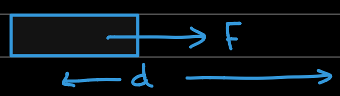
WORK, ENERGY, AND POWER

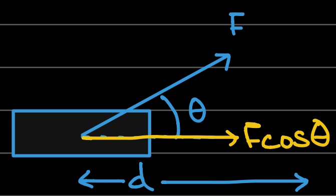
Work Done : Product of the force and the distance moved in the direction of the force

Examples:

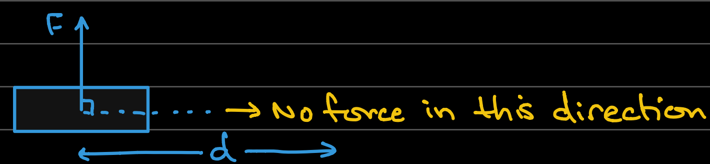
① $w.d = F \times d$



② $w.d = F\cos\theta \times d$
$= Fd\cos\theta$



③ $w.d = 0$



*Hence, if F applied and d moved are perpendiculer, then work done is zero.

Standard Notations used in exams

Work done by the driving force / forward force / engine :

$W = F_D \times d$ where F_D = Driving force

work done against resistance / against friction / by the opposing force

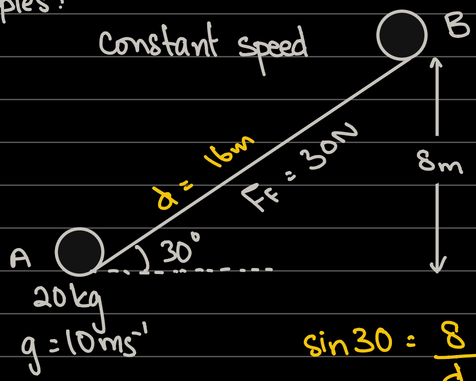
$W = F_F \times d$ where F_F = Frictional / Opposing / Resistive Force

Q. What happens to the work done on any object?
A. In mechanics, work done always gets converted into some form of energy which is why work done and energy have the same units, that is Joules.

Generally .... Work Done

- Kinetic Energy $\frac{1}{2}mv^2$
- Gravitational Energy mgh
- Heat Energy / Work Done against friction

Examples:



Q. Calculate the work done in moving the object from A to B

$\sin 30 = \frac{8}{d}$

$d = 16m$

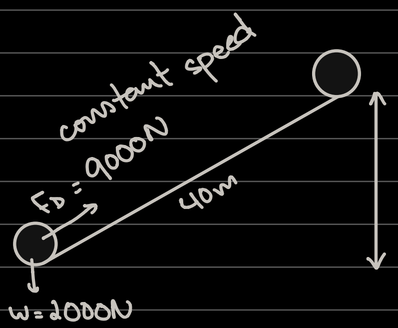
GPE = mgh
= (20)(10)(8)
= 1600 J

ΔKE = 0 since constant speed

w.d against friction = $F_F \times d$
= 30 × 16
= 480 J

Total work done = 1600 + 480
= 2080 J → Ans

2.



Total work done = $F_D \times d$
= 9000 × 40
= 360 KJ → All of this work done results in one of the three energies below

ΔK.E
= 0 since constant speed

G.P.E
= mgh
= (2000)(12)
= 24 KJ

W. done against Friction
= 360 - 24 KJ
= 336 KJ

ENERGY

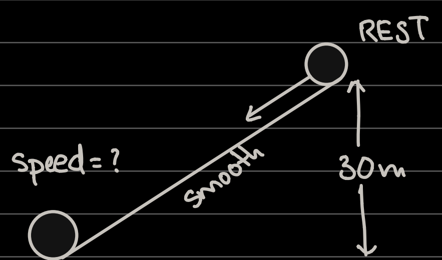
- Defined as the ability to do work

Law of Conservation of Energy:

Energy cannot be created nor destroyed, but it can be transformed from one form to another.

Different formulae for different questions:

1.



Energy at start = Energy at end

G.P.E = K.E

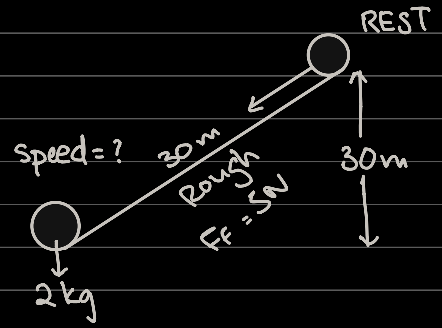
$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$gh = \frac{1}{2}v^2$

$(10)(30) = \frac{1}{2}v^2$

$\therefore\ 24.5ms^{-1} = v$

2.



NOW, energy at the start ≠ energy at the end because of energy lost due to friction

Hence, energy at start − w.d against friction = energy at the end

$$GPE - [F_F \times d] = K.E$$

$$mgh - [5 \times 60] = \frac{1}{2}mv^2$$

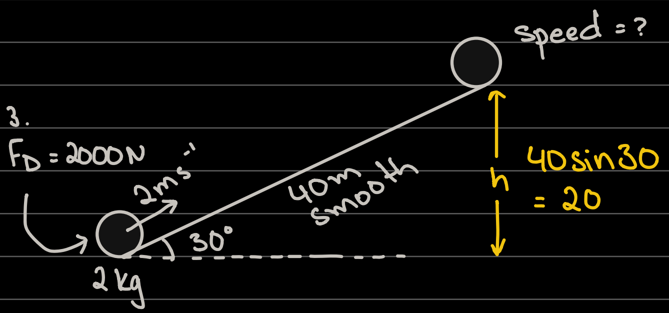
$$(2)(10)(30) \quad 300 = \frac{1}{2}(2)v^2$$

$$600 - 300 = v^2$$

$$300 = v^2$$

$$\therefore, \ 17.3 ms^{-1} = v$$

3.



Energy at the start ≠ Energy at the end because there is a driving force

Hence, Energy at the start + w.d by driving force = Energy at the end

$$KE + [F_D \times d] = KE + mgh$$

$$\frac{1}{2}mv^2 + (2000 \times 40) = \frac{1}{2}mv^2 + (2)(10)(20)$$

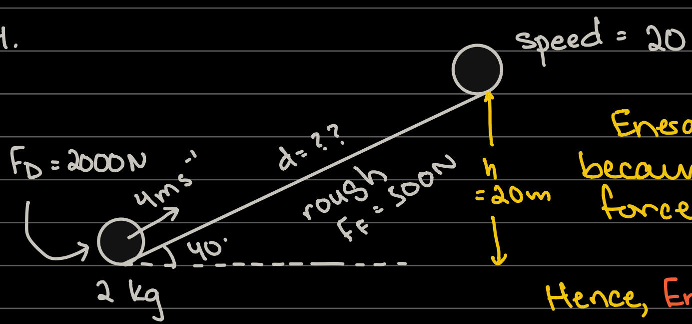
$$\frac{1}{2}(2)(2^2) + 80\,000 = \frac{1}{2}(2)v^2 + 400$$

$$4 + 80000 - 400 = v^2$$

$$\sqrt{79604} = \sqrt{v^2}$$

$$\therefore, \ 282 ms^{-1} = v$$

4.



Energy at the start ≠ Energy at the end because of unbalance driving and frictional forces

Hence, Energy at the start + w.d by driving force − w.d against friction = Energy at the end

$$K.E + [F_D \times d] - [F_F \times d] = K.E + GPE$$

$$\frac{1}{2}mv^2 + (F_D \times d) - (F_F \times d) = \frac{1}{2}mv^2 + mgh$$

$$\frac{1}{2}(2)(4^2) + 2000d - 500d = \frac{1}{2}(2)(20^2) + (2)(10)(d\sin 40)$$

$$16 + 1500d = 400 + 20d\sin 40$$

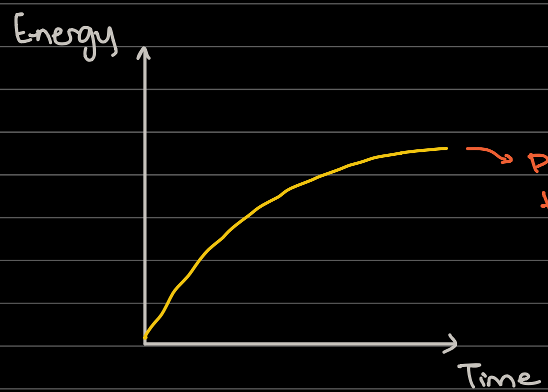
$16 + 1500d - 400 = 20d\sin 40$

POWER: The rate of work done / energy transferred

$P = \frac{\text{work done}}{\text{time}}$ or $P = \frac{\text{Energy}}{\text{Time}}$

$P = \frac{F \times \boxed{d}}{\boxed{t}} \rightarrow \frac{d}{t} = v$

Hence, $P = Fv$



→ Power can be obtained from the gradient

EFFICIENCY:

$\text{Efficiency} = \frac{\text{Useful Power Output}}{\text{Total Power Input}} \times 100$

OR

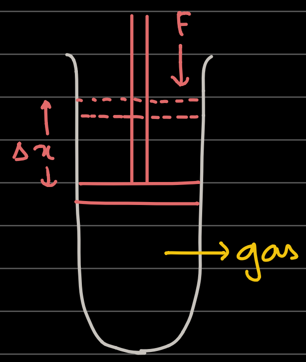
$\text{Efficiency} = \frac{\text{Useful Energy Output}}{\text{Total Energy Input}} \times 100$

→ Used to convert efficiency to a percentage, but technically not part of the definition / formula of efficiency

WORK DONE IN CASE OF GASES : WORK DONE ON GASES

- The diagram below shows a container filled with a gas
- The piston is positioned is shown. The area of the piston is denoted by A. We apply the force F downwards on the piston so that the piston moves a small distance Δx.

- In this case, since the gas molecules will get "compressed", therefore, we will say that the work is done on the gas
  - ↳ This value can be calculated as shown



w.d on the gas :

$$
\begin{aligned}
w.d &= F \times d \\
&= P \cdot \underbrace{a \times d} \\
&= P \cdot \Delta V
\end{aligned}
$$

Q. A pressure of 100kPa causes volume of a gas to change from 50cm[illegible] to $35cm^3$. Calculate the work done on the gas.

$$
\begin{aligned}
\text{w.d on the gas} &= P \cdot \Delta V \\
&= 100 \times 10^3 \times (15 \times 10^{-6}) \\
&= 1.5\,J
\end{aligned}
$$

WORK DONE IN TERMS OF GASES : Work done by gases

- If the gas undergoes expansion which causes the piston to move upwards, then we can say that work has been by the gas.

W.D by the gas $= P \cdot \Delta V$

Q. The volume of a gas at pressure 100kPa changes from $100cm^3$ to $140cm^3$. Calculate the work done by the gas.

$$
\begin{aligned}
\text{w.d by the gas} &= P \cdot \Delta V \\
&= 100 \times 10^3 \times 40 \times 10^{-6} \\
&= 4\,J
\end{aligned}
$$