October 27

Get Clickers and Whiteboards

Finish VPython flyby with energy graphs

Power

$$P = \frac{\text{energy}}{\text{time}}$$

Path Independence of Potential Energy

$$U = -\frac{G M_1 m_2}{r}$$

Change in potential energy is indep of path

Potential energy does not change if you came back to same point

Only depends on initial + final positions

Thermal Energy and Heat Capacity

$$\Delta E = W_{ext} + Q$$

$\Uparrow$ E ?

$$C = \frac{\Delta E_{thermal}}{\Delta T}$$

$$c = \text{specific heat capacity} = \frac{\Delta E_{thermal}}{m \Delta T}$$

$$c = 4.2 \text{ J/K/gram}$$

Ponderable: You have a pot containing 1000 g of water over a fire, and you are also stirring the water with a paddle. The fire adds $Q = 5000$ J into the water. You do $W = 2000$ J of work with the paddle.

What is the increase in energy of the water?

$\Delta E = W + Q$

$E_f = E_i + W_{ext} + Q$

$E_f - E_i = \Delta E_{thermal} = W_{ext} + Q$

$= 2000\text{J} + 5000\text{J}$

$= 7000\text{J}$

What is the change in temperature of the water?

$C = \frac{\Delta E}{\Delta T} = 4.2\text{J/K/gram} \times 1000\text{g} = \frac{7000\text{J}/1000\text{g}}{\Delta T}$

$\Delta T = 1.7\text{K} = 1.7^{\circ}\text{C} = 3^{\circ}\text{F}$

Open and closed systems

First consider case where System is Earth + rock

$\Delta U = mg\Delta y$ → rock close to Earth

Calculate final kinetic energy if rock starts at rest and falls a distance Δy

Do same thing with system just rock.

Rock + Earth System

$$\Delta E = W_{ext} + Q = 0$$

$$(Mc^2 + mc^2 + K_f + U_f) - (Mc^2 + mc^2 + K_i + U_i) = 0$$

$$\Delta K + \Delta U = 0$$

$$K_f + mg\Delta y = 0$$

$$K_f = -mg\Delta y$$

Rock system

$$\Delta E = W_{ext} + Q$$

$$(Mc^2 + mc^2 + K_f + U_f) - (Mc^2 + mc^2 + K_i + U_i) = \vec{F}_{net,ext} \cdot \Delta \vec{r}$$

$$\Delta K = \vec{F}_{net,ext} \cdot \Delta r$$

$$K_f = \langle 0, -mg, 0 \rangle \cdot \langle 0, \Delta y, 0 \rangle$$

$$K_f = -mg\Delta y$$

Horse galloping up a hill (Problem 6.RQ.25 on p253)

Mass M
Const speed v
Hooves don't slip

Starts to gallop, temp rises until temp difference with air makes temperature const.

First consider just horse as system.
What external forces act on horse?
Work done by all forces?
Non-work energy transfers? ΔE of system

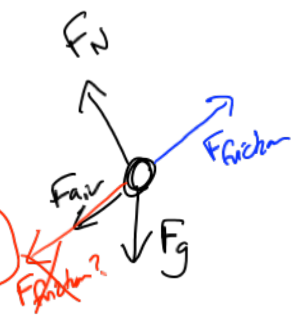
Q1 What objects in the surroundings exert forces on our chosen system, the horse?

A) Earth (gravitational)

B) Earth (gravitational) and ground (contact)

C) Earth (gravitational), ground (contact; friction), and air (contact; air resistance)

D) Earth (gravitational), ground (contact; friction), air (contact; air resistance), and horse's hooves (contact; friction)



Q2 The horse's hooves don't slip on the rocky ground, so the work done by the ground on the horse is

A) $W > 0$ because the force points upward
B) $W > 0$ because work is a positive quantity
C) $W = 0$ because there is no displacement due to the force
D) $W < 0$ because the hooves move downward
E) $W < 0$ because the hill doesn't speed up the horse

$\Delta \vec{r}_{hoof} = 0$

$W = \vec{F} \cdot \Delta \vec{r} = 0$

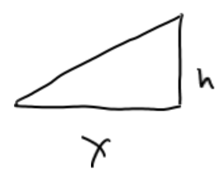
Q3 The displacement of the horse is $< x, h, 0 >$, and the force of the Earth on the horse is $< 0, -Mg, 0 >$. The work done by the Earth on the horse is

A) $\langle 0, -Mgh, 0 \rangle$

B) $\left|\langle 0, -Mgh, 0 \rangle\right| = \sqrt{0^2 + (-Mgh)^2 + 0^2} = Mgh$

C) $-Mgh$

D) $\langle x, h - Mg, 0 \rangle$



$W = \vec{F} \cdot \Delta\vec{r}$

$= \langle 0, -Mg, 0 \rangle \cdot \langle x, h, 0 \rangle$

$= -Mgh$

Q4 The term "Q" in the energy principle $\Delta E_{\text{sys}} = W_{\text{Ext}} + Q$ is microscopic work done on the system due to a temperature difference between the system and the surroundings. When the horse started running, its temperature quickly rose, and its temperature is quite a bit higher than the surroundings. Which of the following is true?

A) $Q < 0$ because there is energy transfer from the horse to the surrounding air
B) $Q = 0$ because air is a thermal insulator
C) $Q > 0$ because the horse is hotter than the surrounding air

Q5 Which of the following correctly represents the energy of the chosen system (the horse)?

A) $Mc^2 + K$

B) $Mc^2 + K + U_{\text{grav}}$

C) $Mc^2 + K + E_{\text{chemical}} + E_{\text{thermal}}$

D) $Mc^2 + K + E_{\text{chemical}} + E_{\text{thermal}} + U_{\text{grav}}$

E

Q6 Which of the following energy terms change during the run at constant speed and constant body temperature (constant because there is energy transfer Q to the surrounding air)?

A) Mc^2

B) K

C) E_{chemical}

D) E_{thermal}

Q7 What is true about the change in E_{chemical} inside the chosen system (the horse)?

A) $\Delta E_{\text{chemical}} > 0$ because the horse provides chemical energy to go up the hill

B) $\Delta E_{\text{chemical}} = 0$ because the horse's temperature doesn't change

C) $\Delta E_{\text{chemical}} < 0$ because the horse provides chemical energy to go up the hill

$$\Delta E_{\text{system}} = W_{ext} + Q$$
$$= (0)_{\text{ground}} - (Mgh)_{\text{Earth}} + (-|Q|)$$
$$= \Delta E_{\text{chemical}} = -Mgh - |Q|$$

Q8 Instead, choose the Universe as the system. What is different about the right side of $\Delta E_{\text{sys}} = W_{\text{Ext}} + Q$?

A) It's the same; the energy principle is fundamental.

B) The right side is zero; there are no surroundings.

C) We have to add potential energy to the right side.

Q9 What is different about the left side of $\Delta E_{\text{sys}} = W_{\text{Ext}} + Q$ if we choose the Universe as the system?

A) The only new term is $\Delta U_{\text{grav}} = +Mgh$

B) The only new term is $\Delta U_{\text{grav}} = -Mgh$

C) The only new term is $\Delta E_{\text{air}} > 0$

D) The new terms are $\Delta U_{\text{grav}} = +Mgh$ and $\Delta E_{\text{air}} > 0$

E) The new terms are $\Delta U_{\text{grav}} = -Mgh$ and $\Delta E_{\text{air}} > 0$

$\Delta E_{ch} + Mgh + \Delta E_{air} = 0$

$\Delta E_{ch} = -Mgh + (-Q)$

$\Delta E_{air} = Q$