Kinetic Energy and Work

by

Nada Saab-Ismail, PhD, MAT, MEd, IB

P4.3x Kinetic and Potential Energy — Calculations

The kinetic energy of an object is related to the mass of an object and its speed: $KE = 1/_2\, mv2$.

P4.3d Rank the amount of kinetic energy from highest to lowest of everyday examples of moving objects.

P4.2A Account for and represent energy transfer and transformation in complex processes (interactions).

P4.3A Identify the form of energy in given situations (e.g., moving objects, stretched springs, rocks on cliffs, energy in food).

Items:

1- Kinetic Energy

2- Work-Energy Theorem

DEFINITION OF KINETIC ENERGY

Kinetic energy (KE) is the energy of moving object.

A curling stone with mass (m) moving down a frictionless ice surface with a speed v, will be able to do work on other stones because it is moving. the amount of kinetic energy in the stone depends on how fast it is moving, and on its mass.

The kinetic energy KE of and object with mass m and speed v is given by

Kinetic Energy
$KE = \frac{1}{2}mv^2$

m; is the mass of the object, in kilogram (kg)
v; is the speed of the object, in meters per second (m/s)
KE; is the kinetic energy in joules (j)

Example 1: A Curling Stone

What is the kinetic energy of a curling stone of mass m = 6.0 kg sliding at a speed v = 4.0 m/s?

Data Table		
m	KE	v
6.0 kg	?	4.0 m/s

KE = 1/2 m v^2 = 1/2 (6.0)$(4.0)^2$ = 48 J

Therefore, the kinetic energy of the curling stone is 48 J.

No machine can operate without fuel. Gasoline is the fuel for automobiles. Food is the fuel for the human body. Food gives you the ability to do work. It gives you energy.

Energy (E) is the ability to do work. Work (W) is the transfer of energy.

Both work and energy have the same unit, the joule (J) . So if you do 5000 J of work on an object, you have transferred 5000 J of your energy to it.

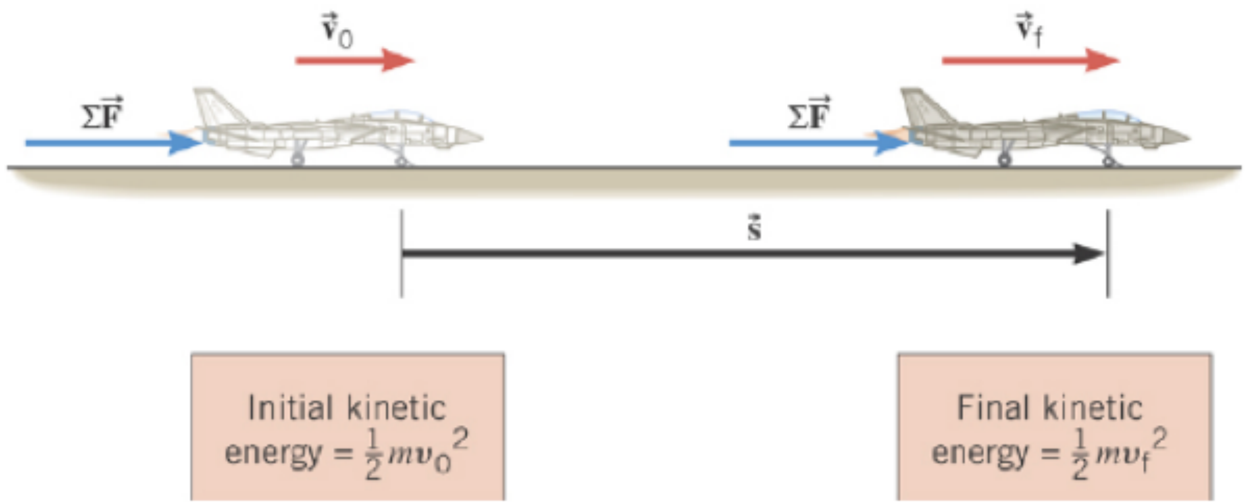
$$\boxed{\mathbf{W = \Delta\, E}}$$

W is the work done on an object, in joules

ΔE is the change in energy of the objects, in joules.

Moving objects and waves transfer energy from one location to another. Moving objects also transfer energy to other objects during interactions (e.g. sunlight transfers energy from the sun to the Earth. The ground gets warm.

THE WORK-ENERGY THEOREM



A net force is moving a jet of mass m from an initial velocity $\mathbf{V}_o$ to a final velocity of $\mathbf{V}_f$, for a distance s. How much work is done to bring the jet to its final speed $\mathbf{V}_f$?

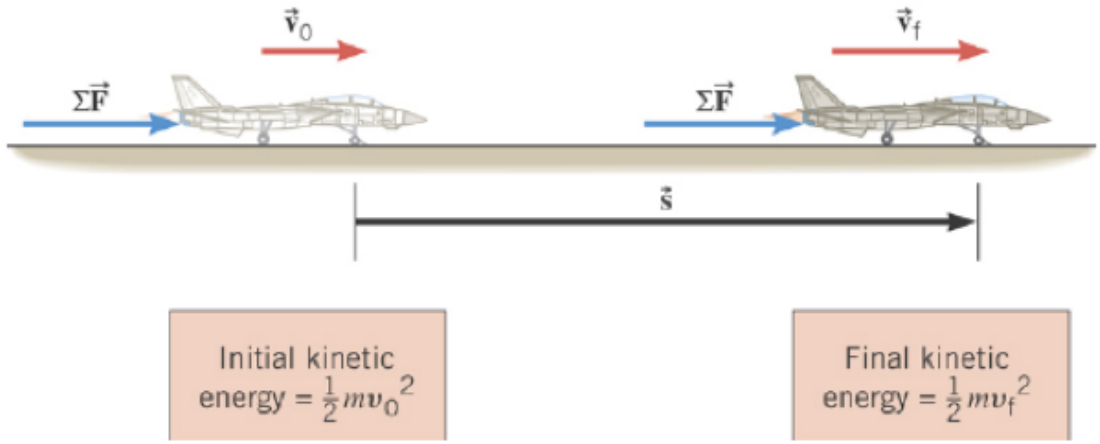
Initial kinetic energy : KE_o,

Final kinetic energy: KE_f

THE WORK-ENERGY THEOREM: when a net external force does work on an object, the kinetic energy of the object changes according to:

Work-Energy Theorem
$W = \mathrm{KE_f} - \mathrm{KE_o} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2$

The work done equals the change in kinetic energy



Example 2: *Passing a Car;*

To pass another car, a compact car of mass 875-kg compact car speeds up from an initial speed of V_o = 22.0 m/s to a final speed of V_f = 44 m/s . Use its initial and final energies and calculate how much work was done on the car to increase its speed?

Data Table			
m	W	v_o	v_f
875 kg	?	22.0 m/s	44 m/s

We need to use the Work-Energy Theorem:

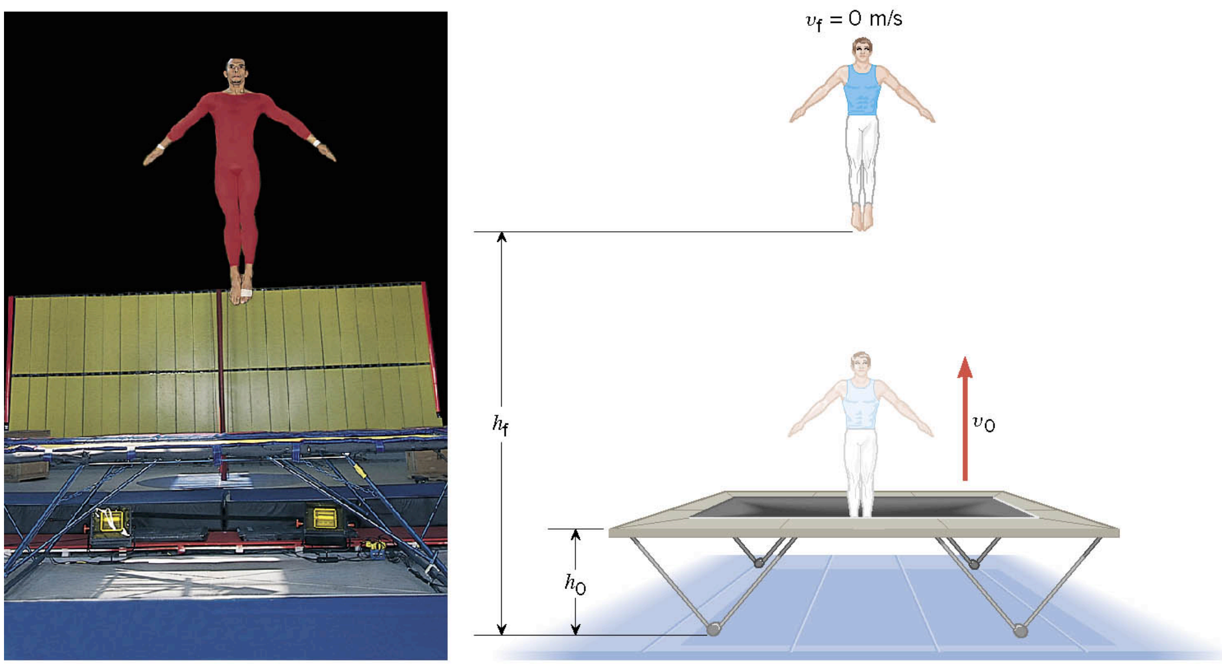
The work done equals the change in kinetic energy.

$$W = \mathrm{KE_f} - \mathrm{KE_o} = \tfrac{1}{2} m v_\mathrm{f}^2 - \tfrac{1}{2} m v_o^2$$

W = 1/2 (875)(22)^2 - 1/2 (875)(44) ^{2} = 635000 Joules

Example 3: *A Gymnast on a Trampoline*.

The gymnast of mass m leaves the trampoline at an initial speed v_o and reaches a final speed v_f of zero before falling back down.



(a) (b)

Work-Energy Theorem:

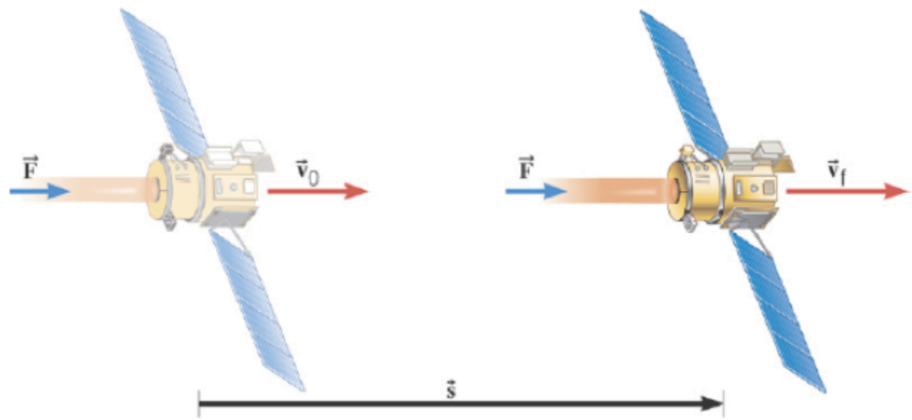
$$W = \mathrm{KE_f} - \mathrm{KE_o} = \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_o^2$$

= - 1/2 m

v_o^2 (because v_f = 0 m/s)

Example 4: *A Space Probe;*

A space probe with mass m = 5.00×10^4 kg. The engine of the space probe generates a force F of 4.00×10^5 N (parallel to the displacement) and moves with an initial velocity v_o of 1.10×10^4 m/s for a distance s of 2.5×10^6 m to reach a final velocity v_f. Calculate v_f .



Data Table				
m	F	v_o	s	v_f
5.00×10^4 kg	4.00×10^5 N	1.10×10^4 m/s	2.5×10^6 m	?

According to the definition of work:

$$W = (F\cos\theta)s = (F\cos 0^{o})s = F \times s$$

$$= (4.00 \times 10^{5}) \times (2.5 \times 10^{6})$$

$$= 1.00 \times 10^{12}\ J$$

According to the work-energy theorem:

$$W = KE_f - KE_o$$

$$KE_f = W + KE_o$$

We can calculate the initial kinetic energy KE_o

$$KE_o = 1/2\ m\ v_o^2$$

$$= 1/2\ (5.00 \times 10^{4})\ (1.10 \times 10^{4})^2$$

$$= 3.02 \times 10^{12}\ J$$

Now, we can calculate the final kinetic energy KE_f

$$KE_f = W + KE_o$$

$$= (1.00 \times 10^{12}) + (3.02 \times 10^{12})$$

$$= 4.02 \times 10^{12} \text{ J}$$

We know that:

$$KE_f = 1/2\ m\ v_f^2$$

Therefore:

$$v_f^2 = 2\ KE_f / m$$

$$= 2\ (4.02 \times 10^{12}) / \ 5.00 \times 10^4$$

$$= 8.04 \times 10^{12} / \ 5.00 \times 10^4$$

Therefore:

$$v_f = 1.27 \times 10^4 \text{ m/s}$$

So, the final speed is 1.27×10^4 m/s

References:

1) Humanic. (2013). www.physics.ohio-state.edu/~humanic/. In Thomas Humanic Brochure Page.

Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current.* *www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

4) Zitzewitz, P. W. (1999). *Glencoe Physics Principles and Problems*. New York: McGraw-Hill Companies, Inc.

5) Schnick, W.J. (n.d.). *Calculus-based physics, A Free Physics Textbook*. Retrieved from http://www.anselm.edu/internet/physics/cbphysics/index.html

6) Nada H. Saab (Saab-Ismail), (2010-2013) Westwood Cyber High School, Physics, Detroit, Michigan, U.S.A.

7) Nada H. Saab (Saab-Ismail), (2009- 2014) Wayne RESA, Bilingual Department, Detroit, Michigan, U.S.A.