Physics 101H

General Physics 1 – Honors

Lecture 18 – 9/29/23

Energy conservation

Summary

Topics

Yesterday: Work & Energy [chapter 7 & chapter 8]

- Work-energy theorem
- Potential energy

Today: Energy conservation [chapter 8]

- Types of energy
- Energy transfer
- Energy conservation

Announcements

Next Wednesday: Midterm 1
Next week: No quiz

What types of energy transfer can we list?

Types of energy

Mechanical energy is the sum of the **kinetic** and **potential energy**

Types of potential energy

- Elastic potential energy
- Gravitational potential energy

Internal energy is energy stored within a system

- Heat energy, stored as kinetic and potential energy in atoms and molecules, corresponding to temperature
- Nonconservative forces typically turn work into internal (thermal) energy
- Discuss this in much more detail in PHYS 102(H)

Energy conservation

You may ask: “So what? Why all the fuss about energy?”

Answer: energy is **conserved**.

- Can’t make or destroy energy
- You can only move it around
- Or change its type

Example: Gravitational potential energy is turned into kinetic energy when you drop something. Along the way, friction turns that kinetic energy into thermal (internal) energy.

Energy transfer

Mathematically

Closed system

No energy transfer to or from the system and its surroundings

Open system

Energy transfer to or from the system and its surroundings

In both cases, recall that power is the **rate of energy transfer**

Example: Neglecting air resistance, determine the speed of a dropped ball when it is a distance y above the ground.

Example: What is the work done when compressing a spring?

Energy conservation in the Universe*

***Not examinable**

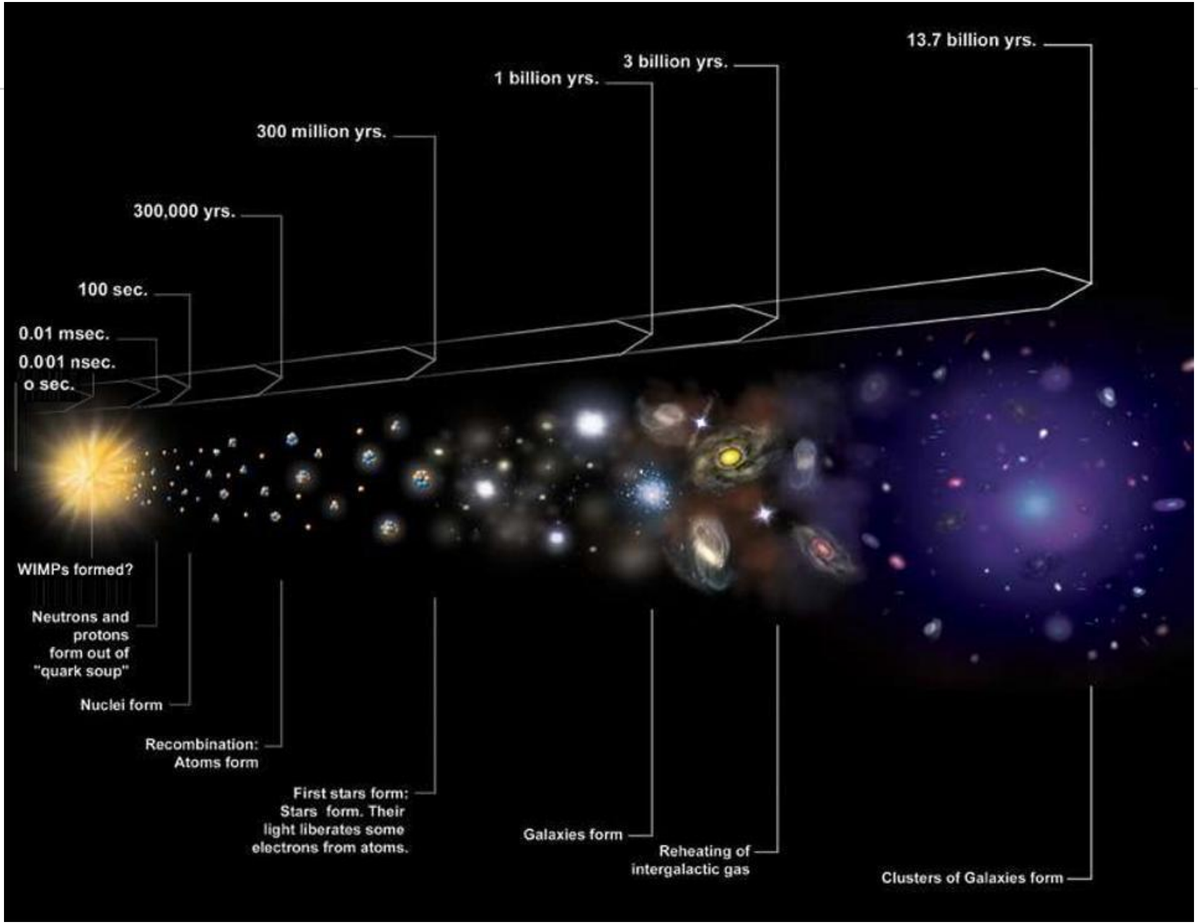
In fact, this is not the whole story (it rarely ever is…)

Defining energy conservation in the context of **general relativity** – the theory of gravity – is considerably more difficult, because spacetime itself carries energy density that contributes to the Universe’s **energy budget**

Further complicated by the **expansion of the Universe**, because energy conservation ultimately arises from time-translation invariance

Energy conservation*

*Not examinable



Want more practice?

Try the following problems **Chapter 8** of the textbook:

- Conceptual questions: 1, 5, 9, 13, 17
- Potential energy: 21, 23, **73**
- Conservative and nonconservative force: 25, 27, 29, **85**
- Conservation of energy: 31, 35, 39, 53, 59, **77**

Answers are provided for questions with **blue** numbers (odd numbered)

Click on the number to be taken to the answer.

But make sure you at least **try** the problem first!

Summary

Topics

Today: Energy conservation [chapter 8]

- Types of energy
- Energy transfer
- Energy conservation

Monday: Review [chapter 1 - chapter 6]

- Review

Announcements

Next Wednesday: Midterm 1
Next week: No quiz

NEXT WEEK:
THE FIRST MIDTERM IS ON WEDNESDAY OCTOBER 4

PHYSICS 101 - HONORS

Lecture 18 9/29/23

Energy transfer (slide 3)

Work
Mechanical waves
Heat
Matter transfer (eg convection)
Electrical transmission
Electromagnetic radiation

Types of energy (slide 4)

$$E_{mech} = \underset{E_K}{\underset{\shortparallel}{K}} + \underset{E_p}{\underset{\shortparallel}{U}} = \frac{1}{2}mv^2 + U$$

Elastic potential energy $U = \frac{1}{2}kx^2$

Gravitational potential energy $U = mgh$

Energy conservation $\Delta E = 0$

$\hookrightarrow \Delta E = \Delta K + \Delta U + \Delta E_{int}$

Power (slide 6)

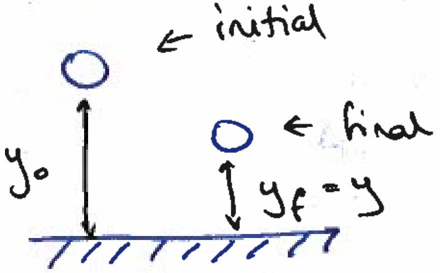
$P = \frac{dE}{dt}$ and when energy is transferred through work, this becomes

$$P = \frac{dW}{dt} = \frac{d(\bar{F}\cdot\bar{r})}{dt}$$

$$= \bar{F}\cdot\frac{d\bar{r}}{dt} = \bar{F}\cdot\bar{v}$$

$\bar{F}$ constant so $\frac{d\bar{F}}{dt} = 0$

Speed example (slide 7)



Initial state

$$E_i = K_i + U_i + E_{int,i}$$
$$= \frac{1}{2}mv_i^2 + mgy_o + 0$$

Final state

$$E_f = K_f + U_f + E_{int,f}$$
$$= \frac{1}{2}mv_f^2 + mgy$$

Energy conservation $\Rightarrow \Delta E = 0$

$$\Rightarrow E_f - E_i = 0$$

$$\Rightarrow \frac{1}{2}mv_f^2 + mgy - \frac{1}{2}mv_i^2 - mgy_o = 0$$

$$\frac{1}{2}m(v_f^2 - v_i^2) + mg(y - y_o) = 0$$

$$\frac{m}{2}(v_f^2 - v_i^2) = mg(y_o - y)$$

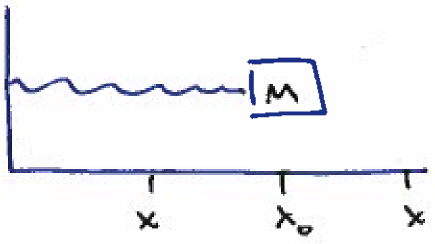
$$v_f^2 - v_i^2 = 2g\Delta y$$ ← look familiar ?!

Spring compression (slide 8)

work done by the spring

Recall from lecture 16: $W = \frac{k}{2}\left(x_1^2 - x_2^2\right)$

Our diagram:



we now treat the spring as part of the system, then compressing or extending the spring stores potential energy in the system

$$W_{ext} = -W = \underbrace{\frac{k}{2}\left(x_2^2 - x_1^2\right)} = \Delta U.$$

elastic potential energy $E_p = \frac{k}{2}x^2$

More generally:

$$W_{int} = \int_{x_1}^{x_2} F\,dx = -\Delta U = -\left(U\big|_{x_2} - U\big|_{x_1}\right)$$

↑ in 1D

comparing these two

$$F_x = -\frac{dU}{dx}$$

In 3D we have $F_x = -\frac{\partial U}{\partial x}$ $F_y = -\frac{\partial U}{\partial y}$ $F_z = -\frac{\partial U}{\partial z}$

$$\bar{F} = -\frac{\partial U}{\partial x}\hat{x} - \frac{\partial U}{\partial y}\hat{y} - \frac{\partial U}{\partial z}\hat{z} \quad \text{or} \quad \bar{F} = -\bar{\nabla} U$$

← a scalar

N.B a vector

gradient (vector operator)

Equation Summary

Work	$W = \int_{x_1}^{x_2} \bar{F} \cdot \overline{dS}$	
	$W = \bar{F} \cdot \Delta \bar{x}$	for constant force
Work-energy theorem	$W = \Delta K + \Delta U$	
Kinetic energy	$K = \frac{1}{2} m v^2$	
Potential energy	$U_p = mgh$	gravitational
	$U_s = \frac{1}{2} k x^2$	spring
Energy conservation	$\Delta E = 0$	
Power	$P = \frac{dE}{dt}$	
	$P = \bar{F} \cdot \bar{v}$	constant force
Potential	$\bar{F} = -\bar{\nabla} U$	
	$F = -\frac{dU}{dx}$	in 1D