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Physics 111 - Class 9B
PE & Energy Conservation

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November 3, 2021

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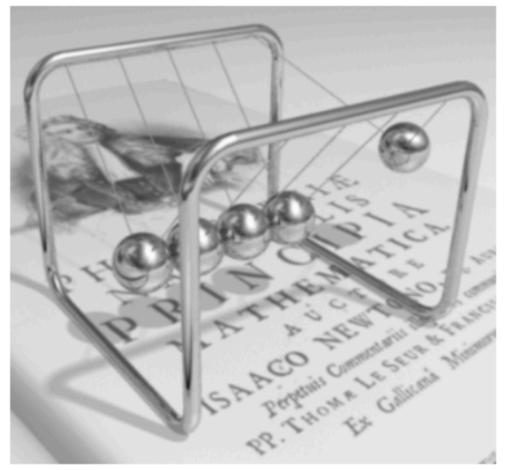
Class Outline

- Logistics / Announcements
- Chapter 8 Section Summary
- Energy Skatepark Demo
- Clicker Questions
- Worked Problems

Logistics/Announcements

- Lab this week: Lab 6
- HW8 due this week on Thursday at 6 PM
- Learning Log 8 due on Saturday at 6 PM
- HW and LL deadlines have a 48 hour grace period
- Test/Bonus Test: Bonus Test 3 available this week (Chapters 5 & 6)
  - Test Window: Friday 6 PM - Sunday 6 PM



Physics 111

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Unsyllabus

ABOUT THIS COURSE

Course Syllabus (Official)

Course Schedule

Accommodations

How to do well in this course

GETTING STARTED

Before the Term starts

After the first class

In the first week

Week 1 - Introductions!

PART 1 - KINEMATICS

Week 2 - Chapter 2

Week 3 - Chapter 3

Week 4 - Chapter 4

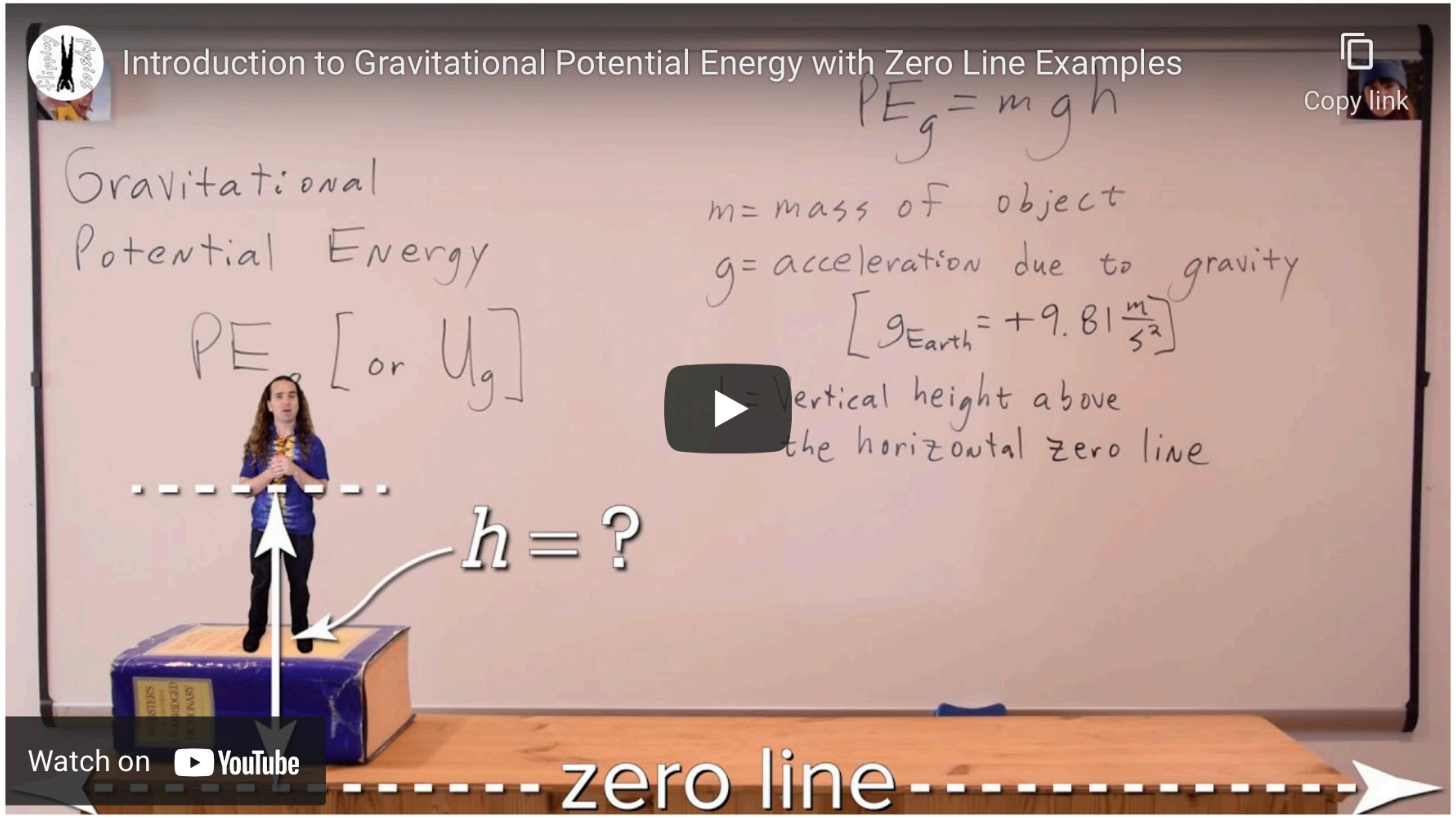
PART 2 - DYNAMICS

Videos

Below are the assigned videos for this week. The videos are collapsible so once you're done with one, you can move to the next one. In the sidebar on the right, you can use the checklists to keep track of what's done.

Required Videos

1. Introduction to Gravitational Potential Energy with Zero Line Examples



- Notes
- Direct link to Mr. P's page

Required Videos

Optional Videos

Checklist of items

- [x] Video 1
- [x] Video 2
- [ ] Video 3
- [ ] Video 4
- [x] Video 5
- [ ] Video 6
- [ ] Video 7
- [x] Video 8
- [ ] Video 9
- [ ] Video 10

Table of contents

Preface
Mechanics
1 Units and Measurement
2 Vectors
3 Motion Along a Straight Line
4 Motion in Two and Three Dimensions
5 Newton's Laws of Motion
6 Applications of Newton's Laws
7 Work and Kinetic Energy
8 Potential Energy and Conservation of Energy
Introduction
Mon 8.1 Potential Energy of a System
8.2 Conservative and Non-Conservative Forces
Fri 8.3 Conservation of Energy
Wed 8.4 Potential Energy Diagrams and Stability
8.5 Sources of Energy
Chapter Review
9 Linear Momentum and Collisions
10 Fixed-Axis Rotation
11 Angular Momentum
12 Static Equilibrium and Elasticity

Figure 8.1 Shown here is part of a Ball Machine sculpture by George Rhoads. A ball in this contraption is lifted, rolls, falls, bounces, and collides with various objects, but throughout its travels, its kinetic energy changes in definite, predictable amounts, which depend on its position and the objects with which it interacts. (credit: modification of work by Roland Tanglao)

Chapter Outline

8.1 Potential Energy of a System
8.2 Conservative and Non-Conservative Forces
8.3 Conservation of Energy
8.4 Potential Energy Diagrams and Stability
8.5 Sources of Energy

In George Rhoads' rolling ball sculpture, the principle of conservation of energy governs the changes in the ball's kinetic energy and relates them to changes and transfers for other types of energy associated with the ball's interactions. In this chapter, we introduce the important concept of potential energy. This will enable us to formulate

Wednesday's Class

8.4 Potential Energy Diagrams and Stability
8.5 Sources of Energy

EXAMPLE 8.1

Basic Properties of Potential Energy

A particle moves along the *x*-axis under the action of a force given by $F = -ax^2$, where $a = 3\ \text{N/m}^2$. (a) What is the difference in its potential energy as it moves from $x_A = 1\ \text{m}$ to $x_B = 2\ \text{m}$? (b) What is the particle's potential energy at $x = 1\ \text{m}$ with respect to a given 0.5 J of potential energy at $x = 0$?

EXAMPLE 8.1

Basic Properties of Potential Energy

A particle moves along the x-axis under the action of a force given by $F = -ax^2$, where $a = 3\text{ N/m}^2$. (a) What is the difference in its potential energy as it moves from $x_A = 1\text{ m}$ to $x_B = 2\text{ m}$? (b) What is the particle's potential energy at $x = 1\text{ m}$ with respect to a given 0.5 J of potential energy at $x = 0$?

Solution

a. The work done by the given force as the particle moves from coordinate x to $x + dx$ in one dimension is

$$dW = \vec{\mathbf{F}} \cdot d\vec{\mathbf{r}} = F dx = -ax^2 dx.$$

Substituting this expression into Equation 8.1, we obtain

$$\Delta U = -W = \int_{x_1}^{x_2} ax^2 dx = \frac{1}{3}(3\text{ N/m}^2)x^3\Big|_{1\text{ m}}^{2\text{ m}} = 7\text{ J}.$$

b. The indefinite integral for the potential energy function in part (a) is

$$U(x) = \frac{1}{3}ax^3 + \text{const.},$$

and we want the constant to be determined by

$$U(0) = 0.5\text{ J}.$$

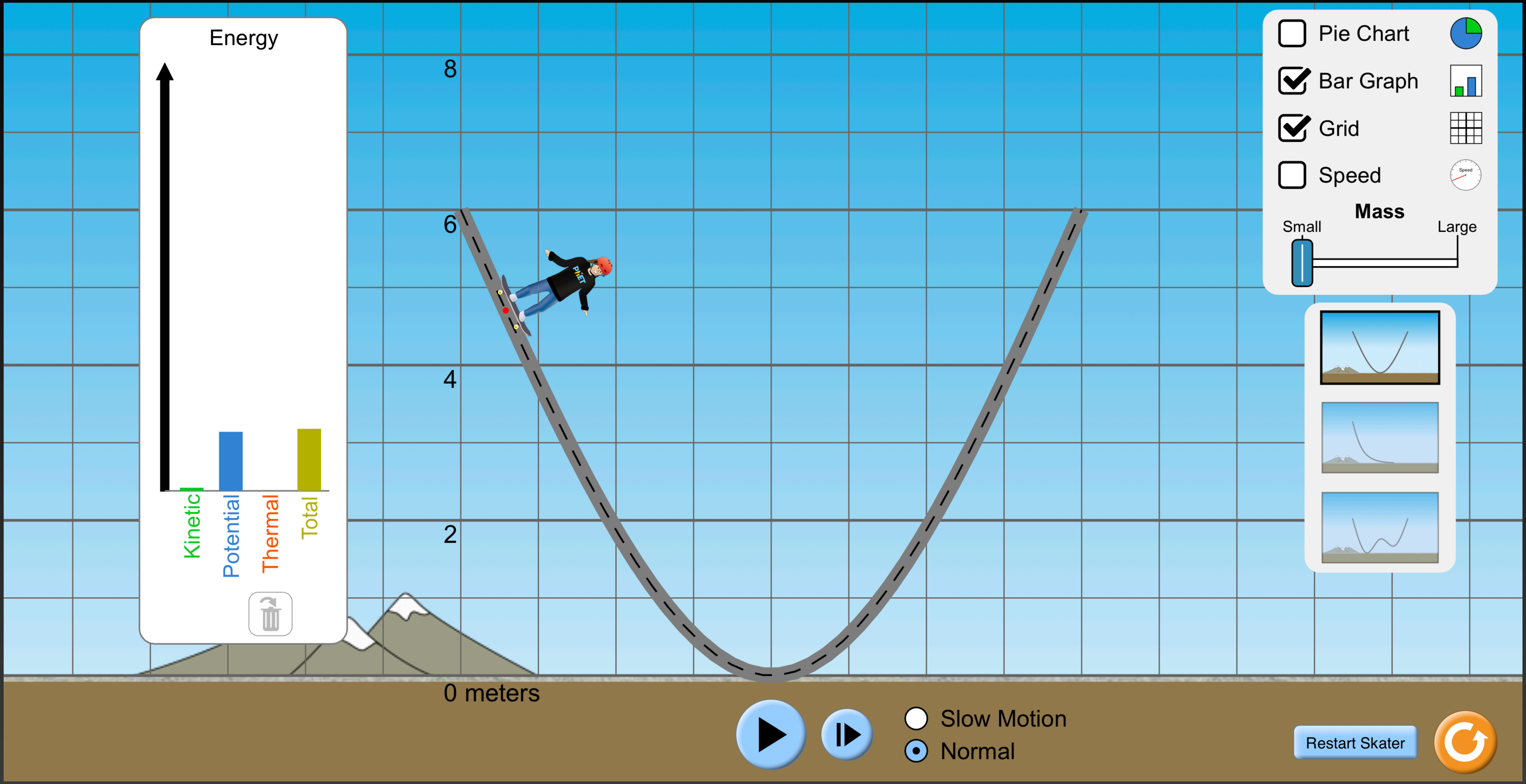
Thus, the potential energy with respect to zero at $x = 0$ is just

$$U(x) = \frac{1}{3}ax^3 + 0.5\text{ J}.$$

Therefore, the potential energy at $x = 1\text{ m}$ is

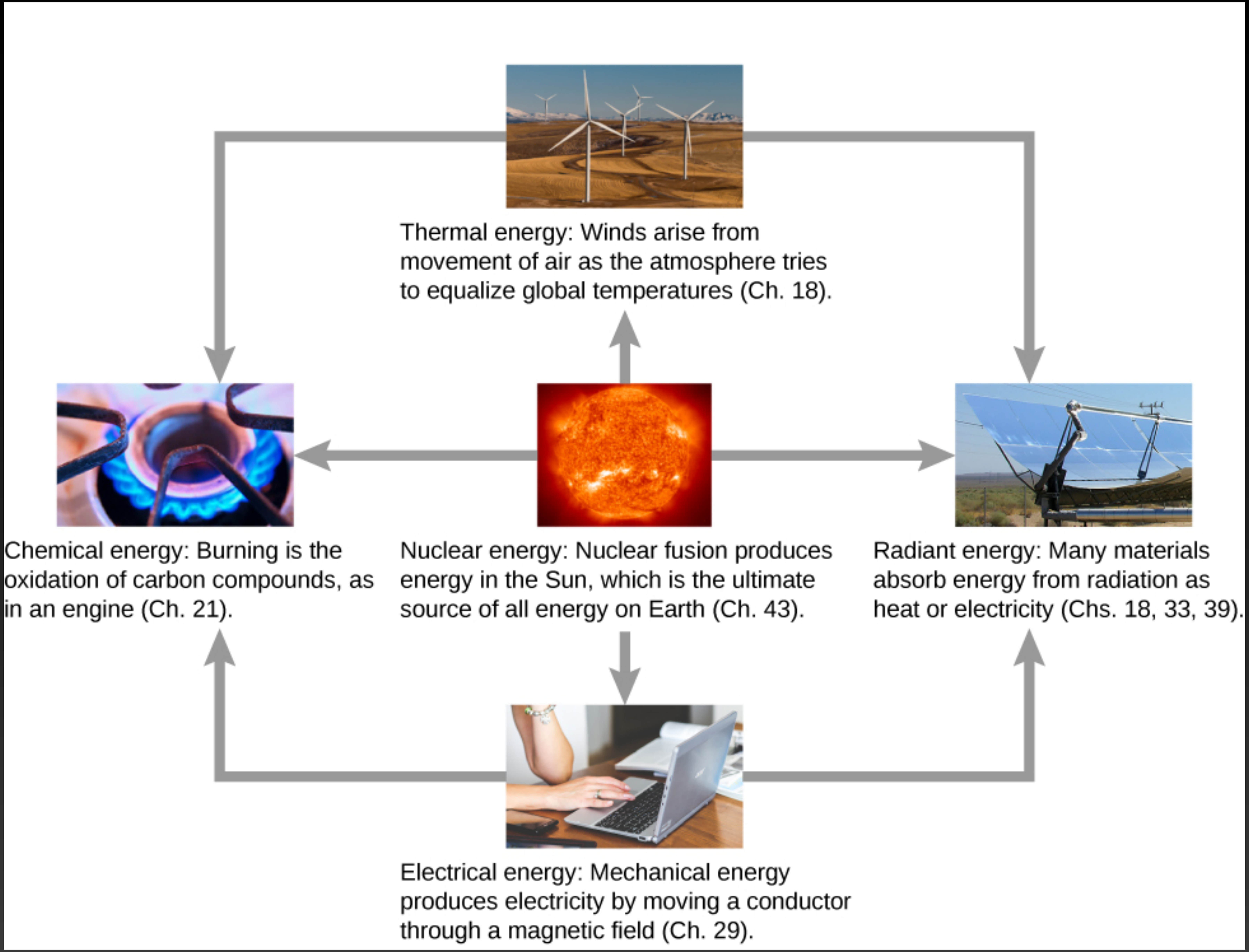
$$U(1\text{ m}) = \frac{1}{3}\left(3\text{ N/m}^2\right)(1\text{ m})^3 + 0.5\text{ J} = 1.5\text{ J}.$$

Energy Skatepark



Energy Skatepark

Energy Types



Key Equations

Difference of potential energy	$\Delta U_{AB} = U_B - U_A = -W_{AB}$
Potential energy with respect to zero of potential energy at $\vec{\mathbf{r}}_0$	$\Delta U = U(\vec{\mathbf{r}}) - U(\vec{\mathbf{r}}_0)$
Gravitational potential energy near Earth's surface	$U(y) = mgy + \text{const.}$
Potential energy for an ideal spring	$U(x) = \frac{1}{2}kx^2 + \text{const.}$
Work done by conservative force over a closed path	$W_{\text{closed path}} = \oint \vec{\mathbf{F}}_{\text{cons}} \cdot d\vec{\mathbf{r}} = 0$
Condition for conservative force in two dimensions	$\left(\frac{dF_x}{dy}\right) = \left(\frac{dF_y}{dx}\right)$
Conservative force is the negative derivative of potential energy	$F_l = -\frac{dU}{dl}$
Conservation of energy with no non-conservative forces	$0 = W_{nc,AB} = \Delta(K + U)_{AB} = \Delta E_{AB}.$

Clicker Questions

CQ.8.1

Which activity requires a person to exert force on an object that causes the object to move but does not change the kinetic or potential energy of the object?

a) moving an object to a greater height with acceleration

b) moving an object to a greater height without acceleration

c) carrying an object with acceleration at the same height

d) carrying an object without acceleration at the same height

A B C D E

CQ.8.1

Which activity requires a person to exert force on an object that causes the object to move but does not change the kinetic or potential energy of the object?

a) moving an object to a greater height with acceleration

b) moving an object to a greater height without acceleration

c) carrying an object with acceleration at the same height

✔ d) carrying an object without acceleration at the same height

Detailed solution: Carrying an object at a given height at a constant speed does not change the KE or PE because the speed and height do not change. Force is exerted to oppose the force of gravity.

A B C D E

CQ.8.2

You are riding a bicycle up a gentle hill. It is fairly easy to increase your potential energy, but to increase your kinetic energy would be harder.

a) True

b) False

A

B

C

D

E

CQ.8.2

You are riding a bicycle up a gentle hill. It is fairly easy to increase your potential energy, but to increase your kinetic energy would be harder.

✓ a) True

b) False

Detailed solution: PE can be increased continuously by riding up a gentle hill. An increase in KE would require you to ride ever faster and faster. There is a limit to how fast you can ride, so eventually you would feel exhausted.

A B C D E

CQ.8.3

How much work is done by gravity when a 7.64 kg boulder falls to the ground from the top of a 33.4 m tall cliff?

a) 0.0 J, because gravity doesn't do work

b) 2.24 J

c) 26.0 J

d) 2500 J

A B C D E

CQ.8.3

How much work is done by gravity when a 7.64 kg boulder falls to the ground from the top of a 33.4 m tall cliff?

a) 0.0 J, because gravity doesn't do work

b) 2.24 J

c) 26.0 J

✔ d) 2500 J

Detailed solution: The work done will be equivalent to the gravitational potential energy before it falls: use mgh.

A

B

C

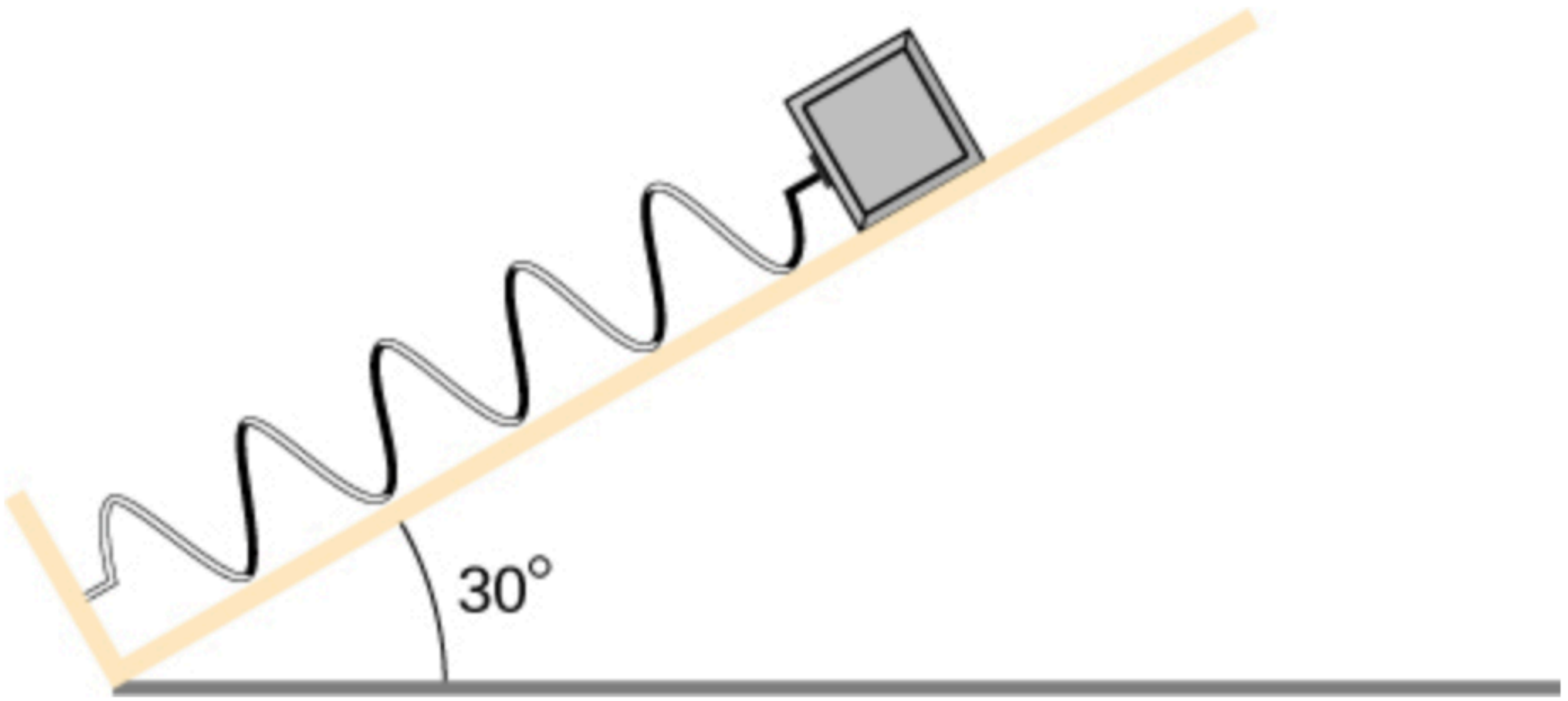
D

E

Activity:
Worked Problems

64 . A block of mass 500 g is attached to a spring of spring constant 80 N/m (see the following figure). The other end of the spring is attached to a support while the mass rests on a rough surface with a coefficient of friction of 0.20 that is inclined at angle of $30°$. The block is pushed along the surface till the spring compresses by 10 cm and is then released from rest. (a) How much potential energy was stored in the block-spring-support system when the block was just released? (b) Determine the speed of the block when it crosses the point when the spring is neither compressed nor stretched. (c) Determine the position of the block where it just comes to rest on its way up the incline.

WP 8.1



WP 8.1

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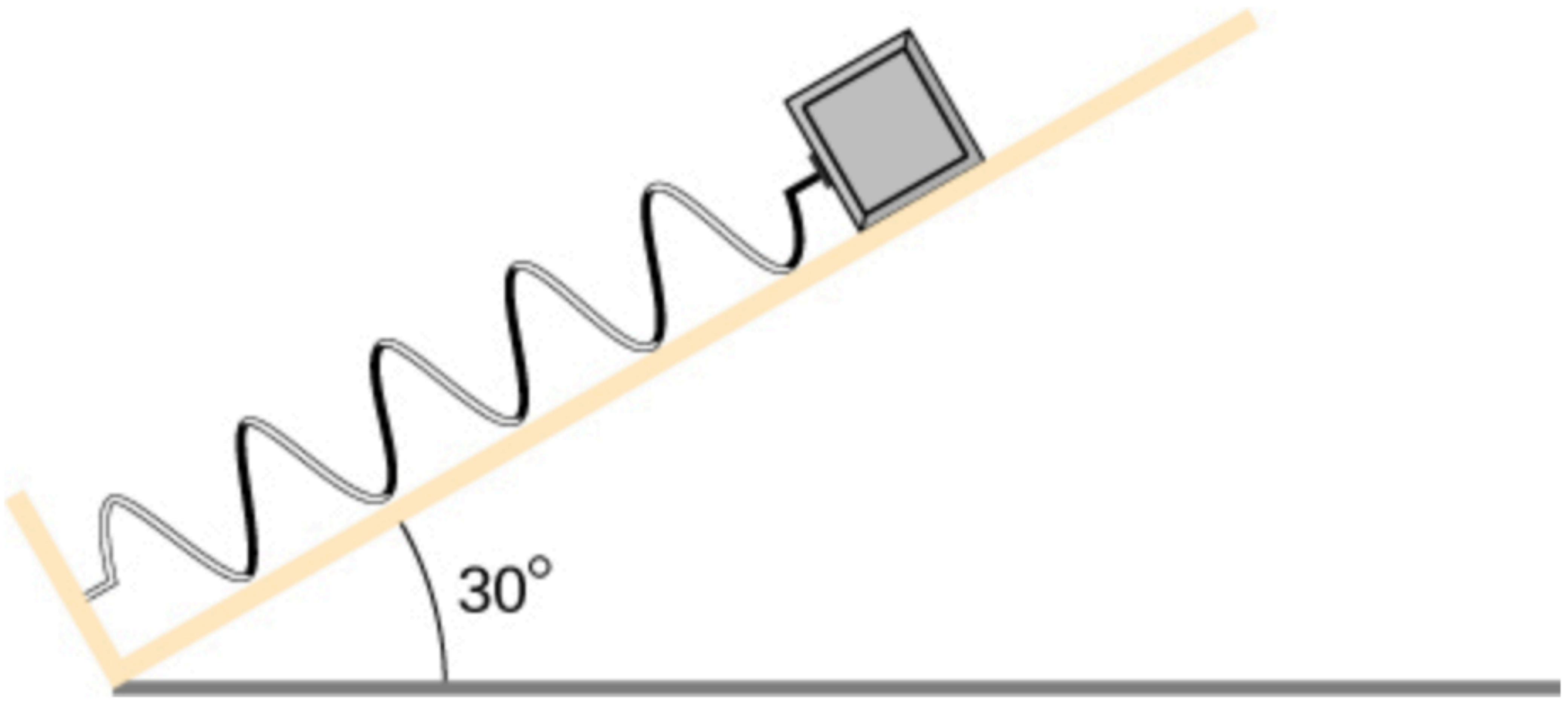

See you next class!

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