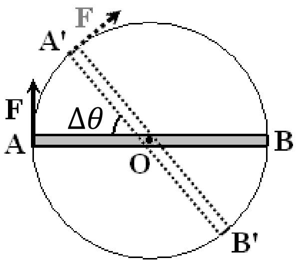
$= mg_x \times d \times \cos(\overrightarrow{mg}_x ; \vec{d}) + 0$



- Downwards motion:
  $\alpha(\overrightarrow{mg}_x ; \vec{d}) = 0° \Longrightarrow$
  $W_{\overrightarrow{mg}} = +mgd \sin\alpha$

- Upwards motion:
  $\alpha(\overrightarrow{mg}_x ; \vec{d}) = 180° \Longrightarrow$
  $W_{\overrightarrow{mg}} = -mgd \sin\alpha$

2. **Work done by a force having a constant moment M**



$W_{\vec{F}} = \boldsymbol{M} \times \Delta\theta$

($\Delta\theta = \theta - \theta_0$ is the angle described by the object in rotation.

III- Power due to the force

- **Definition**: The power is the time rate at which work is done by a force
- The average power: $P_{av} = \frac{\text{work done}}{\text{taken time}} = \frac{w}{\Delta t}$ or $P_{av} = \frac{W}{\Delta t}$
- The instantaneous power: $\boldsymbol{P} = \lim_{\Delta t \to 0} \left(\frac{\Delta \boldsymbol{W}}{\Delta t}\right) = \frac{\mathbf{d}\boldsymbol{W}}{\mathbf{dt}} = \overrightarrow{\boldsymbol{F}} . \overrightarrow{\boldsymbol{V}_\iota}$
- **In rotational motion P = M ×** $\boldsymbol{\theta'}$ *(where* $\boldsymbol{\theta'} = \frac{d\theta}{dt}$ *is the angular velocity in* $\boldsymbol{rad/s}$*)*
- In S.I units, ***W*** is in joules (**J**), **t** is in (**s**) and **P** is in Watt (**W**).
- $1\, kWh = 1000 \times W \times 3600s = 36 \times 10^5 J$

if the power P is constant then
$P = P_{av}$

Note 2

IV-Energy:

Energy is the ability to produce work. The SI unit of energy is the Joule (J).

1. **Kinetic Energy:** is the energy stored in a body or a system due to its velocity.
   - Case of a particle or a rigid body in translation**:** $\boldsymbol{E_k} = ½\, \boldsymbol{m}\, \boldsymbol{v}^2$
   - Case of a system of particles**:**

   $$E_{k\,(system)} = \sum E_{k(particles)} = ½\, m_1 v_1^2 + ½\, m_2 v_2^2 + \cdots$$

   - For a rigid body in rotation**:** $\boldsymbol{E}_{\boldsymbol{k}(\mathbf{system})} = ½\, \boldsymbol{I}\boldsymbol{\theta'}^2$

Work-energy theorem
$\Delta E_k = E_{kf} - E_{ki} = \sum W_{\vec{F}_{ext}}$

Note 3

2. **Potential energy:** is the energy stored in the system, due to the interaction between its particles.
Potential energy could be elastic, gravitational, torsion...

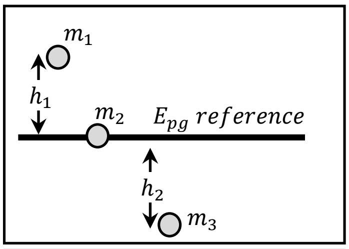
- **Gravitational potential energy (E_{pg}): $E_{pg} = \pm m\, g\, h$**

  e.g. (on the adjacent figure)

$E_{pg1} = +m_1 g h_1$

$E_{pg2} = +m_2 g h_2 = 0$

$E_{pg3} = -m_3 g h_3$



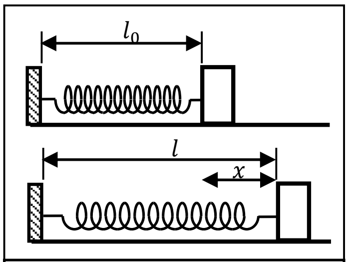
Variation of E_{pg}
$\Delta E_{pg} = m\, g\, (h_f - h_i)$
$= -W_{m\vec{g}}$

Note 4

- **Elastic potential energy**

  $E_{pe} = \frac{1}{2} k\, (\Delta\, l)^2 = \frac{1}{2} kx^2$

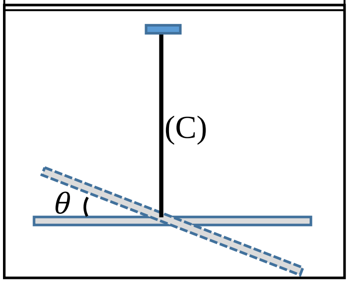
  k: spring constant (or stiffness) expressed in N/m (SI)



- **Torsion Potential energy**

  $E_{pt} = \frac{1}{2}\, C(\theta)^2$

  C: is the torsion constant of the wire is in Nm/rad **(SI)**



Analogy	
Spring	Torsion wire
k: spring constant	**C**: torsion constant
$T = -kx$	$M = -C\theta$
$E_{Pe} = \frac{1}{2}kx^2$	$E_{Pt} = \frac{1}{2}C\theta^2$

3. **Mechanical Energy**: is the sum of the kinetic energy and potential energy of a system $E_m = E_k + E_{pg} + E_{pe}$

- **Conservation of mechanical energy:** If no non - conservative forces acting on the system: $E_m = constant$ and $\Delta E_m = 0$ **so** $E_{mi} = E_{mf}$
- **Non conservation of mechanical energy:** If non – conservative forces exist

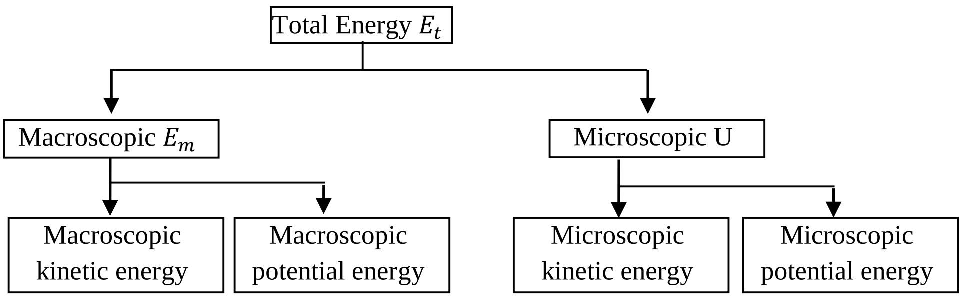
  $\Delta E_m = \sum W_{\vec{F}(non-conservative\ forces)}$

  - Non conservative forces: friction, traction, push…
  - Conservative forces: weight, normal, tension of spring.

$W_{\vec{F}(non-conservative\ forces)} \neq 0$
$\Rightarrow E_m \neq const.$
$|\Delta E_m| = |E_{mf} - E_{mi}|$
This is the amount of energy gained by the system in the form of E_m or lost in thermal form.

Note 5

4. **Total Energy $E_t = E_m + U$**



Energy-isolated system:
$E_t = E_m + U = constant$
$\Longrightarrow \Delta E_m = -\Delta U$ **(e.g.: the system [(S), Earth, atmosphere].**

In addition, if $\Delta U = 0$ then $\Delta E_m = 0$ therefore $E_m = E_K + E_P =$ constant
As a result, $\Delta E_K = -\Delta E_P$

Note 6