LABOR, ENERGY AND POWER

Name: ________________________________

Cell number: _________________________

E-mail address: _________________________

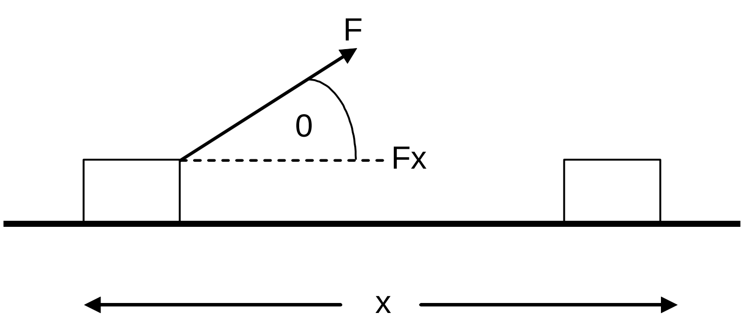
DEFINITIONS	
The ***labour*** done on an object by a constant force F is **FΔxcosθ,** where F is the size of the force, Δx is the size of the displacement and θ the corner between the force and the displacement.	
Labour-energy theory	The labour done on an object through a net force is equalled to the change in kinetic energy of the object.
Conservative force	A force of which labour is done to move an object between two points that is independent of the route followed.
Non-conservative force	A force of which labour is done to move an object between two points that is dependent of the route followed.
The principle of the retention of mechanical energy	The total mechanical energy in a closed system stays constant.
Power	The pace at which labour is done or energy is used.

SYMBOLS AND UNITS			
Labour (W, W_{nc})	Joule (J)	Kinetic energy (Ek)	Joule (J)
Force (F)	Newton (N)	Potential energy (Ep)	Joule (J)
Horizontal displacement (Δx)	Meter (m)	Height (h)	Meter (m)
Frictional force (*f*)	Newton (N)	Mass (m)	Kilogram (kg)
Power (P)	Watt (W)	Initial velocity (v_i)	$m.s^{-1}$
Velocity (v)	$m.s^{-1}$	Terminal velocity (v_f)	$m.s^{-1}$

LABOUR

Labour = force x displacement OR W = FΔx

- Labour is a scalar.
- SI-unit for labour is Joule (J).
- 1J labour is done if a force of 1N follows a displacement of 1m.



A block with mass m, is being pulled with force F at an angle θ with the horizontal. The block undergoes a displacement Δx in a straight line.

From the sketch you can see that:

- Force F is not in the same direction as the displacement.

- The force that does the labour is the component of Force F that works in the direction parallel to the block's displacement.
- Force F has 2 perpendicular components:
- A vertical component $F_y = F \sin \theta$.
- A horizontal component $F_x = F \cos \theta$.
- F_y tends to lift the block and F_x tends to pull the block horizontally.
- To calculate labour we therefore use F_x because it is parallel to the displacement.

Thus, the following formula is used to calculate labour:

$W = F_{net}\Delta x \cos \theta$ where θ is the angle between F and x.

Thus: **$W_{net} = F_{net}\Delta x \cos \theta = \Delta E_k$**

- ✓ The first thing you have to do is to determine whether the object is accelerating or not.
- ✓ If the object's acceleration is 0 (velocity is constant or 0) then the W_{net} is 0. (Then F_{net} en $\Delta E_k = 0$).
- ✓ If the object accelerates, net power is being exercised in the direction of the acceleration. First calculate the net force and then the labour.
- ✓ Choose the movement direction as positive.
- ✓ Remember that the net force is in the direction of the acceleration. It is not necessarily in the direction of the movement (negative acceleration). Therefore the value of θ can be 0° or 180°.
- ✓ It is **important** to draw a force diagram or a free body diagram before trying to solve the problem.
- ✓ The formula **$W_{net} = F_{net}\Delta x \cos \theta$** is applicable to any force. If, for example, you are asked to calculate the labour caused by friction force, you then apply the formula: $W_{wrywing} = F_{wrywing} \Delta x \cos \theta$. Remember to determine the value of θ and then replace it in the formula.

$W = F\Delta x \cos \theta$ ***Object moves at a constant velocity.***	$W_{net} = F_{net}\Delta x \cos \theta$ ***Object's velocity changes.***

Positive labour:

F works in the direction of Δx, θ = 0°.

Negative labour:

F works against the direction of Δx, θ = 180°.

No labour:

Displacement of object is perpendicular on F, θ = 90°.

ENERGY

Energy is the ability to do labor and is measured in Joules.

Mechanical Energy
The sum of the Kinetic Energy and Gravitational Potential energy at a point.

Kinetic Energy
The energy that an object has because of its movement.
$E_k = ½ mv^2$

Gravity Potential Energy
The energy that an object has because of its position relative to a reference point.
$E_p = mgh$

THE LABOR-ENERGY THEORY

Net labor done on an object = change in the object's kinetic energy.
$W_{net} = \Delta E_k$
$W_{net} = E_{kf} - E_{ki}$
$W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$

If the **acceleration** of an object is **given**, F_{net} can be calculated with Newton's 2nd principle/law.

If the object **accelerates**:
- F_{net} is in the direction of Δx, therefore $\theta = 0°$.
- W_{net} is a positive value, terminal velocity > initial velocity.

If the object **decelerates**:
- F_{net} is against the direction of Δx, therefore $\theta = 180°$.
- W_{net} is a negative value, terminal velocity < initial velocity.

If the objects **moves at a constant velocity** no labor is done.

RETENTION OF MECHANICAL ENERGY

In the absence of external forces on the system, the mechanical energy in the system stays constant, which is why:

ME (A) = ME (B)
$(E_p + E_k)_A = (E_p + E_k)_B$
$(mgh + \frac{1}{2}mv^2)_A = (mgh + \frac{1}{2}mv^2)_B$

The retention of mechanical energy can be used where objects are thrown vertically upwards if the effect of the air resistance is ignored. Seeing as there are no external forces, the total momentum of the system will be preserved.

FRICTION

- Friction is always in the opposite direction of movement
- For labour done through friction force, θ is always 180°.
- Friction does negative labour.
- The size of the friction force is influenced by the friction coefficient of the object and the surfaces that it is in contact with.
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EFFECT OF FRICTION

When **friction** is involved, mechanical energy gets lost and that is why the **principle of mechanical energy** matters. Non-conservative forces are now involved.

W_{nc} is calculated when you are asked to calculate **labour through friction**

$$W_{nc} = \Delta E_p + \Delta E_k$$
$$= mg(h_f - f_i) + \frac{1}{2}m(v_f^2 - v_i^2)$$

W_{nc} is **positive** when energy is **added** to the system.
W_{nc} is **negative** when energy is **removed** from the system.

POWER

$$P = \frac{W}{\Delta t} = \frac{F\Delta x}{\Delta t} = Fv$$

The unit of power is Watts, 1 W power is when 1J labour is done per second.

When force F moves an object at a **constant velocity,** the **average power** of the force is $P_{gem} = F_{gem}v$.

When information is provided on **time**, calculate the labour done by the force first and then the power.