# Chapter 6 - Work, Energy, Oscillations

Work = Force x distance

↳ transfer of energy

forms of energy
* motion -> velocity -> kinetic energy
* chemical energy -> food -> gasoline -> camp fire
* heat -> atomic/molecular vibrations - kinetic energy
* nuclear energy -> sun -> abombs
* light -> electromagnetic energy
* potential energy
    * energy of position
    * object having height
    * object compressing a spring
    * charge in an electric force field

simple machines
* lever
* incline plane (wedge)
* pulley

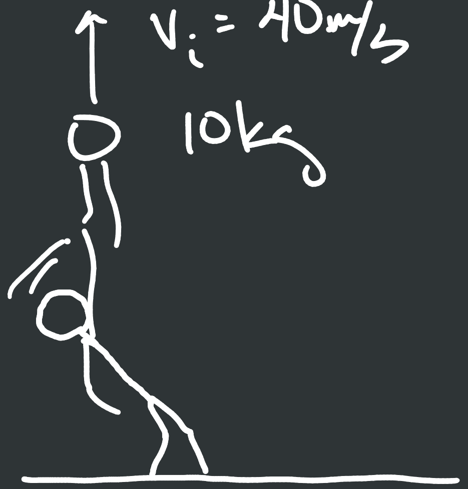
$$\text{Work}_{in} = \text{Work}_{out}$$

$$1 = \frac{\text{Work out}}{\text{Work in}}$$

ideal

$$\text{efficiency} = \frac{\text{Work out}}{\text{Work in}}$$

$a = -10\,m/s^2$




$v_f = v_i + a \cdot t$

$\Delta y = v_i \cdot t + \frac{1}{2}at^2$

$9.8\,m/s^2$

| $t$ | $v_f$ | $\Delta y$ | $\frac{1}{2}mv^2 + m \cdot g \cdot \Delta y$ |
|---|---|---|---|
| 1s | 30.2 m/s | 35.1 m | $\frac{1}{2}(10kg)(30.2\,m/s)^2 + 10kg \cdot 9.8\,m/s^2 \cdot 35.1m$<br>$8000\,kg\,m^2/s^2$ |
| 2s | 20.4 m/s | 60.4m | $\frac{1}{2}(10kg)(20.4\,m/s)^2 + 10kg \cdot 9.8\,m/s^2 \cdot 60.4m$<br>$8000\,kg\,m^2/s^2$ |
| 3s | 10.6 m/s | 75.9m | $8000\,kg\,m^2/s^2$ |
| 4s | 0.8 m/s | 81.6m | $8000\,kg\,m^2/s^2$ |
| 0s | 40 m/s | 0 | $\frac{1}{2}(10kg)(40\,m/s)^2 + 10kg \cdot 9.8\,m/s^2 \cdot$<br>$8000\,kg\,m^2/s^2$ |

$$\frac{kg \cdot m^2}{s^2} = \frac{kg \cdot m}{s^2} \cdot m$$

how fast is the ball going when it is 20m above my hand?

$$\Delta y = v_i \cdot t + \frac{1}{2}at^2 \qquad v_f = v_i + at$$

$$\frac{1}{2}mv^2 + mg\Delta y = 8000$$

20m

$$\frac{1}{2}(10)v^2 + 10(9.8)(20) = 8000$$

$$5v^2 + \underbrace{200 \cdot 9.8}_{1960} = 8000$$

$$5v^2 + 1960 = 8000$$
$$-1960 \quad -1960$$

$$\frac{5v^2}{5} = \frac{6040}{5}$$

$$v^2 = 1208$$

$$v = \sqrt{1208} = \underline{\underline{34.75\,m/s}}$$

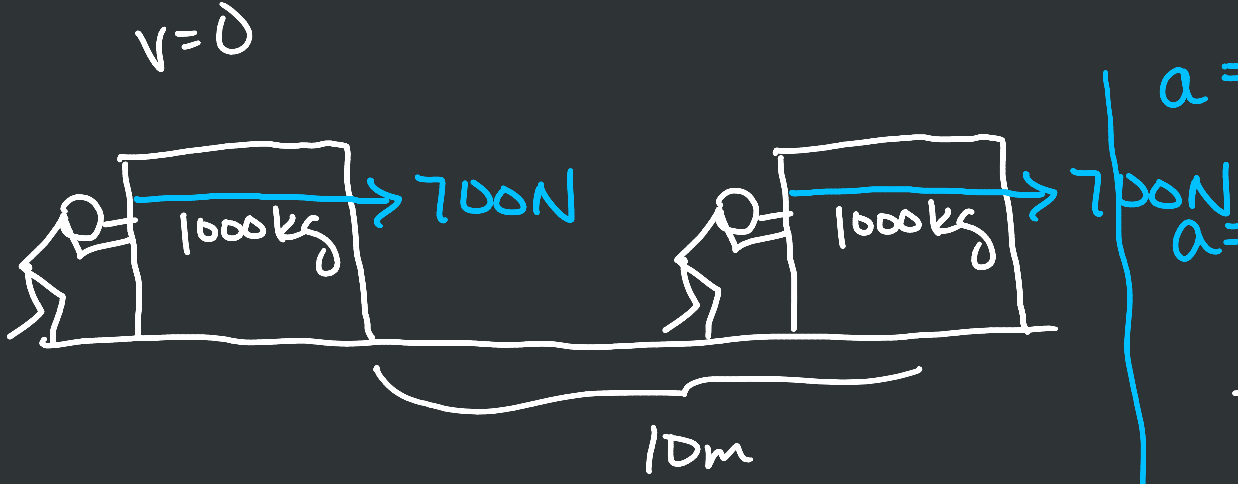
# Kinetic Energy

$$K = \frac{1}{2} \cdot \text{mass} \cdot \text{velocity}^2$$

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

$$\left[\frac{kg\,m^2}{s^2}\right] = [\text{Joule}]$$

$$= [\text{calorie}]$$




$$a = \frac{F_{NET}}{m}$$

$$a = \frac{700}{1000} = .7\ m/s^2$$

$t = ?$

$v_f = ?$

$$\underline{Work} = F \cdot \Delta x$$

$$= 700N \cdot 10m = \underline{7000\ J}$$

$$\boxed{Work = \Delta K}$$

$$K = 7000J = \frac{1}{2}mv^2$$

$$7000J = \frac{1}{2}(1000kg)\,v^2$$

$$7000J = 500\,v^2$$

$$14 = v^2 \longrightarrow v = \sqrt{14} = 3.74\ m/s$$

Potential Energy - recoverable energy → easily converted back to kinetic energy

→ result of a conservative force

- gravity
- springs (Hooke's Law)
- electric force

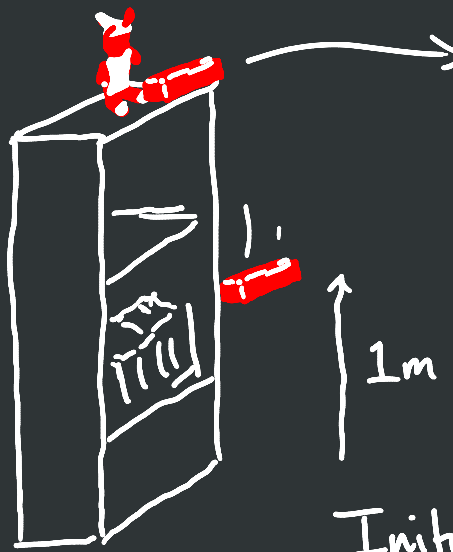
non-conservative

- friction
- push/pull from outside

Gravitational Potential Energy

$$U_G = \text{mass} \times g \times \text{height}$$

$$U_G = mgh$$




$m = 2\,kg$

$h = 2\,m$

$$U_G = mgh$$
$$= 2kg \cdot 9.8\,m/s^2 \cdot 2m$$
$$U_G \approx \underline{39.2}\ \text{Joules}$$

<u>Total</u> <u>Energy</u> = Kinetic Energy + Pot. Energy

<u>Initial</u> <u>Total</u> <u>Energy</u> = $\underset{?}{\underline{\text{Final}}}$ Total Energy

$$39.2J = K + U$$

$$\hookrightarrow mgh_{1m} = 2 \cdot 9.8\,m/s^2 \cdot 1m$$
$$= 19.6J$$

$$39.2J = K + 19.6J$$
$$-19.6J \qquad -19.6J$$
$$K = 19.6J$$

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

$$19.6J = \frac{1}{\cancel{2}}(\cancel{2}kg)v^2$$

$$\sqrt{19.6\,m^2/s^2} = v = 4.43\,m/s$$

What is v when the brick hits the ground?

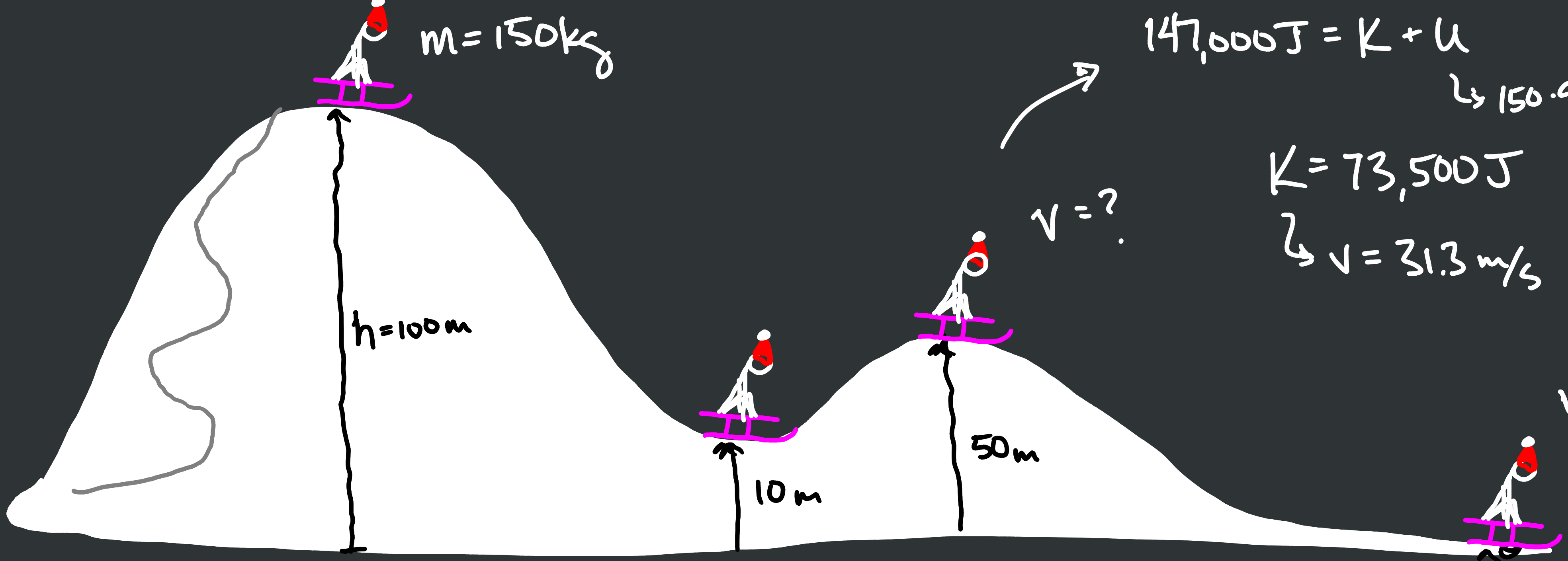
hits $\rightarrow h = 0\ m$

$$39.2\,J = K + \cancel{U}^{\,0}$$

$$39.2\,J = K = \frac{1}{2}mv^2$$

$$39.2 = \frac{1}{2}(2)v^2$$

$$v = 6.3\ m/s$$




$147{,}000J = K + U$

↳ $150 \cdot 9.8 \cdot 50$

$K = 73{,}500J$

↳ $v = 31.3\ m/s$

$U_G = mgh$

$= 150kg \cdot 9.8 m/s^2 \cdot 100m$

$= 147{,}000J$

$E_{total} = 147{,}000J$

$147{,}000J = K + U$

↳ $150kg \cdot 9.8 \cdot 10m = 14{,}700J$

↳ how fast?

$K = 132{,}300\ J$

$132{,}300J = \frac{1}{2}(150kg)v^2$

$v = 42\ m/s^2$

$147{,}000J = K + \cancel{U}^{\,0}$

$v = 44.3\ m/s$

Power - rate of energy change (or work done)

lift 200, 1kg bricks 2m high in 10 minutes | lift 150 3kg bricks 1.5m in 20 min

Compare
- who did more work
- who did more work faster? } power

$$\text{Power} = \frac{W}{t} = \frac{\text{Force} \cdot \Delta x}{t} = F \cdot V$$

$$\text{efficiency} = \frac{\text{work out}}{\text{work in}} = \frac{P_{out} \cdot \cancel{time}}{P_{in} \cdot \cancel{time}} = \frac{P_{used}}{P_{available}}$$

$P_{used} \rightarrow F_f \cdot V_{avg}$, $V_{avg} \rightarrow \frac{V_f + V_i}{2}$

$F_f \rightarrow F_f = m \cdot a$, $a \rightarrow \frac{\overbrace{V_f - V_i}^{\Delta v}}{t}$

$$P = \frac{E}{t} = \frac{\frac{E}{gal} \cdot gal}{t}$$

$\frac{\text{miles}}{\text{gal}} \rightarrow \frac{\text{gal}}{\text{mile}} \rightarrow \frac{\text{gal}}{\text{meter}} \cdot \text{meters}$

$$P = \frac{\frac{E}{gal} \cdot \frac{gal}{met.} \cdot meter}{time} = \frac{E}{gal} \cdot \frac{gal}{met.} \cdot V_{avg}$$

# Spring (Elastic) Potential Energy

$$U_s = \frac{1}{2} \times \underbrace{\text{spring constant}}_{\text{stiffness of the spring}} \times (\text{compression } \underline{\text{distance}})^2$$

change in length of the spring

also stretch

$k = [N/m]$

$$U_s = \frac{1}{2} k (\Delta x)^2 = \frac{1}{2} k x^2$$