

HNRS 227 Lecture #3 and #4

Chapter 3



Energy

presented by Prof. Geller

Recall from Chapter 1 & 2



- ⌘ Units of length, mass and time
- ⌘ Metric Prefixes
- ⌘ Density and its units
- ⌘ The Scientific Method
- ⌘ Speed, velocity, acceleration
- ⌘ Force
- ⌘ Falling objects
- ⌘ Newton's Laws of Motion
- ⌘ Newton's Law of Universal Gravity

Main Concepts for 3



⌘ Work

⌘ Potential Energy

⌘ Kinetic Energy

⌘ Conservation of Energy

⌘ Types/Sources of Energy

iClicker Question



⌘ What defines the scientific method?

- A A set of related hypotheses can be pieced together into a self consistent description of natural observations
- B A concept or idea that seems to explain a phenomenon or set of observations
- C A reiterative process based on observations, logic, and skepticism
- D A set of hypotheses that have withstood observational or experimental tests
- E Theories that accurately describe the workings of physical reality, and have stood the test of time and been shown to have great and general validity

iClicker Question



⌘ How many arcseconds are there in an arcminute?

A 60 arcseconds

B 360 arcseconds

C 3600 arcseconds

D 600 arcseconds

E These are incompatible units.

iClicker Question



⌘ What is the result if you multiply 10^{15} by 10^{15} ?

A 10^{15}

B 10^{30}

C 10^{150}

D 10^{25}

E 2×10^{15}

iClicker Question

⌘ What is the result if you add 10^{15} to 10^{15} ?

A 10^{15}

B 10^{30}

C 10^{150}

D 10^{25}

E 2×10^{15}

iClicker Question

⌘ What is the result if you raise 10^{15} to the 15th power?

A 10^{15}

B 10^{30}

C 10^{150}

D 10^{225}

E 2×10^{15}

iClicker Question



⌘ Which unit of the following is the largest?

A Kilometer

B Astronomical Unit (AU)

C Light Year (ly)

D Parsec (pc)

E Gigameter

iClicker Question



⌘ What is the difference between speed and velocity?

- A Speed is a vector and velocity is a scalar quantity.
- B Speed is a scalar and velocity is a vector quantity.
- C There is no difference between speed and velocity.
- D All of the above are true statements.

iClicker Question



⌘ What is acceleration?

A The change in distance per change in time.

B The change in position per unit of time.

C The ratio of the change in velocity per change in time.

D The change of time per unit of length.

iClicker Question

⌘ An worm inside a bus goes from the back toward the front at 2 miles/hour. The bus is moving in a straight line at 30 miles/hour. What is the speed of the worm?

- A The speed of the worm is 2 miles per hour relative to the bus.
- B The speed of the worm is 32 miles per hour relative to the ground.
- C The speed of the worm is 30 miles per hour relative to the ground.
- D Both A and B above are true.
- E A, B and C above are true.

iClicker Question



- ⌘ What happens to the velocity and acceleration of an object in free fall?
- A The velocity decreases as the acceleration remains the same.
 - B The velocity increases as the acceleration remains the same.
 - C The velocity increases and the acceleration decreases.
 - D The velocity increases and the acceleration increases.
 - E Both velocity and acceleration decrease.

iClicker Question



⌘ In the equation $d = \frac{1}{2} * a * t^2$, if a is 9.8 meters per second per second and t is in seconds, what is the unit of d ?

- A seconds
- B meters
- C kilometers
- D feet per second
- E meters per second

iClicker Question



⌘ Neglecting air resistance, what are the forces acting on a bullet after it has left the barrel of a rifle?

- A The force of air acting up and gravity acting down.
- B Only the force of gravity acting straight down.
- C There are no forces acting at this point.
- D All of the above are true.

iClicker Question



- ⌘ How does the force of gravity on a ball change as a ball is thrown straight up in the air?
- A The force of gravity increases.
 - B The force of gravity decreases.
 - C The force of gravity remains the same.
 - D The force of gravity increases then decreases.
 - E The force of gravity decreases then increases.

iClicker Question for Thought



⌘ Is it possible for a small car to have the same momentum as a large truck?

A Yes

B No

⌘ Yes, the small car would have to be moving with a much higher velocity, but it can have the same momentum since momentum is mass times velocity.

iClicker Question

⌘ A 30.0 kilogram shell is fired from a 2,000 kilogram cannon with a velocity of 500 meters per second. Can the velocity of the cannon be determined?

A No

B Yes

Work = Force times distance

⌘ Definition of work

⊞ "work is equal to the force that is exerted times the distance over which it is exerted"

⊞ work in Joules =

⊞ force in Newtons * distance in meters

⊞ $W = f * d$

Question for Thought

⌘ A spring clamp exerts a force on a stack of papers it is holding together. Is the spring clamp doing work on the papers?

Yes

No

⌘ If the spring clamp does not cause the paper to move, it is not acting through a distance and no work is done.

Power - Work per unit time



⌘ Power defined

- ☒ "power is the amount of work done divided by the time it takes to do that work"
- ☒ power in Watts = work in Joules / time in seconds
- ☒ $P = W / t$

Question for Thought

⌘ A lamp bulb is rated 100 Watts. Is there a time factor included in the rating?

No

Yes

⌘ Because a time factor is in the rating. A watt is a unit of power, and power is work per unit time. A 100 W light bulb uses energy at a rate of 100 J per s.

Question for Thought

⌘ A kWhr is

- A a unit of work
- B a unit of energy
- C a unit of power
- D More than one of the above is true.

⌘ A kWhr is a unit of work, and since energy is the ability to do work, it is also a unit of energy. In terms of units, a watt is a joule per second, and an hour, as a second, is a unit of time. The time units cancel, leaving a unit of a joule, which can be used to measure either work or energy.

Kinetic Energy

⌘ Definition

☒ "Kinetic energy equals the mass of the moving object times the square of that object's speed, times the constant 1/2."

☒ kinetic energy in Joules = 0.5 * mass in kilograms * speed in meters per second * speed in meters per second

☒ $K.E. = 0.5 * m * v^2$

Question for Thought



⌘ Is work related to energy?

Yes

No

⌘ Energy is the ability to do work, and doing work on something gives it energy.

Question for Thought

⌘ Does a person standing motionless in the aisle of a moving bus have kinetic energy?

Yes

No

⌘ Relative to the bus, the person has no kinetic energy because the person is at rest relative to the bus. Relative to the ground, however, the person does have kinetic energy because the person is moving with the same speed as the bus.

Question for Thought



⌘ A joule of work and a joule of energy are fundamentally the same?

Yes

No

⌘ A joule is one newton-meter. A joule of work is from a force acting through a distance while a joule of energy is the ability to perform one joule of work. The use of the same unit means that work and energy are fundamentally the same thing.

Potential Energy



⌘ Definition

- ☒ “gravitational potential energy of any object equals its weight times its height above the ground”
- ☒ gravitational potential energy in Joules = mass in kilograms * acceleration due to gravity * height in meters
- ☒ $P.E. = m * g * h$

Question for Thought



- ⌘ What is the relationship between the work done while moving a book to a higher bookshelf and the potential energy that the book has on the higher shelf?

- ⌘ The work done is equal to the increase in gravitational potential energy.

Question for Thought



⌘ Compare the energy needed to raise a mass 10 meters on Earth to the energy needed to raise the same mass 10 meters on the Moon. Explain the difference, if any.

⌘ The energy required is less on the moon because the weight of the object (the downward force due to gravity) depends upon the force of gravity, which is less on the moon than on the earth. Less energy is needed to do the work of raising the mass on the moon, and the elevated object on the moon has less potential energy as a consequence of the work done.

Question for Thought



- ⌘ What happens to the kinetic energy of a falling book when the book hits the floor?
- A The kinetic energy is destroyed.
 - B The kinetic energy is converted to heat only.
 - C The kinetic energy is converted to heat and sound.

Mass as Energy

⌘ Definition

- ☒ “every object at rest contains potential energy equivalent to the product of its mass times the speed of light squared”
- ☒ energy in joules = mass in kilograms * speed of light in meters per second * speed of light in meters per second
- ☒ $E = m * c^2$

Energy Interchangeability

⌘ Potential Energy

- ☒ gravitational
- ☒ chemical
- ☒ elastic
- ☒ electromagnetic

⌘ Kinetic Energy

- ☒ moving objects
- ☒ heat
- ☒ sound and other waves

⌘ Mass

- ☒ $E = m * c^2$

**Energy is
Conserved**

Question for Thought



- ⌘ If energy cannot be destroyed, why do some people worry about the energy supplies?
- ⌘ Energy is eventually converted into unrecoverable radiant energy, so new sources of convertible energy must be found in order to continue performing useful work.

Question for Thought



⌘ Why are petroleum, natural gas, and coal called fossil fuels?

⌘ Fossil fuels contain energy from plants or animals that lived millions of years ago. These plants and animals are known from the fossils they left behind, and the energy in the fuels represents energy stored from these ancient organisms.

Question for Thought



- ⌘ From time to time people claim to have invented a machine that will run forever without energy input and develops more energy than it uses (perpetual motion). Why would you have reason to question such a machine?
- ⌘ The machine would not be in accord with the principle of conservation of energy.

Sample Question



⌘ One thousand two hundred joules of work are done while pushing a crate across a level floor for a distance of 1.5 meters. What force was used to move the crate?

Sample Question



1.

$$\begin{aligned}W &= Fd \quad \therefore F = \frac{W}{d} \\ &= \frac{1,200\text{J}}{1.5\text{m}} \\ &= \frac{1,200}{1.5} \text{ (N} \cdot \text{m)} \left(\frac{1}{\text{m}}\right) \\ &= 800 \text{ N} \\ &= 8.0 \times 10^2 \text{ N}\end{aligned}$$

Sample Question



- ⌘ A) What is the kinetic energy of a 30.0 gram bullet that is traveling at 200.0 meters per second?
- ⌘ B) What velocity would you have to give a 60.0 gram bullet to give it the same kinetic energy?

Sample Question

6. (a)

$$\begin{aligned} KE &= \frac{1}{2}mv^2 \\ &= \frac{1}{2}(0.0300 \text{ kg})\left(200.0\frac{\text{m}}{\text{s}}\right)^2 \\ &= \frac{1}{2}(0.0300 \text{ kg})\left(40,000.0\frac{\text{m}^2}{\text{s}^2}\right) \\ &= \frac{1}{2}(0.0300)(40,000.0) \text{ kg} \times \frac{\text{m}^2}{\text{s}^2} \\ &= 600 \frac{\text{kg} \cdot \text{m}}{\text{s}^2} \times \text{m} \\ &= 6.00 \times 10^2 \text{ Nm} \\ &= 6.00 \times 10^2 \text{ J} \end{aligned}$$

Sample Question

(b)

$$\begin{aligned} KE &= \frac{1}{2}mv^2 \quad \therefore v = \sqrt{\frac{2KE}{m}} \\ &= \sqrt{\frac{(2)(600\text{J})}{0.0600\text{ kg}}} \\ &= \sqrt{\frac{(2)(600)\text{ Nm}}{0.0600\text{ kg}}} \\ &= \sqrt{\frac{1,200\frac{\text{kg}\cdot\text{m}}{\text{s}^2}\text{ m}}{0.0600\text{ kg}}} \\ &= \sqrt{20,000\frac{\text{kg}\cdot\text{m}^2}{\text{s}^2}} \times \frac{1}{\text{kg}} \\ &= \sqrt{20,000\frac{\text{m}^2}{\text{s}^2}} \\ &= 141\frac{\text{m}}{\text{s}} \end{aligned}$$

Sample Question



- ⌘ A) How much work is done in raising a 50.0 kilogram crate a distance of 1.5 meters above a storeroom floor?
- ⌘ B) What is the change of potential energy as a result of this move?
- ⌘ C) How much kinetic energy will the crate have as it falls and hits the floor?

Sample Question

10. (a)

$$\begin{aligned}W &= Fd \\&= mgd \\&= (50.0 \text{ kg})\left(9.8 \frac{\text{m}}{\text{s}^2}\right)(1.5 \text{ m}) \\&= 50.0 \times 9.8 \times 1.5 \frac{\text{kg} \cdot \text{m}}{\text{s}^2} \times \text{m} \\&= 735 \text{ N} \cdot \text{m} \\&= 740 \text{ J}\end{aligned}$$

Sample Question

(b)

$$\begin{aligned} PE &= mgh \\ &= (100 \text{ kg}) \left(9.8 \frac{\text{m}}{\text{s}^2} \right) (15 \text{ m}) \\ &= 50.0 \times 9.8 \times 1.5 \frac{\text{kg} \cdot \text{m}}{\text{s}^2} \times \text{m} \\ &= 735 \text{ N} \cdot \text{m} \\ &= 740 \text{ J} \end{aligned}$$

(c) Since the PE lost is equal to the KE gained, then $KE = 740 \text{ J}$.

Sample Question



- ⌘ A) What distance will a 10 horsepower motor lift a 2000 pound elevator in 30.0 seconds?
- ⌘ B) What would be the average velocity of the elevator during the lift?

Sample Question


16. (a)

$$P = \frac{mgh}{t} \quad \therefore \quad h = \frac{Pt}{mg}$$

$$\begin{aligned} & (10.0 \text{ hp}) \left(\frac{550 \frac{\text{ft} \cdot \text{lb}}{\text{s}}}{1.00 \text{ hp}} \right) (30.0 \text{ s}) \\ &= \frac{\hspace{10em}}{2,000.0 \text{ s}} \\ &= 82.5 \text{ ft} \end{aligned}$$


(b)

$$\bar{v} = \frac{d}{t} \quad \therefore \quad \bar{v} = \frac{82.5 \text{ ft}}{30.0 \text{ s}} = 2.75 \frac{\text{ft}}{\text{s}}$$



⌘ The magnitude of the force that a baseball player exerts with a 6 kilogram baseball bat on a 0.1 kilogram ball is measured to be 60 Newtons. What is the magnitude of the force that the ball exerts on the bat?

- ⌘ A. 6 Newtons
- ⌘ B. 10 Newtons
- ⌘ C. 50 Newtons
- ⌘ D. 60 Newtons
- ⌘ E. 0.6 Newtons



⌘ Which two terms represent a vector quantity and the scalar quantity of the vector's magnitude, respectively?

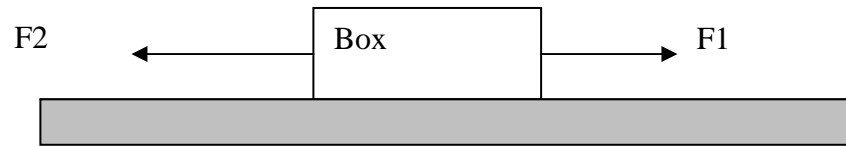
⌘ A. acceleration and velocity

⌘ B. weight and force


⌘ C. speed and time

⌘ D. velocity and speed

⌘ E. time and distance



- ⌘ In the diagram above, a box is on a frictionless horizontal surface with forces F_1 and F_2 acting as shown. If the magnitude of F_2 is greater than the magnitude of F_1 , then the box is
- ⌘ A. moving at constant speed in the direction of F_1
 - ⌘ B. moving at constant speed in the direction of F_2
 - ⌘ C. accelerating in the direction of F_1
 - ⌘ D. accelerating in the direction of F_2
 - ⌘ E. not moving at all.



⌘ A 5 kilogram rock and a 2 kilogram stone fall freely from rest from a height of 1000 meters. After they fall for 2 seconds, the ratio of the rock's speed to the stone's speed is


⌘ A. 1 to 1

⌘ B. 1 to 2

⌘ C. 2 to 1

⌘ D. 4 to 1

⌘ E. 100 to 1



⌘ When a satellite is a distance R from the center of Earth, the force due to gravity on the satellite is F . What is the force due to gravity on the satellite when its distance from the center of the Earth is $4R$?


⌘ A. $9 F$

⌘ B. $4 F$

⌘ C. $F / 4$

⌘ D. $F / 9$

⌘ E. $F / 16$



⌘ The speed of a car is increased uniformly from 10 meters per second to 50 meters per second in 4 seconds. Which of the following is closest to the magnitude of the car's acceleration?


⌘ A. 50 m/s^2


⌘ B. 12.5 m/s^2

⌘ C. 2.5 m/s^2

⌘ D. 10 m/s^2

⌘ E. 40 m/s^2

- 
- ⌘ The metric unit of a Joule (J) is a unit of
 - ⌘ A. potential energy.
 - ⌘ B. work.
 - ⌘ C. kinetic energy.
 - ⌘ D. All of the above (A, B, and C) are measured in Joules.
 - ⌘ E. None of the above (A, B, and C) are measured in Joules.

- 
- ⌘ Which statement is true about the concept of power?
 - ⌘ A. Power is the distance over which work is done.
 - ⌘ B. Power is the time at which energy is expended.
 - ⌘ C. Power is the work done per unit time.
 - ⌘ D. All of the above (A, B, and C) can be said about power.
 - ⌘ E. None of the above (A, B, and C) is true about power.



⌘ A kilowatt-hour is a unit of


⌘ A. power.


⌘ B. work.

⌘ C. time.

⌘ D. area.

⌘ E. volume.

- 
- ⌘ Which of the following best describes the law of conservation of energy?
 - ⌘ A. Energy must not be used up faster than it is created or the supply will run out.
 - ⌘ B. Energy can be neither created nor destroyed.
 - ⌘ C. Energy is conserved because it is easily destroyed.
 - ⌘ D. Conservation is a law describing how to destroy matter.
 - ⌘ E. Energy conservation is a law recently passed by Congress.



⌘ What is the work done by applying a force of 50 Newtons on a 100 kilogram object over a distance of 10 meters?

⌘ A. 1,000 Joules

⌘ B. 100 Joules

⌘ C. 500 Joules

⌘ D. 10,000 Joules

⌘ E. 5,000 Joules



⌘ What is the power consumed by a 100 Joules energy source in 4 seconds?


⌘ A. 400 Watts

⌘ B. 100 Watts

⌘ C. 200 Watts

⌘ D. 50 Watts

⌘ E. 25 Watts



⌘ What is the kinetic energy of a ball of mass 200 grams thrown with a velocity of 20 meters per second?

⌘ A. 4,000 Joules

⌘ B. 40 Joules

⌘ C. 20,000 Joules

⌘ D. 40,000 Joules

⌘ E. 2,000 Joules