Title Generalized work-energy principle E6

Ingredients

Sketch

At/Through t_i t_f $[t_i, t_f]$

Owner System

Quantity Total energy Total work

Variable $\Sigma K_i + \Sigma U_{G,i} + \Sigma U_{S,i} + \Sigma U_{INT,i}$ | $\Sigma K_f + \Sigma U_{G,f} + \Sigma U_{S,f} + \Sigma U_{INT,f}$ | ΣW

Giver External environment

Recipe

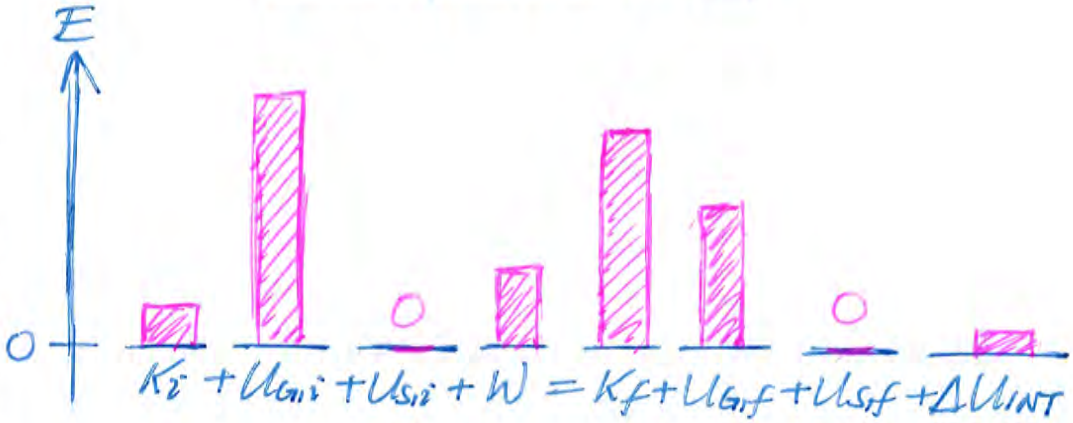
Diagram the relationship

ΣW

$\Sigma K_i + \Sigma U_{G,i} + \Sigma U_{S,i} + \Sigma U_{INT,i} \rightarrow \Sigma K_f + \Sigma U_{G,f} + \Sigma U_{S,f} + \Sigma U_{INT,f}$

Graphically present quantities

Energy bar chart



Mathematical relationship

$\Sigma K_i + \Sigma U_{G,i} + \Sigma U_{S,i} + \Sigma U_{INT,i} + \Sigma W = \Sigma K_f + \Sigma U_{G,f} + \Sigma U_{S,f} + \Sigma U_{INT,f}$

Shorthand: $K_i + U_{G,i} + U_{S,i} + W = K_f + U_{G,f} + U_{S,f} + \Delta U_{INT}$

Page E6
Title: Generalized work-energy principle

The top half of this sheet consists of an "**Ingredients**" section with a row labeled "Sketch", a row labeled "At/Through", a row labeled "Owner", a row labeled "Quantity", a row labeled "Variable", and a row labeled "Giver."

Sketch: A roller coaster track with peaks and valleys is on a firm, horizontal surface. Under the surface is the label, "Earth". A cart on the roller-coaster track is shown in an earlier snapshot at a higher height, more to the left and a later snapshot at a lower height, more to the right. Trailing whooshies indicate that the cart is moving in both snapshots. The whooshies are longer in the second snapshot. A dashed system bubble surrounds the cart, the roller-coaster track, the surface, and the label, "Earth". Outside of the dashed bubble, a cartoon of a cloud blows air along the track. A vertical dashed axis arrow shows that +h points up the page. A tickmark on the vertical axis indicates that the height h = 0 at the surface of the Earth. The placement of the tickmark for 0 on the vertical axis is arbitrary. Choosing the surface of the Earth to have a height of 0 is merely a common choice.

Remaining rows of Ingredients section are used for a flowchart illustrating the following:
The Owner is the System. At initial time t-sub-i, the System owns the Quantity Initial total energy denoted by the Variable expression Sigma-K-sub-i + Sigma-U-sub-G,i + Sigma-U-sub-S,i + Sigma-U-sub-INT,i. At final time t-sub-f, the System owns the Quantity Final total energy Sigma-K-sub-f + Sigma-U-sub-G,f + Sigma-U-sub-S,f + Sigma-U-sub-INT,f. Through the course of the interval from initial time t-sub-i to final time t-sub-f, the System receives the Quantity Total Work denoted by the Variable Sigma-W given by Giver External environment.

The bottom half of this sheet consists of a "**Recipe**" section with a row labeled "Diagram the relationship", a row labeled "Graphically present quantities", and a row labeled "Mathematical relationship".

Diagram the relationship
A flowchart arrow shows that Initial total energy Sigma-K-sub-i + Sigma-U-sub-G,i + Sigma-U-sub-S,i + Sigma-U-sub-INT,i contributes to Final total energy Sigma-K-sub-f + Sigma-U-sub-G,f + Sigma-U-sub-S,f + Sigma-U-sub-INT,f. Another arrow shows that Total work Sigma-W also contributes to Final total energy Sigma-K-sub-f + Sigma-U-sub-G,f + Sigma-U-sub-S,f + Sigma-U-sub-INT,f.

Graphically present quantities
Energy bar chart
Plot E on the vertical axis. Draw a tickmark labeled 0. At the height of this tickmark, draw eight horizontal segments to the right, spaced apart so that each horizontal segment is labeled underneath by one of the terms of the equation K-sub-i + U-sub-G,i + U-sub-S,i + W = K-sub-f + U-sub-G,f + U-sub-S,f + Delta-U-sub-INT. Fill in a concrete example bar chart. Write the number 0 above the terms U-sub-S,i and U-sub-S,f. This is consistent with the Sketch from the "Ingredients" section. The Sketch doesn't show any springs, so the System doesn't own Spring potential energy. From the horizontal segment labeled K-sub-i, extend upward a short, shaded rectangular bar representing the relatively small initial kinetic energy of the cart. From the horizontal segment labeled U-sub-G,i, extend upward a tall, shaded rectangular bar representing the relatively high gravitational potential energy of the Earth and cart. From the horizontal segment labeled W, extend upward a modestly tall, shaded rectangular bar to represent the positive work done by the air blowing against the cart as the cart travels from the initial snapshot to the final snapshot in the Sketch in the "Ingredients" section. From the horizontal segment labeled K-sub-f, extend upward a rather tall, shaded rectangular bar representing the relatively high final kinetic energy of the cart. From the horizontal segment labeled U-sub-G,f, extend upward a modestly tall, shaded rectangular bar representing the decreased gravitational potential energy of the Earth and cart in the final snapshot. From the horizontal segment labeled Delta-U-sub-INT, extend upward a short, shaded rectangular bar representing a small increase in the internal energy of the System. Adjust the heights of bars in the bar chart, if needed, to make sure that the sum of the graphically represented values of the first four terms of the labeling equation equals the sum of the graphically represented values of the last four terms of the labeling equation.

Mathematical relationship
Sigma-K-sub-i + Sigma-U-sub-G,i + Sigma-U-sub-S,i + Sigma-U-sub-INT,i + Sigma-W = Sigma-K-sub-f + Sigma-U-sub-G,f + Sigma-U-sub-S,f + Sigma-U-sub-INT,f
Shorthand: K-sub-i + U-sub-G,i + U-sub-S,i + W = K-sub-f + U-sub-G,f + U-sub-S,f + Delta-U-sub-INT