LECTURE 8- KINETIC ENERGY AND WORK

Chapter 7
Professor Noronha-Hostler
Professor Montalvo
Dr. Mae Jemison

First Women of Color in Space, 9 Honorary doctorates, head of 100 Year Starship organization (interstellar travel)
TODAY’S OBJECTIVES

- Kinetic Energy
- Work
- Relationship between kinetic energy, mass, and speed
ENERGY

- Ability to do work
- Kinetic Energy - energy associated with motion
CONSERVATION OF ENERGY

Energy can be transferred from one type to another or from one object to another, but the total amount of energy is the same.
CONSERVATION OF ENERGY
CONSERVATION OF ENERGY
CONSERVATION OF ENERGY
KINETIC ENERGY (K)

Object at rest $K=0$

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

Units

1 Joule $= 1 J = 1 \text{ kg} \cdot m^2/s^2$
HOW MUCH KINETIC ENERGY DOES USAIN BOLT HAVE?

When he’s running at this top speed $v=44.72 \text{ km/h}$ and has a mass of $m=94 \text{ kg}$.

$$v = 44 \frac{\text{km}}{\text{h}} = 44 \frac{\text{km}}{\text{h}} \frac{1000\text{m}}{1\text{km}} \frac{1\text{h}}{3600\text{s}} = 12 \text{ m/s}$$

Then, his kinetic energy is

$$K = \frac{1}{2}mv^2 = \frac{1}{2}94 \text{ kg} \cdot (12 \text{ m/s})^2 = 6800 \text{J}$$
WORK

Work (W) is energy transferred to or from an object by means of a force acting on the object. Not the same as any mental/physical labor!
WORK (VECTOR FORM)

\[ W = \vec{F} \cdot \vec{d} \]

\[ W = Fd \cos \theta \]
IS WORK A SCALAR?

- A.) Yes, Dot products are always scalars.
- B.) No, Dot products are always vectors.
- C.) It’s impossible to say.
- D.) Sometimes.
- E.) I don’t know.
IS WORK A SCALAR?

A.) Yes, Dot products are always scalars.
B.) No, Dot products are always vectors.
C.) It’s impossible to say.
D.) Sometimes.
E.) I don’t know.
SIGN OF WORK

- $W > 0$ Force is in the direction of motion
- $W < 0$ Force opposes the direction of motion
- $W = 0$ Force is perpendicular to the direction of motion
NET WORK

\[ W_{net} = W_F - W_f = Fd - fd \]
WORK-KINETIC ENERGY
THEOREM

- Change in the kinetic energy of a particle = net work done on a particle

\[ \Delta K = K_f - K_i = W \]

thus,

\[ K_f = K_i + W \]
EXAMPLE

A 3 kg box is pushed across a floor with an initial speed of \( v_0 = 2 \text{ m/s} \). If the coefficient of friction is 0.7, how far will the box travel?

First, we determine the force of friction

\[
f_k = \mu F_N = \mu mg = 0.7 (3 \text{ kg})(9.8 \text{ m/s}^2) = 21N
\]

Then, we can calculate the work done by the frictional force

\[
W = Fd \cos \theta = -f_k d = (-21N) d
\]
A 3 kg box is pushed across a floor with an initial speed of $v_0 = 2 \text{ m/s}$. If the coefficient of friction is 0.7, how far will the box travel?

Next, we use the work-kinetic energy theorem to find the net work

$$W_{net} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$= 0 - \frac{1}{2} 3 \text{ kg} \ (2 \text{ m/s})^2 = -6 \text{ J}$$
EXAMPLE

A 3 kg box is pushed across a floor with an initial speed of $v_0=2 \text{ m/s}$. If the coefficient of friction is 0.7, how far will the box travel?

Finally, we set the work equal to itself and solve for $d$

\[
W_{net} = -6J \quad \quad \quad W = (-21N) \ d
\]

\[-6J = (-21N)d \]

\[d = 0.29m\]
WORK DONE BY GRAVITY

\[ W_g = F_g d \cos \theta = mgd \cos \theta \]

If the ball is going up, the gravity is opposing its motion

\[ W_g = mgd \cos 180^\circ = - mgd \]
WORK DONE BY GRAVITY

\[ W_g = F_g d \cos \theta = mgd \cos \theta \]

If the ball is falling, the gravity is enhancing its motion

\[ W_g = mgd \cos 0^\circ = mgd \]
WORK DONE LIFTING

\[ \Delta K = K_f - K_i = W_a + W_g \]
AM I DOING WORK ON THE BOX?

- A.) Yes
- B.) No
- C.) It’s not possible to say
- D.) Only if you stand on one foot and quack like a duck
- E.) I don’t know
AM I DOING WORK ON THE BOX?

- A.) Yes
- B.) No
- C.) It’s not possible to say
- D.) Only if you stand on one foot and quack like a duck
- E.) I don’t know
VARIABLE FORCE

Work is the area underneath the curve

\[ W = \int_{x_i}^{x_f} F(x) \, dx \]

Where does this come from?
SMALL AMOUNTS OF WORK

\[ \Delta W_j = F_{j,avg} \Delta x \]

\[ W = \sum_j \Delta W_j = \sum_j F_{j,avg} \Delta x \]
LIMIT OF X->0

\[ W = \lim_{\Delta x \to 0} \sum_j F_{j,\text{avg}} \Delta x \]
VARIABLE FORCE

Work is the area underneath the curve

\[ W = \int_{x_i}^{x_f} F(x) \, dx \]
3D

\[ \vec{F} = F_x \hat{i} + F_y \hat{j} + F_z \hat{k} \]
\[ d\vec{r} = dx \hat{i} + dy \hat{j} + dz \hat{k} \]

\[ W = \vec{F} \cdot d\vec{r} = F_x dx + F_y dy + F_z dz \]
What is the work done by the force $F(x) = x$ in a distance from $x_0$ to $x_f$?

- A.) $W = x_0$
- B.) $W = x_f$
- C.) $W = \frac{1}{2} x_f^2 - \frac{1}{2} x_o^2$
- D.) $W = \frac{x_f}{x_0}$
- E.) $W = 0$
What is the work done by the force $F(x) = x$ in a distance from $x_0$ to $x_f$?

- A.) $W = x_0$
- B.) $W = x_f$
- C.) $W = \frac{1}{2} x_f^2 - \frac{1}{2} x_o^2$
- D.) $W = \frac{x_f}{x_0}$
- E.) $W = 0$
POWER

Power - how quickly work is done

Average power

\[ P_{avg} = \frac{W}{\Delta t} \]

Instantaneous power

\[ P = \frac{dW}{dt} \]
CONNECTING POWER TO FORCE

\[ P = \frac{dW}{dt} = \frac{Fx \cos \theta}{dt} \]

\[ = F \cos \theta \left( \frac{dx}{dt} \right) \]

\[ P = Fv \cos \theta \]

\[ P = \vec{F} \cdot \vec{v} \]
POWER UNITS

1 Watt = 1 J/s

1 horsepower = 746 W

1 kilowatt-hour = 1 kW h

1 kW \cdot h = 3.60 \cdot 10^6 J
If a runner doubles their velocity over a distance of a meter, What is the net work done by the runner? Initial kinetic energy is $K_0$

A.) Kinetic energy does not change because energy is conserved

B.) $W=2 \ K_0$

C.) $W=0.5 \ K_0$

D.) $W=4 \ K_0$

E.) $W=3 \ K_0$
If a runner doubles their velocity over a distance of a meter, what is the net work done by the runner? Initial kinetic energy is $K_0$

- A.) Kinetic energy does not change because energy is conserved
- B.) $W=2\ K_0$
- C.) $W=0.5\ K_0$
- D.) $W=4\ K_0$
- E.) $W=3\ K_0$
NEXT WEEK

- Potential Energy
- Conservation of Energy