





Section 3.1



The man shown uses 40N of force to lift the box 1.5m off the ground. How much work did he do?



A different, much cooler man uses 40N of force to push against the brick wall of a large building. After 2 minutes, he is feeling pretty tired. How much work did he do?

 $W = F \cdot d$ A) None B) 20 J C) 40 J D)80 J E) 4800 J



Positive and Negative

- Same direction:
 F (+) and d(+),
 then W = +
- Positive work speeds you up
- Opposite directions:
 F (+) and d (-), then W = -
 - Negative work slows you down

A frictional force f = 450N acts on the player as he slides into second base, covering a distance d = 2.5m. Calculate the amount of work done on the player by friction.

d = 2.5m



work time Power



• Power = work per time, or rate at which work is done

- Watt = W = (Joule)/(second)
- kilowatt = kW = 1000 Watts

Running up the stairs in one minute (60 sec), **Anna develops 40 Watts** of power. Anna's friend Beth weighs a little more, but it only takes her 55 seconds to run the same set of stairs.

- A) Beth develops greater power than Anna.
- B) Beth develops the same 40W of power as Anna. If the stairs are the same, it does not matter who runs up them! Or down them.
- C) Beth develops less power than Anna.



Horsepower



- I hp = 746 W
- Historical artifact!
- James Watt made the comparison, by literally making the comparison
- He estimated that an average pony could lift 220 lb through 100 ft per minute, working a 4 hour shift
- Poor pony!
- No ponies were harmed in the making of this slide

Section 3.2 Motion, Position, and Energy

What is Energy?

- Energy is a property
- An object's energy enables it to do work
- Doing work on an object changes its energy



 Several types: gravitational, electrical, magnetic, spring

- All depend on where, not how fast
- An object at rest can still have PE

Potential Energy: The Energy of Position



Potential energy stored in the stretched bowstring will be converted to kinetic energy when the string is released.



Gravitational PE

- PE is a form energy, so it should look like work
- Units of PE are same as KE are same as work: Joule = N⋅m

Do you reference the ground? The surface of the water? the track itself?



PE is Relative

- There is no location you can point to and say, "*PE* = 0 right here, all the time."
- Think of *h* as the **change in position**, not the absolute position
- You may want the floor to be *h*=0, or you may want the tabletop to be *h*=0
- The situation should determine where it makes sense to have *h*=0

Compare using point 1 as your reference level for PE with using point 3.



- A) The *PE* will be the same no matter where you declare h = 0. $PE_1 = PE_2 = PE_3$ for the coaster car.
- B) If you use point 1 for reference, PE_1 is some positive value, and $PE_2 = 0$, and PE_3 is negative.
- C) When you use point 3 for reference, $PE_3 = 0$, and both PE_1 and PE_2 will be negative.
- D) When you use point 3 for reference, $PE_3 = 0$, but both PE_1 and PE_2 will be positive!

Kinetic Energy: The Energy of Motion

- $KE = \frac{1}{2}mv^2$
- No motion, no KE: object at rest has KE = o
- KE can only be (+), cannot be (-)



The skier shown has a mass of 55kg. She is moving at 12m/s. What is her kinetic energy?

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

Answer numerically.

A car traveling north has 365kJ of kinetic energy.

True or false: the same car traveling at the same speed, but headed south, will have -365kJ of kinetic energy.



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

Same KE?

Ball	Mass (kg)	Speed (m/s)	КЕ (J)
Football	0.426	10	21.3
Basketball	0.625	8.25	21.3
Tennis	0.057	27.35	21.3
Golf	0.046	30.5	21.3
Baseball	0.142	17.34	21.3

Section 3.3 Energy Flow

THEFT

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- Doing work on an object changes its energy: $W = \Delta E$
- You can re-write Newton #2 to say this: $\frac{1}{2}m(v_i)^2 + W = \frac{1}{2}m(v_f)^2$
- Now separate PE from the rest of the work being done: $(PE_i + KE_i) + W_{nc} =$ $(PE_f + KE_f)$

Work and Energy

A standard hockey puck (m = 0.160kg) has an initial speed $v_i = 20$ m/s. How much work will the force of friction do on the puck to bring it to rest ($v_f = 0$)?

 $\frac{1}{2}m(v_i)^2 + W = \frac{1}{2}m(v_f)^2$ $W = \frac{1}{2}m(v_f)^2 - \frac{1}{2}m(v_i)^2$ $W = 0 - \frac{1}{2}(0.160 \text{ kg})(20 \text{ m/s})^2$ $W = -\frac{1}{2}(0.160)(400)\text{ J}$

A) -320J
B) -32J
C) 0J
D) +32J
D) +32J
E) +320J
F) +640J





- Different forms ≠ different kinds
- Different forms means energy arises for different reasons
- All forms are interchangeable

Kitten says he gets his energy from sleeping. Sasquatch says he got his energy from the food he ate. Who is right?



A) Kitten B) Sasquatch C) Both D) Neither

- Kinetic energy, gravitational PE, spring PE
- Mechanical has to do with the overall bulk motion or position of an object



- Form of potential energy: stored by atoms/molecules
- Chemical potential can be released in a chemical reaction
- Logs in the fireplace: the flames you see and the heat you feel are the energy being released as the wood burns (which is a chemical reaction between the wood and the oxygen in the air)

THE CHEMISTRY OF GLOW STICK COLOURS





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Radiant (Electromagnetic) Energy



 Visible light, but actually all of the electromagnetic spectrum

- Infrared, visible, UV are actually all the same thing
- Ultimate source of this energy is electron vibrations



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- Where mechanical and radiant energy intersect
- Many obvious examples of converting electrical to mechanical energy

- It's the nucleus, not the electrons here
- If a nucleus is unstable, it will try to get stable
- It will release energy and/or particles to reconfigure itself

Ruclear Bregy

True or false:

Chemical energy can be transformed into electrical energy. Also, electrical energy can be transformed into mechanical energy.

Back in my day, we drove lemons—and by golly, we *liked* it!

- All forms are interchangeable
- Turn on the light: electrical energy converted to light (radiant energy)*
- Eat breakfast, walk across campus: chemical energy converted to mechanical energy*

- Drive across town: chemical energy converted to mechanical energy*
- Turn on the radio: radiant energy converted in mechanical energy
- *Plus radiant energy in the form of heat. There's always waste heat. Always.



Conservation CONSERVATION PYRAMID WHERE DO I BEGIN?

- Move it, don't lose it
- Energy cannot be created or destroyed, but it can change form and/ or be transferred form one object to another
- If you think you are seeing a violation of this law, look harder. The energy you think you lost might not be where you thought it should be, but it will be somewhere.



- Compress spring: stored spring PE
- Release spring: PE converted to KE of the ball
- Ball collides with block: some energy transferred to block
- Ball+block: KE converted to gravitational PE
- Angle indicator lets you calculate how much gravitational PE
- You never have as much PE at the end as you predict (from knowing the spring constant and the masses)

Ballistic Pendulum: Where does the energy go?



Energy Transfer

How do you get energy from Object A to Object B?

It depends; what kind of energy are you transferring, and what are these objects A and B?

Section 3.4

NATURAL GAS SHARE OF ENERGY USE:

23.8 percent

· ADVANTAGE: Fewer harmful emissions than coal and oil · WILDLIFE IMPACTS: Habitat loss related to drilling and infrastructure; collisions between tankers and whales; potential for leaks of gas and contaminants; greenhouse gas emissions; ocean acidification * ACTION: Enforce safeguards to water supplies and sensitive habitats; prevent collisions by requiring ships to slow down when endangered whales are nearby

WIND SHARE OF ENERGY USE:

COAL

SHARE OF ENERGY USE: *

22.5 percent

* ADVANTAGE: Most abundant fossil fuel in the U.S.

· WILDLIFE IMPACTS: Greenhouse gases, mercury, other

pollutants, acid rain, ocean acidification, habitat loss

related to mining

* ACTION: Transition to other fuels when possible;

develop technologies to reduce or contain

emissions: reforest and reclaim

mined areas

 ADVANTAGE: Renewable; zero emissions · WILDLIFE IMPACTS: Birds may strike turbine blades and towers; bats are also trapped and killed by wind vortices · ACTION: Use data on migration pathways to inform decisions about siting

Energy Sources Today

0.5 percent

NUCLEAR SHARE OF ENERGY USE:

8.5 percent

* ADVANTAGE: Generates electricity on a large scale with no greenhouse gas emissions * WILDLIFE IMPACTS: Habitat loss associated with fuel extraction, processing, waste management, siting, and infrastructure; short- and long-term release of radioactive materials + ACTION: Contain radioactive materials at all stages of the fuel cycle

BIOMASS SHARE OF ENERGY USE:

3.9 percent

* ADVANTAGE: Renewable and carbon neutral, with cleaner emissions than from fossil fuels · WILDLIFE IMPACTS: Agricultural land set aside for conservation reserves is now reverting to row-crops for biofuels · ACTION: Conduct research on ethanol production from crops that are more sustainable and provide more wildlife habitat than corn

PETROLEUM SHARE OF ENERGY USE: 37.1 percent

· ADVANTAGE: Fuels from petroleum are portable and light for the amount of energy they contain, making them the fuel of choice for motor transportation as well as other uses · WILDLIFE IMPACTS: Habitat loss related to drilling and infrastructure; oil spills; acid rain and ocean acidification; noise from undersea exploration can disrupt animal communications ACTION: Reduce noise from underwater energy exploration in biologically critical habitats and during biologically critical seasons (e.g., mating, calving, feeding); avoid sensitive terrestrial habitats

SOLAR

SHARE OF ENERGY USE: <0.5 percent

* ADVANTAGE: Renewable; zero emissions · WILDLIFE IMPACTS: Large-scale application in natural areas, such as deserts, could cause habitat loss ACTION: Site installations on existing structures and already-developed land

HYDROELECTRIC SHARE OF ENERGY USE:

2.5 percent

 ADVANTAGE: Renewable, large-scale electricity generation •WILDLIFE IMPACTS: Inundation of riparian habitat for reservoirs; disruption of aquatic ecosystems, especially for migratory fish such as salmon · ACTION: Identify sensitive wildlife and mitigate impact

Conserving Energy, Conserving Wildlife

E nergy consumption in the United States is about 4.5 times greater per capita than the world average, and about 70 percent more than the average for other developed nations. The potential for increasing energy efficiency is large and available now, on a cost-effective basis using current technology. Conserving energy means conserving wildlife, by reducing the need for new power plants, curtailing emissions, and preserving habitats.

True or false:

In 2013, the United States (with 5% of the global population) consumed 18% of the world's energy.



Source: US Energy Information Administration

Estimated U.S. Energy Consumption in 2019: 100.2 Quads



Source: LLNL March, 2020. Data is based on DOE/EIA MER (2019). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 21% for the transportation sector and 49% for the industrial sector, which was updated in 2017 to reflect DOE's analysis of manufacturing. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Quad = unit of energy = 10¹⁵ (quadrillion) BTU = 1.055×10¹⁸ Joules







Source: LLNL 2013. Data is based on DOE/EIA-0214(2011), June 2013. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. Interstate and international electricity trade are lumped into net imports or exports and are calculated using a system-wide generation efficiency. End use efficiency is estimated for each sector as 65% residential, 65% commercial, 80% industrial and 21% transportation. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

1200 trillion = 1.2×10¹⁵ BTU = 1.2 Quads = 1.266×10¹⁸ Joules

Conserving Energy

Not the same as conservation of energy!

- Do more with less: increase efficiency
- Just use less: why is this so difficult to understand?

CONSERVATION PYRAMID

WHERE DO I BEGIN?



Section 3.5

Energy Sources Tomorrow

U.S. energy consumption by energy source, 2018

total = 101.3 quadrillion total = 11.5 guadrillion Btu British thermal units (Btu)

eia²



2% - geothermal 6% - solar

Note: Sum of components may not equal 100% because of independent rounding. Source: U.S. Energy Information Administration, Monthly Energy Review, Table 1.3 and 10.1. April 2019, preliminary data

Not Much Changes

- What coal has lost, natural gas has gained
- About the same proportions in renewables



US Energy Consumption By Source: 2015



Note: Sum of components may not equal 100% because of independent rounding.