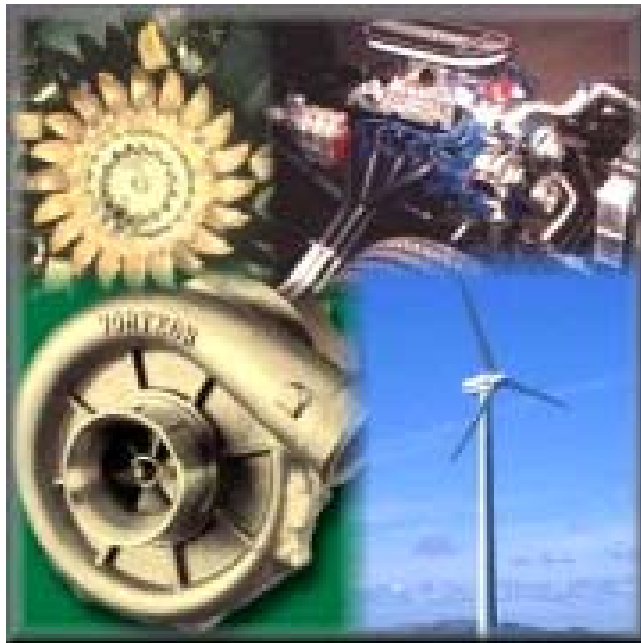


PHYSICS 231

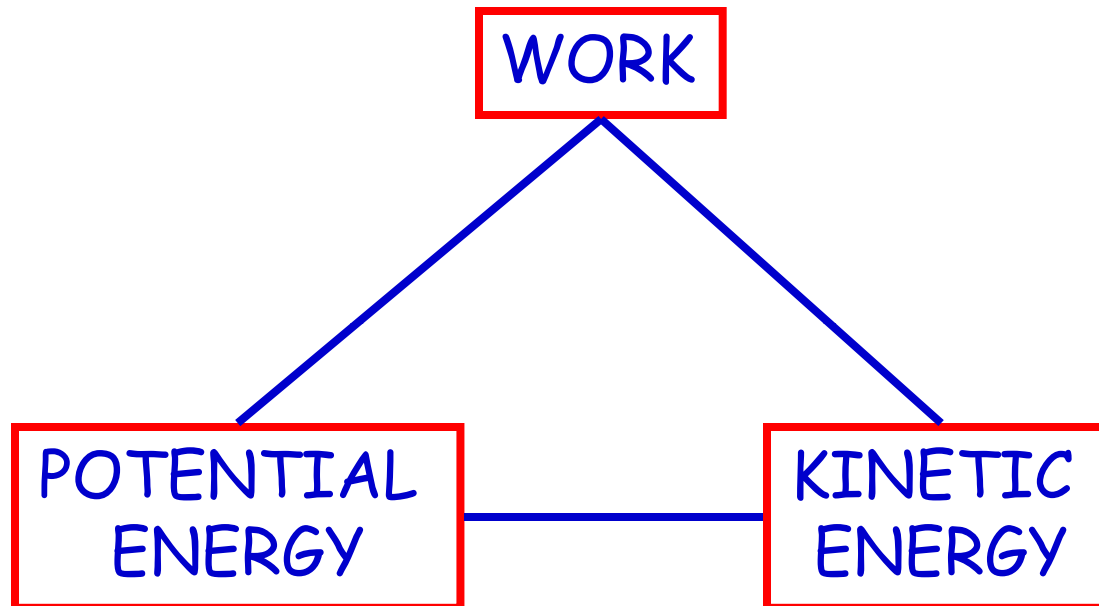
Lecture 11: work, energy and power



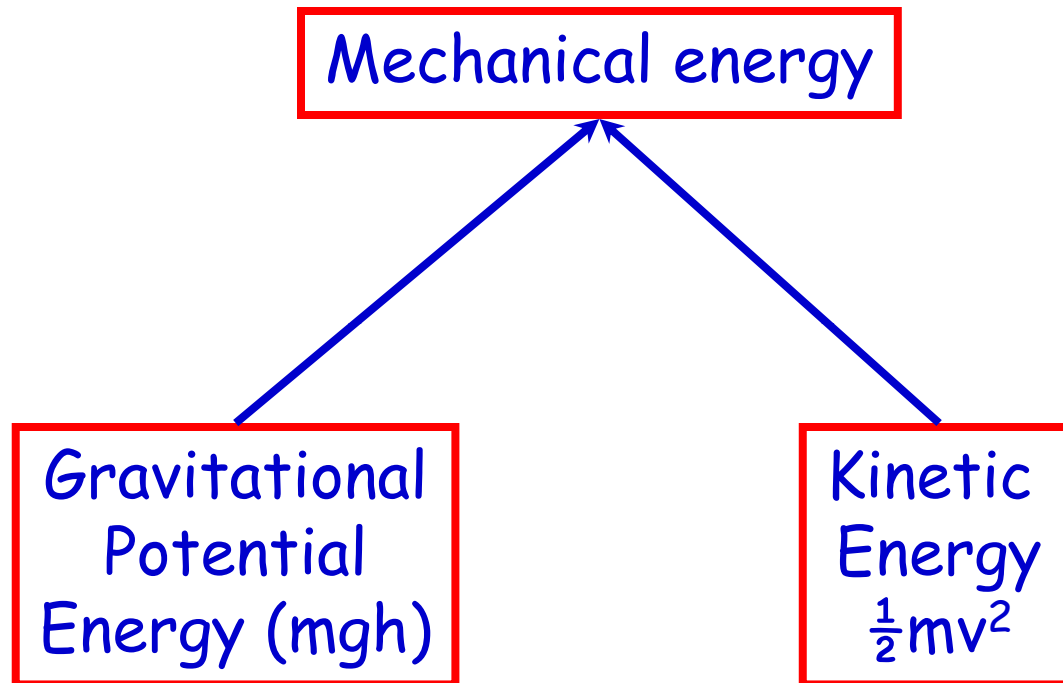
Previously

- Work: $W = F \cos(\theta) \Delta x$ Energy transfer
 - Power: $P = W / \Delta t$ Rate of energy transfer
 - Potential energy (PE) Energy associated with position.
 - Gravitational PE: mgh Energy associated with position in grav. field.
 - Kinetic energy KE: $\frac{1}{2}mv^2$ Energy associated with motion
- NEXT:**
- Conservative force: Work done does not depend on path
 - Non-conservative force: Work done does depend on path
 - Mechanical energy ME: $ME = KE + PE$
 - Conserved if only conservative forces are present
 $KE_i + PE_i = KE_f + PE_f$
 - Not conserved in the presence of non-conservative forces
 $(KE_i + PE_i) - (KE_f + PE_f) = W_{nc}$

Work and energy



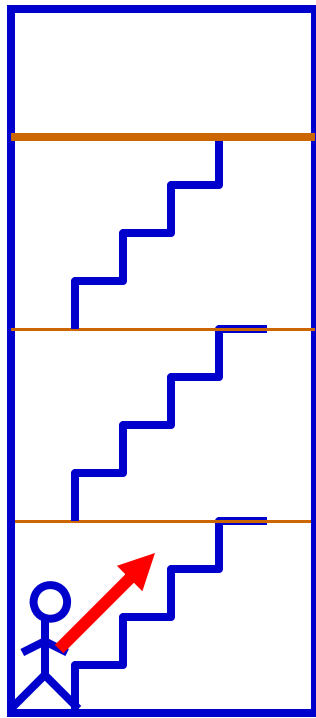
Mechanical Energy



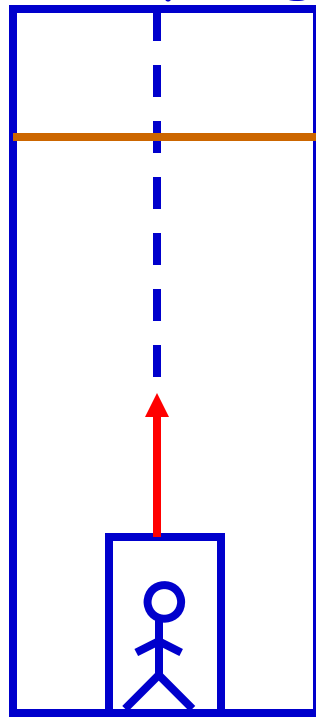
Conservative forces

A force is **conservative** if the work done by the force when moving an object from A to B **does not depend on the path** taken from A to B.

Example: gravitational force



$h=10\text{m}$



Using the stairs:

$$W_g = mgh_f - mgh_i = mg(h_f - h_i)$$

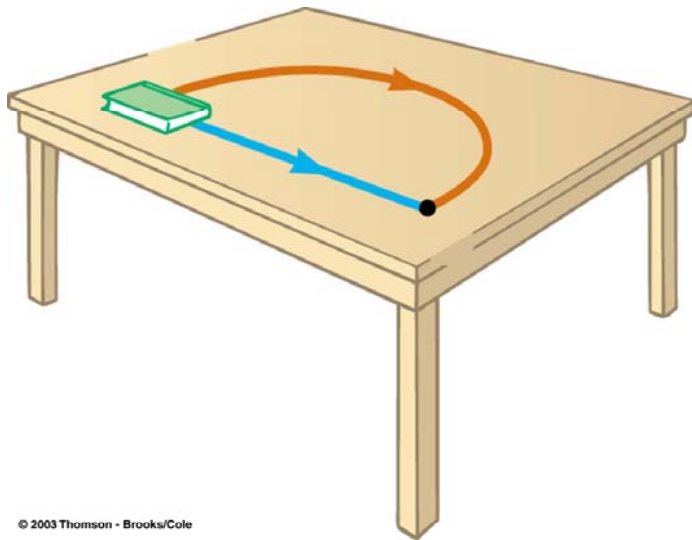
Using the elevator:

$$W_g = mgh_f - mgh_i = mg(h_f - h_i)$$

The path taken (longer or shorter) does not matter: only the displacement does!

Non conservative forces

A force is non-**conservative** if the work done by the force when moving an object from A to B **depends on the path** taken from A to B.



Example: Friction

You have to perform more work Against friction if you take the **long path**, compared to the **short path**. The friction force changes kinetic energy into heat.

Heat, chemical energy (e.g battery or fuel in an engine) Are sources or sinks of **internal** energy.

Conservation of mechanical energy only holds if the system is closed **AND** all forces are conservative

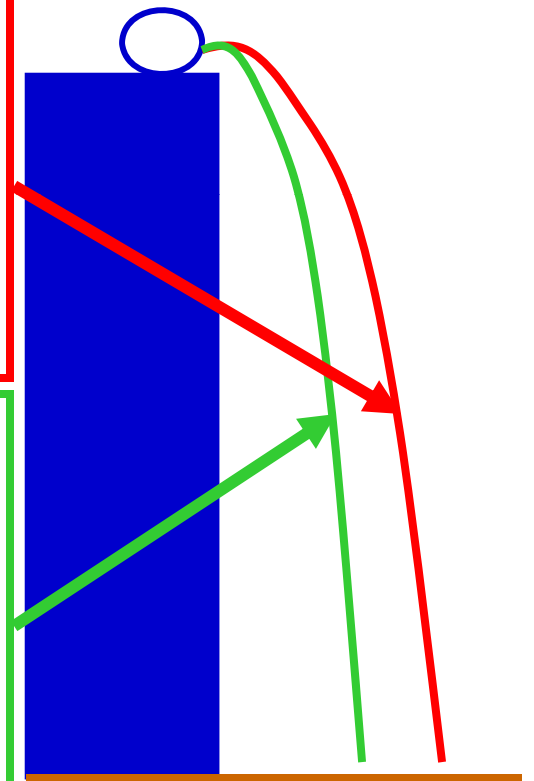
$ME_f - ME_i = (PE + KE)_f - (PE + KE)_i = 0$ if all forces are conservative

Example: throwing a snowball from a building neglecting air resistance

$ME_f - ME_i = (PE + KE)_f - (PE + KE)_i = W_{nc}$ if some forces are nonconservative.

W_{nc} = work done by non-conservative forces.

Example: throwing a snowball from a building taking into account air resistance



Example of closed system

A snowball is launched horizontally from the top of a building at $v=12.7$ m/s. The building is 35m high. The mass is 0.2 kg. Is mechanical energy conserved?

$$V_0=12.7 \text{ m/s}$$

At launch:

$$ME=mgh+\frac{1}{2}mv^2$$

$$=0.2*9.81*35+\frac{1}{2}*0.2*12.7^2=84.7 \text{ J}$$

At ground:

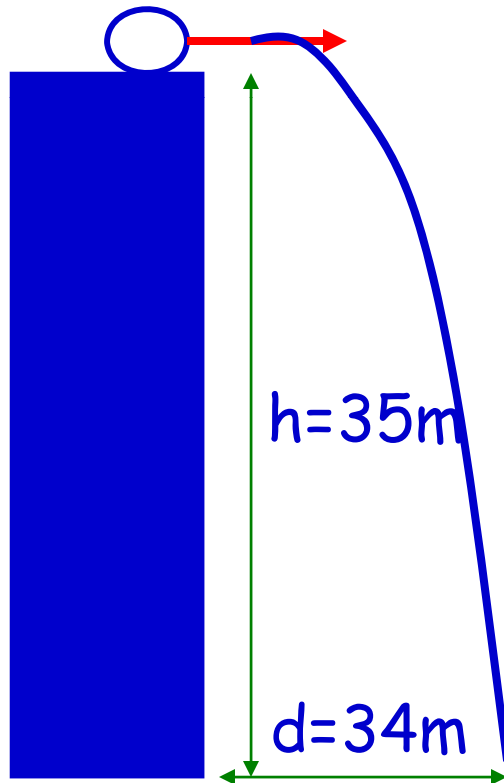
$$a\Delta h=(v_{\text{ver}}^2-v_{0,\text{ver}}^2)/2 \quad \text{so } v_{\text{ver}}=26.2 \text{ m/s}$$

$$V=\sqrt{(V_{\text{hor}}^2+V_{\text{ver}}^2)}=\sqrt{(12.7^2+26.2^2)}=29.1$$

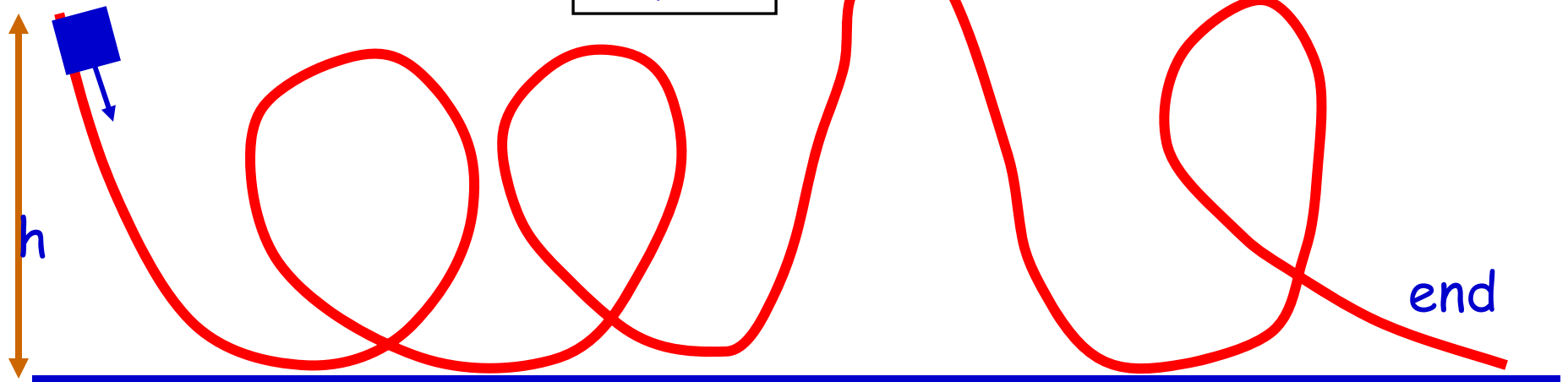
$$ME=mgh+\frac{1}{2}mv^2$$

$$=0.2*9.81*0+\frac{1}{2}*0.2*29.1^2=84.7 \text{ J}$$

ME is conserved!!



Quiz



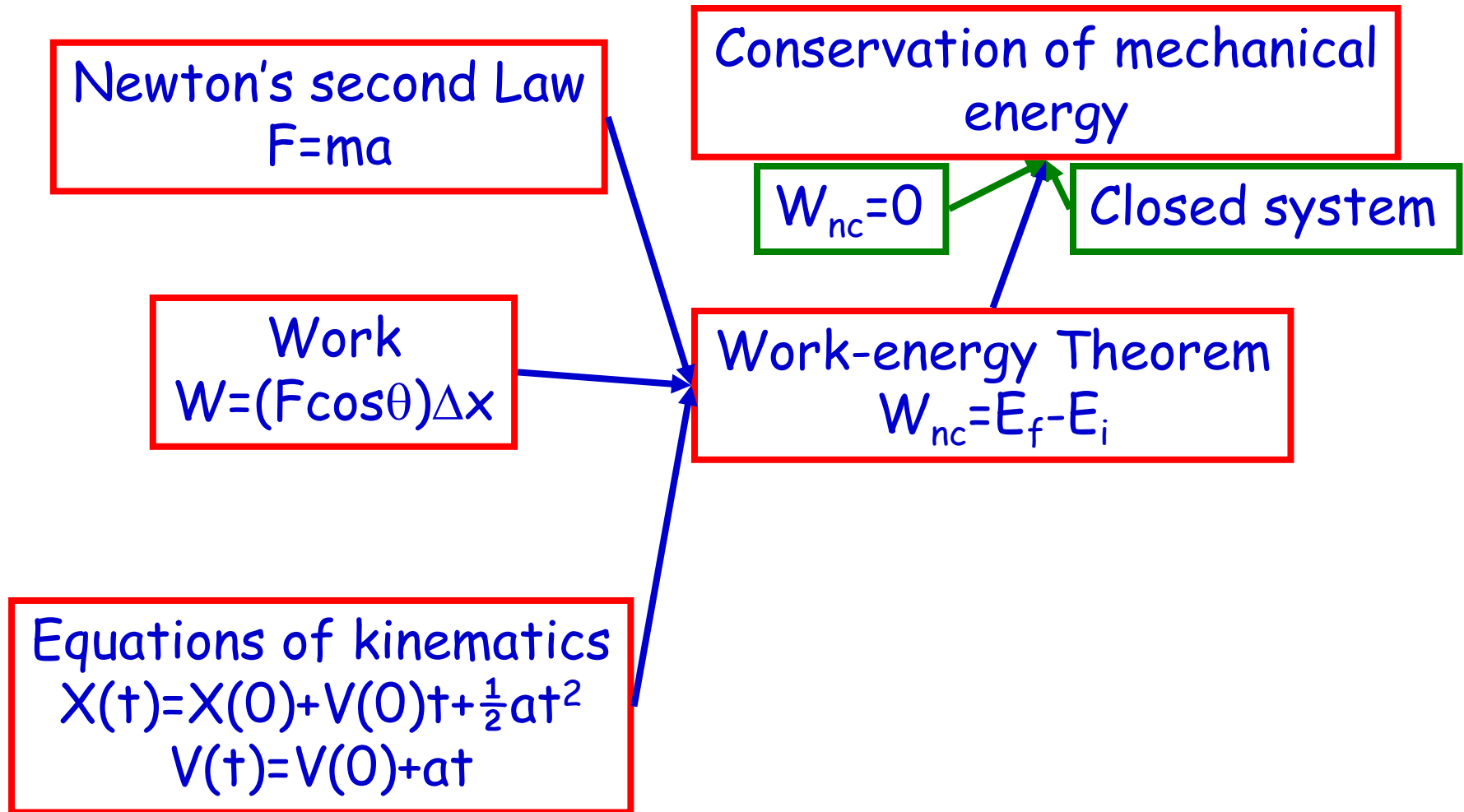
Consider the above rollercoaster (closed system). The cart starts at a height h . What is its velocity v at the end?
Hint: consider the mechanical energy in the beginning and the end.

- a) $v=2gh$ b) $v=gt_{\text{trip}}$ c) $v=\sqrt{2gh}$ d) $v=\sqrt{2gh/m}$ e) $v=0$ m/s

$$mgh = \frac{1}{2}mv^2$$
$$v = \sqrt{2gh}$$

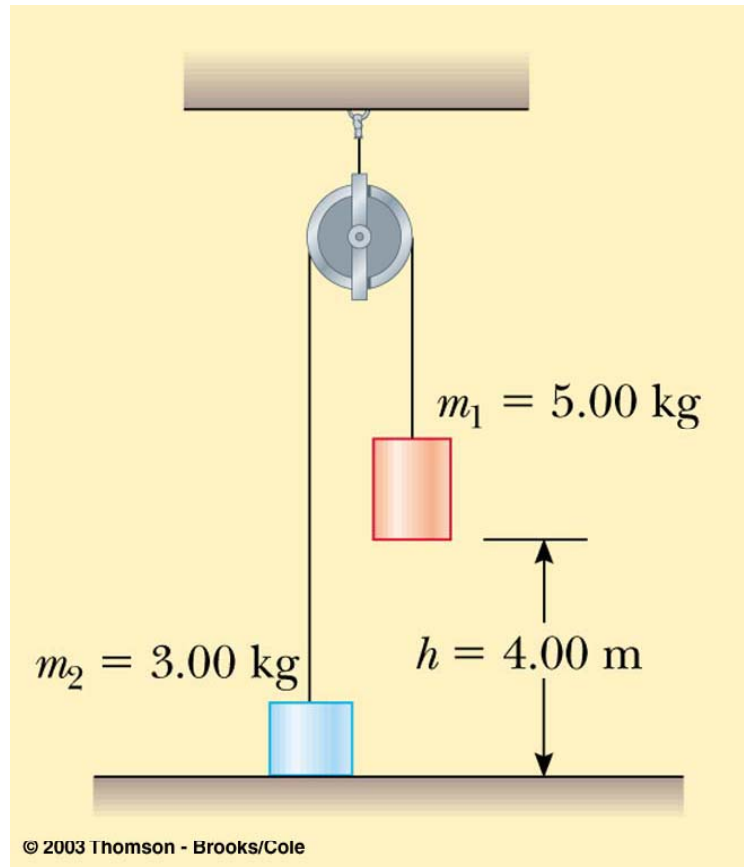
kinetic energy: $0.5mv^2$
potential energy: mgh

Overview



Conservation of mechanical energy

A) what is the speed of m_1 and m_2 when they pass each other?



$$(PE_1 + PE_2 + KE_1 + KE_2) = \text{constant}$$

At time of release:

$$PE_1 = m_1 g h_1 = 5.00 * 9.81 * 4.00 = 196. \text{ J}$$

$$PE_2 = m_2 g h_2 = 3.00 * 9.81 * 0.00 = 0.00 \text{ J}$$

$$KE_1 = 0.5 * m_1 * v^2 = 0.5 * 5.00 * (0.)^2 = 0.00 \text{ J}$$

$$KE_2 = 0.5 * m_2 * v^2 = 0.5 * 3.00 * (0.)^2 = 0.00 \text{ J}$$

$$\text{Total} = 196. \text{ J}$$

At time of passing:

$$PE_1 = m_1 g h_1 = 5.00 * 9.81 * 2.00 = 98.0 \text{ J}$$

$$PE_2 = m_2 g h_2 = 3.00 * 9.81 * 2.00 = 58.8 \text{ J}$$

$$KE_1 = 0.5 * m_1 * v^2 = 0.5 * 5.00 * (v)^2 = 2.5v^2 \text{ J}$$

$$KE_2 = 0.5 * m_2 * v^2 = 0.5 * 3.00 * (v)^2 = 1.5v^2 \text{ J}$$

$$\text{Total} = 156.8 + 4.0v^2$$

$$196 = 156.8 + 4.0v^2 \text{ so } v = 3.13 \text{ m/s}$$

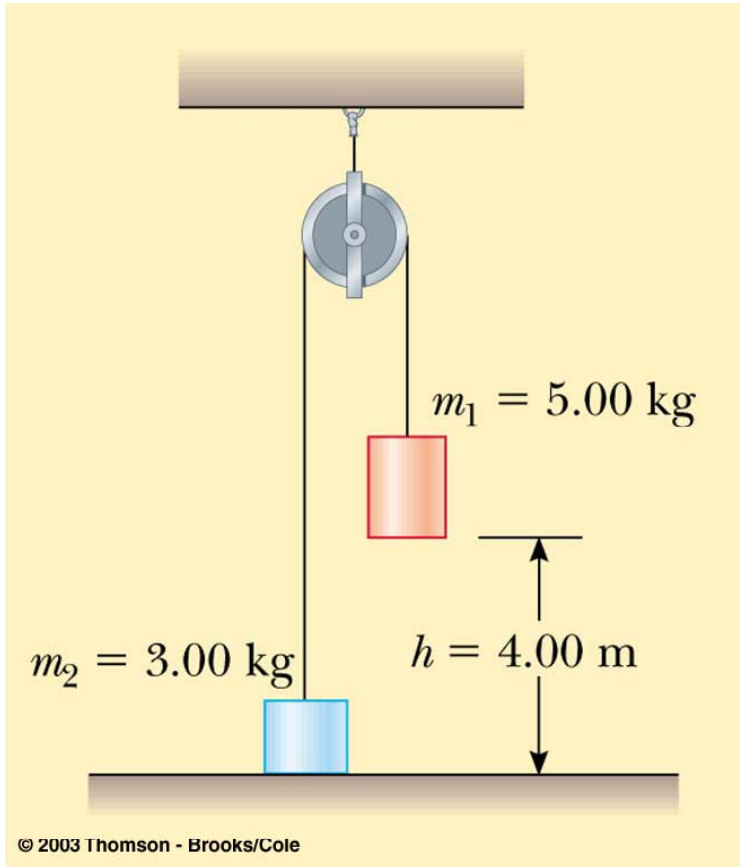
work

How much work is done by the gravitational force when the masses pass each other?

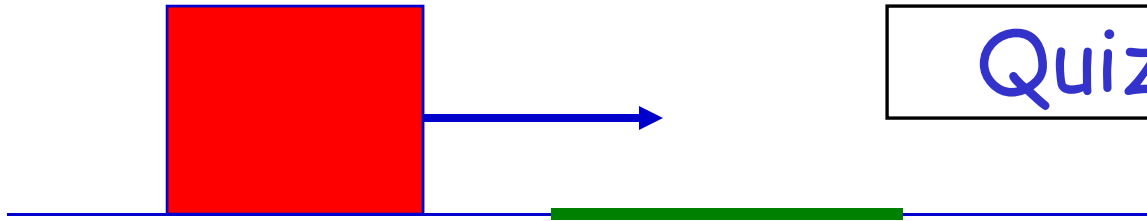
$$W = F\Delta x = m_1 g 2.00 + (m_2 g)(-2.00) = 39.2 \text{ J}$$

$$\Sigma Pe_{\text{start}} - \Sigma Pe_{\text{passing}} = (196. - 98. - 58.8) = 39.2 \text{ J}$$

The work done by F_g is the same as the change in potential energy



Quiz

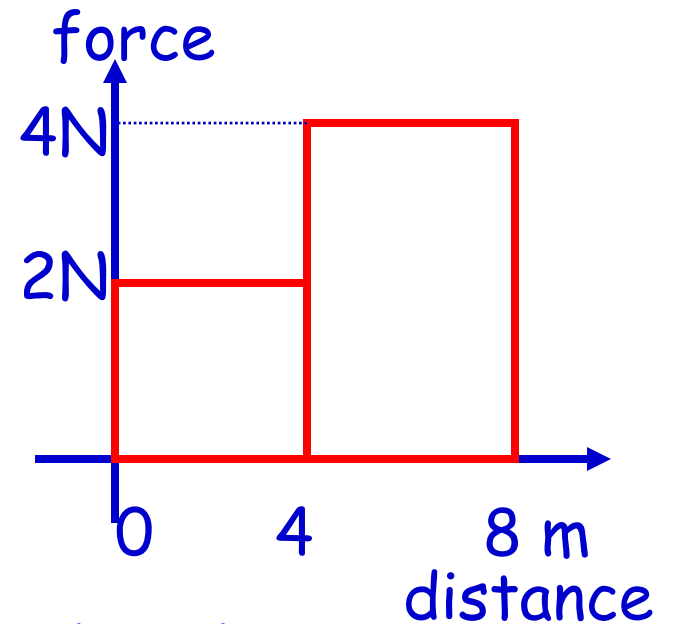


A person is dragging a block over a floor, with a force parallel to the floor.

After 4 meter, the floor turns rough and instead of a force of 2N and force of 4N must be applied.

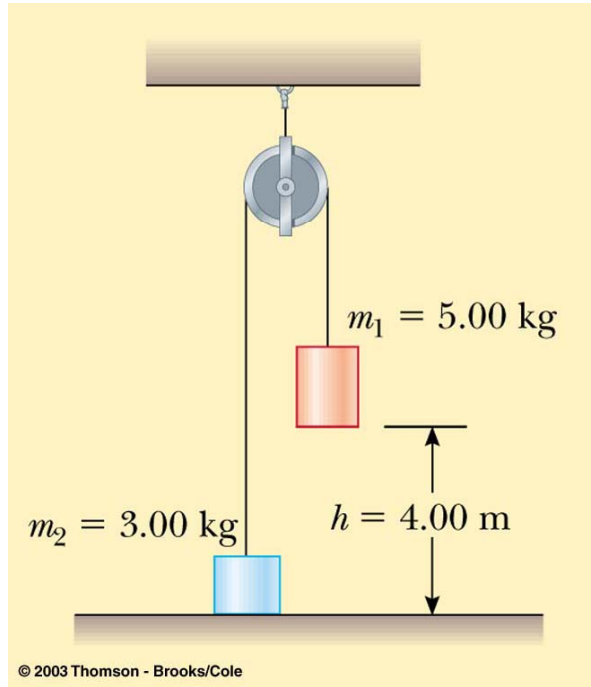
The force-distance diagram shows the situation. How much work did the person do over 8 meter?

- a) 0 J b) 16 J c) 20 J **d) 24 J** e) 32 J



Work: area under F-x diagram: $4 \times 2 + 4 \times 4 = 24 \text{ J}$

Friction (non-conservative)



The pulley is not completely frictionless. The friction force equals 5 N. What is the speed of the objects when they pass?

$$(\Sigma PE + \Sigma KE)_{\text{passing}} - (\Sigma PE + \Sigma KE)_{\text{start}} = W_{\text{nc}}$$
$$W_{\text{nc}} = F_{\text{friction}} \Delta x = -5.00 \cdot 2.00 = -10.0 \text{ J}$$

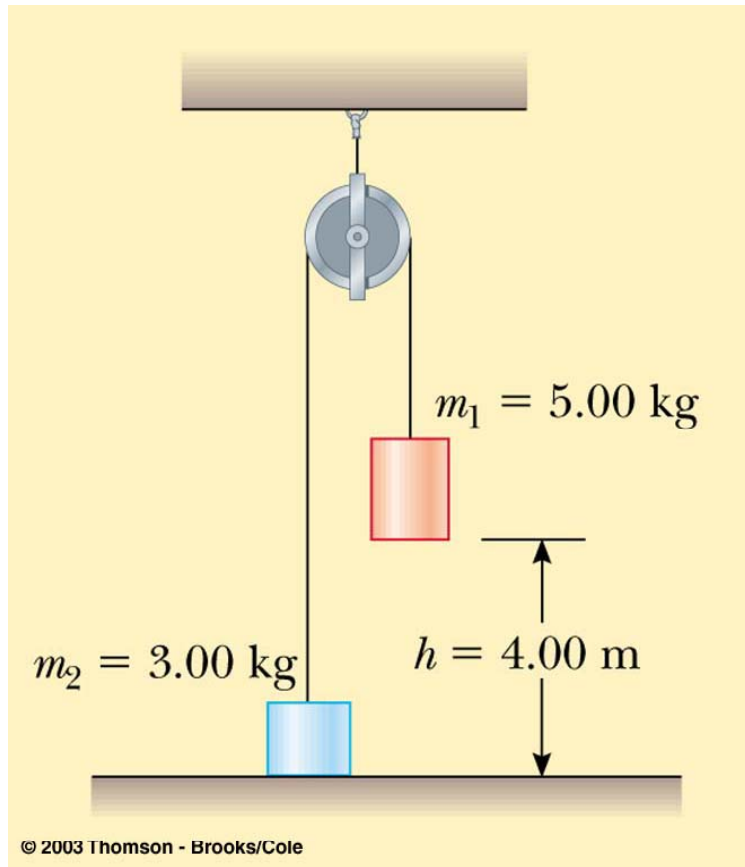
$$(156.8 + \Sigma KE) - (196.) = -10 \text{ J}$$

$$\Sigma KE = 29.2 \text{ J} = 0.5 \cdot (m_1 + m_2) v^2 = 4v^2$$

$$v = 2.7 \text{ m/s}$$

Note: m_1 and m_2 are moving with the same speed, though along opposite directions.

quiz (extra credit)



In the absence of friction, when m_1 starts to move down:

- 1) potential energy is transferred from m_1 to m_2
- 2) potential energy is transformed into kinetic energy
- 3) m_1 and m_2 have the same kinetic energy

- a) 1) and 2) and 3) are true
b) only 2) and 3) are true

- c) only 1) and 2) are true
d) only 2 is true.