Adult Basic Education

Science

Physics 2104B

Forces, Momentum, Work and Energy

Study Guide

Prerequisite: Physics 2104 A

Credit Value: 1

Text: *Physics: Concepts and Connections*. Nowikow et al. Irwin, 2002

Physics Concentration

Physics 1104
Physics 2104A
Physics 2104B
Physics 2104C
Physics 3104A
Physics 3104B
Physics 3104C

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To the Student

I. Introduction to Physics 2104B

This course follows from Physics 2104 A and further develops the concept of motion. You will learn about momentum, energy, work and power.

Before beginning this course ensure you have the text(s), a calculator, and a ruler and pencil (and pen). Your calculator should be a scientific calculator capable of finding trigonometric values and using scientific notation. If you have not used trigonometric functions recently, you may have to review them with your Mathematics instructor.

II. Use of Science Study Guides

Before beginning this course, ensure you have the text and any other resources needed *(see the information in the Introduction to this course for specifics)*.

As you work through the Study Guide, you will see that it is divided according to the Units listed in the Table of Contents. When you open a unit it will have the following components:

To the Student

Reading for this Unit:
Here you will find the chapters, sections and pages of the text you will use to cover the material for this unit. Skim the sections of the textbook, look at the titles of the sections, scan the figures and read any material in the margins. Once you have this overview of the unit, you are ready to begin. Do not be intimidated by the content. You will work through the text, section by section, gaining knowledge and understanding of the material as you go.

References and Notes	Work to Submit
This left hand column guides you through the material to read from the text. Read any highlighted notes that follow the reading instructions. The symbols ▶▶ direct you to the questions that you should complete when finished a reading assignment..	You come across three (3) headings in this right hand column. **Writing:** This section comprises your notes for the unit. Here you will find either written questions or references to specific questions or problems from your text. You may want to write out each question followed by the answer. This material should be checked by your instructor before moving on to the next unit. Mathematical problems should have their solutions checked <u>as you go</u>. **Laboratory:** This section indicates if there is a Lab that should be completed for the unit. Let the instructor know in advance that you will be ready for the lab. A lab report should be submitted for each Lab. Your instructor will provide guidelines as to how s/he wants the report written. **Assignment:** This section indicates if there is an assignment that should be completed for the Unit. The information in the "References and Notes" column will indicate how you obtain the assignment. These assignments frequently relate the science content to technology, society and the environment.

III. Recommended Evaluation

Written Notes	10%
Labs/Assignments	20%
Test(s)	20%
Final Exam *(entire course)*	50%
	100%

The overall pass mark for the course is 50%.

Unit 1 - Gravity and Friction

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit:	*Physics: Concepts and Connections:* Chapter 5: Section 5.1: pages 158 Section 5.2: pages 158 -159 Section 5.3: pages 160 - 168 Section 5.4: pages 168 - 171 Section 5.5: pages 172 - 179 Section 5.6: pages 179 - 181 Lab 5.1: page190

References and Notes	Work to Submit
	Writing:
Read pages 158 to 159 Section 5.1 and 5.2. ▶▶	1.1 Explain how mass differs from weight.
The difference between mass and weight is very important in physics. In everyday life we are always on earth so we can interchange our units for mass and weight without causing problems.	1.2 What is inertia? 1.3 Which object would have the greater inertia, an elephant or a mouse?
Read pages 160 to 162 of Section 5.3 up to Example 1. ▶▶	1.4 How does your weight change as your distance from the earth changes?
Inverse Square Laws appear several times in Physics.	1.5 What is an inverse square law?
You will meet field lines in greater detail in Physics 3104B.	1.6 What is Newton's universal law of gravity in words? in equation format?
	1.7 What is ***g***?
	1.8 What are field lines?

Unit 1 - Gravity and Friction

References and Notes	Work to Submit
	1.9 Do you have to touch an object to feel the effects of a force? (Think magnets).
Study Examples 1 and 2 on pages 162 to 162. ▶▶	1.10 Complete Questions 20 (a) and (b), 21 and 22 on pages 186 to 187.
	1.11 What does $\vec{g}$ represent?
	1.12 How do we find the weight of an object at or near the surface of a celestial body (e.g. planet)?
Read page 163 and study Examples 3, 4 and 5 on pages 164 to 166. ▶▶	1.13 What happens to an object's weight as the distance from the planet increases?
Read the information under the heading ***Surviving for Long Periods of Time in Space*** *on page 167 to 168.* ▶▶	1.14 Complete Question 1 (a) to (d) on page 167.
	1.15 What happens to the bodies of astronauts when they experience weightlessness for a long period of time.
Read pages 172 to 175 of Section 5.5 up to Example 8 ▶▶	1.16 What two factors determine the size of the frictional force?
	1.17 What does the letter μ represent?
A normal force is a contact force exerted by a surface on an object.	1.18 Describe the two types of frictional forces.
	1.19 Which has the greater friction, an object at rest or in motion?
	1.20 When is a force of friction involved in a calculation?

Unit 1 - Gravity and Friction

References and Notes	Work to Submit
Study Examples 8 and 9 on pages 173 to 175. ▶▶	1.21 Complete Questions 39 and 40 on page 188.
Study Examples 10 to 11 on pages 175 to 177. ▶▶	1.22 Complete Questions 1 and 3 on page 179.
Remember $\vec{F}_n$ is the reaction force of a surface pressing back. If you are having trouble with Examples 10-11, you may want to study Section 5.4 and then return to Examples 10-11.	
Inform your instructor you are ready for Core Lab #	**Laboratory:** Complete and submit to your instructor: Core Lab #1: Lab 5.1 Kinetic Friction on page 190.

Unit 2 - Momentum

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit: *Physics: Concepts and Connections:*

Chapter 8: Section 8.1: pages 277-278
Section 8.2: pages 278-283
Section 8.3: pages 288-293
Lab 8.2: page 315

Appendix A *"The Physics of Karate"*

References and Notes	Work to Submit
	Writing:
Read page 277 of Section 8.1 to Example 1. ▶▶	2.1 What is the symbol for momentum? 2.2 What is the physics definition of momentum? 2.3 How is momentum changed? 2.4 What are the S.I. units of momentum?
Study Example 1 on pages 277 - 278. ▶▶ *In problem 1 make sure that your units match that needed for momentum i.e. kg and m/s.*	2.5 Complete Problem 1 on page 278.
Read pages 278 to 279 of Section 8.2. ▶▶	2.6 What is impulse? What symbol is used to represent impulse? 2.7 What are two mathematical ways of writing Newton's Second Law?
Read the sidebar "The case of $\Delta m \neq 0$" on page 279. ▶▶	2.8 What effect is observed in the case of rockets when mass is decreasing and thrust does not change?

Unit 2 - Momentum

References and Notes	Work to Submit
Study Figure 8.5 on page 279 ▶▶	2.9 Explain the cause and effect relationship in terms of impulse and change in momentum.
Study Example 2 on page 280. ▶▶	2.10 Complete Problems 4 and 5 on page 286.
In 5(b) don't forget to convert km/h to m/s and use one of your kinematics equations.	
Starting page 280 read from "Impulse" to end of page 281 ▶▶	2.11 Explain how the nature of the material (wood or mesh) affects a catcher's ability to catch the ball.
	2.12 Complete Question 2 on page 286.
Study Example 3 on page 282 and particularly note Figures 8.12 and 8.13 ▶▶	2.13 Complete Questions 28 to 43 and 46 to 48 (a) on pages 307-308.
You should tell your instructor that you are ready for Core Lab #2 from page 315 of your text. ▶▶	**Laboratory:** Core Laboratory #2: Linear Momentum in One Dimension: Dynamic Laboratory Carts
Read *"The Physics of Karate*"from Appendix A. ▶▶	**Assignment:** Complete Questions 1-2 at the end of *The Physics of Karate.*

Unit 2 - Momentum

References and Notes	Work to Submit
	Writing:
Read pages 288 to 292 of Section 8.3 ▶▶	2.14 State the Law of Conservation of Momentum in words and as an algebraic expression. Explain what each variable represents.
Note: Momentum is a vector and can be assigned a positive or negative value depending on the velocity. Remember that movement to the right and top is usually given a positive value, while movement to the left and down are given negative values.	2.15 Complete Problems 1 and 2 on page 292
Read "Rubber Bullets" on page 292 to 293.▶▶	2.16 Explain how rubber bullets knock over a dummy, while metal bullets can penetrate a dummy.
	2.17 Complete Problems 64 and 68 on page 310.

Unit 3 - Work and Power

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit: *Physics: Concepts and Connections:*
Chapter 9: Section 9.2: pages 325-330
Section 9.3: pages 331-332

References and Notes	**Work to Submit**
Read pages 325 to 326 of Section 9.2 ▶▶	**Writing:** 3.1 What is work? 3.2 What is the mathematical expression for work? Explain what each variable represents. 3.3 What is the S.I. unit for work? How is that unit defined in terms of other S.I. units? 3.4 Is work a vector or scalar quantity? 3.5 Complete Problems 1(a) and (b) on page 330.
Read page 327 to 328 and study Example 2. ▶▶ *If you don't understand where the cos**θ** arises from, ask your instructor to explain. You may need to review your right angle triangle trigonometry for this.* *In Example 2 (b) the applied angle is 180° from the direction of movement.*	3.6 Complete Problems 1(c) and 2 on page 330.

Unit 3 - Work and Power

References and Notes	Work to Submit
Read the remainder of Section 9.2: pages 328 to 329 ▶▶	3.7 Complete Problems 5(a), (b) and 6 on page 330.
Make sure you read the info in the side bars.	
In 5(b) remember that the force applied for the first 4 cm is equal and opposite to the force applied for the next 4 cm.	
Read all of Section 9.3 from pages 331 to 332. ▶▶	3.8 Define power.
	3.9 What is the unit for power?
	3.10 How does power determine how energy is delivered?
	3.11 Complete Problems 1 on page 332 and 41 to 43 on page 370.

Unit 4 - Kinetic and Potential Energy

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit: *Physics: Concepts and Connections:*

Chapter 9: Section 9.1: pages 323-324
Section 9.4: pages 332-336
Section 9.5: pages 336-341
Lab 9.2: pages 378-379

Chapter 5: Section 5.6: pages 179-181

References and Notes	Work to Submit
	Writing:
Read pages 323 to 324 of Section 9.1 ▶▶	4.1 Define kinetic energy. 4.2 Briefly describe two types of kinetic energy. 4.3 Define potential energy. 4.4 Briefly describe seven types of potential energy.
Read pages 332 to 333 of Section 9.4 ▶▶ *Remember that a J = N·m = kg·m/s² ·m or kg·m²/s².* *Also $E_k = ½ mv^2$ or $½ m (v_2-v_1)^2$*	4.5 What is the equation for kinetic energy? Explain what each variable represents and what S.I. unit is used for each variable. 4.6 Complete Problem 3 on page 336.
Read all of page 334 ▶▶	4.7 What is the mathematical expression for the work-energy theorem? 4.8 Complete Problem 52 on page 371.
Read page 335 ▶▶	4.9 Describe the transfer of kinetic energy in karate.

Unit 4 - Kinetic and Potential Energy

References and Notes	Work to Submit
	4.10 How is power measured in a karate strike?
Read pages 336 to 338 of Section 9.5 ▶▶	4.11 Complete Question 9 on page 368.
	4.12 What is gravitational potential energy?
	4.13 What is the mathematical expression for gravitational potential energy and what does each variable represent?
	4.14 Complete Problems 1-3 on page 338.
	4.15 Complete Problem 67 on page 372.
Read pages 179 to 181 of Section 5.6 ▶▶	4.16 What is *k* and how is it obtained?
	4.17 State Hooke's Law.
Read pages 338 up to 340 of Section 9.6 to Example 12 ▶▶	4.18 Complete Problem 2 on page 181.
	4.19 Explain how potential energy is stored in a spring.
	4.20 What is equilibrium for a spring?
	4.21 What sign conventions are used for *F* and *x* for springs?
	4.22 What is meant by elastic and inelastic as applied to springs?
	4.23 What is the equation for elastic potential energy? Explain what each variable represents.

Unit 4 - Kinetic and Potential Energy

References and Notes	Work to Submit
Study Example 12 on pages 340 to 341 ▶▶	4.24 Complete Problems 1-3 on page 341.
In 1 (b) the maximum potential energy is when the spring is stretched the most.	
Let your instructor know you are ready to start Lab 9.2 on page 378-379. ▶▶	**Laboratory:** Complete and submit Core Lab #3: Work and Kinetic Energy.
Your instructor may have a quiz for you at this point on the material.	

Unit 5 - Conservation of Energy

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit: *Physics: Concepts and Connections:*
Chapter 9: Section 9.7: pages 342-343
Section 9.8: pages 343-349

References and Notes	Work to Submit
	Writing:
Read pages 342 to 343 of Section 9.7. ▶▶	5.1 State the Law of Conservation of Energy in three (3) ways.
	5.2 Describe what happens to the gravitational potential energy of a ball when it is dropped.
Read pages 343 to 344 of Section 9.8. ▶▶	5.3 What is the equation for the total mechanical energy?
Study Examples 14 and 15 on pages 345 to 347. ▶▶	5.4 Complete Problems 1(a) - (g) and 2 on page 348.

Unit 6 - Simple Harmonic Motion and Efficiency

To fulfill the objectives of this unit, students should complete the following:

Reading for this unit: *Physics: Concepts and Connections:*
Chapter 9: Section 9.10: pages 357-361
Section 9.11: pages 362-365

References and Notes	Work to Submit
Read pages 357 to 359 Section 9.10 ▶▶	6.1 What is damping?
	6.2 Using Figure 9.41, explain why damping occurs.
	6.3 What is the equation for the acceleration of a mass on a spring? Explain what each variable represents.
Read pages 359 to 361 and Appendix B ▶▶	6.4 What is SHM?
	6.5 What is the mathematical expression for the total energy of the mass-spring system? Explain what each variable represents.
	6.6 What is periodic motion?
	6.7 What is the equilibrium position?
	6.8 What is the value of the Force at the equilibrium position?
	6.9 What is amplitude (A)?
	6.10 What is the speed of the block when the displacement = ± A ?

Unit 6 - Simple Harmonic Motion and Efficiency

References and Notes	Work to Submit
	6.11 Complete Problem 1 on page 361.
	6.12 Complete Problems 104 to 106 on page 376.
Read pages 362 to 365 of Section 9.11 ▶▶	6.13 Define efficiency.
	6.14 Why are compact fluorescent bulbs considered to be more efficient that incandescent bulbs?
	6.15 What is a heat pump and why is it not used everywhere?
	6.16 How can a heat pump be integrated into part of a home heating system to more efficiently heat and cool a home.
Prepare for a final test on the entire course.	6.17 Complete Questions 111 and 112 on page 376.

Appendix A

The Physics of Karate

Outcomes:

1. Analyze natural and technological systems to interpret and explain their structure and dynamics.

2. Describe the functioning of a natural technology based on principles of momentum .

3. Apply Newton’s Laws of motion to explain the interaction of forces between two objects.

4. Apply quantitatively the law of conservation of momentum to one-dimensional collisions and explosions.

5. Interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables.

6. Use appropriate language and conventions when describing events related to momentum and energy (114-9).

Introduction

What kind of person would intentionally bring their hand or foot crashing down onto a slab of wood or concrete? A daredevil? A Hollywood stunt person? As it turns out, that kind of person is simply someone who understands the physics of karate - someone like you!

Karate means "open or empty hand", and began as a form of weaponless combat in 17th century Japan. In recent years it has become popular in our culture, as a form of fitness, self-defense and self-expression. Karate participants - called Karateka - often break concrete or wooden boards as a demonstration of the strength developed through training. Surprisingly there are no tricks involved in accomplishing such a feat. What is involved is a physics-based knowledge of how to do it properly. "Few things offer more visceral proof of the power of physics than a karate chop. Punch a brick with your bare hand, untutored in the martial arts, and you may break a finger. Punch it with the proper force, momentum and positioning and you'll break the brick instead" (Rist, 2000).

Theory

Force, Speed and Area

Karateka agree that the secret to karate lies in the force, speed and focus of the strike. The more quickly a board is hit, the harder the strike. Maximum hand velocity is actually achieved when the arm reaches 75-80% of extension. Since the hand cannot move forward a distance greater than the length of the arm, it must have a velocity of 0 at full arm's extension. To get the hardest hit, contact must be made with the object before this slowdown begins. Thus a good karate chop has no follow-through (as would a good tennis or golf swing). The hand is typically in contact with the object for fewer than five milliseconds.
How fast can a karate punch actually move? Experiments done with a strobe light on karateka throwing punches found that beginners can throw a punch at about 6.1 m/s (20 feet/sec), while black belts could chop at 14 m/s (46 feet/sec). At the latter speed a black belt can deliver about 2800 N to the object being hit. (Splitting a typical concrete slab requires only about 1900 N). A concrete slab could probably support a force of 2800 N if it were not concentrated into such a small area. Minimizing the striking surface of the hand, and therefore the

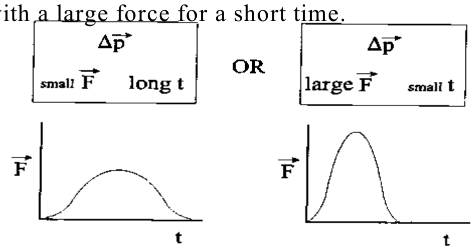
area of the target being hit, maximizes the amount of force and energy transferred per unit area. To understand why speed and focus are so important, the principles of momentum and impulse must also be considered.

Momentum and Impulse

Momentum $(\vec{p})$ is defined as an object's mass times its velocity. Change in momentum, $(\Delta \vec{p})$ is defined as impulse $(\vec{J})$, and is given by force multiplied by time. According to Newton's third law, momentum is a conserved quantity. The third law states that for every action force on an object in a given time, there is an equal and opposite reaction force by that object for the same amount of time. Thus, any momentum lost by the first object is exactly gained by the second object. Momentum is transferred from one object to the other. Using,

$$\vec{J} = \Delta \vec{p} = \vec{F} t$$

we can see that if $(\Delta \vec{p})$ remains fixed, then force and time are inversely proportional. This means that if force increases, then time decreases and vice versa. It follows that a fixed amount of momentum can then be transferred with a small force for a long time or with a large force for a short time.



The quicker the karateka can make the chop, the larger the force transferred to the target. According to Newton's second law $(\vec{F} = m\vec{a})$ the part of the object struck with this force will begin to accelerate or oscillate. Breakage occurs if the small area hit accelerates enough, relative to the stationary ends of the object. The object will experience strain and begin to crack from the bottom up.

What about the strain experienced by the hand or foot? Fortunately bone can withstand about forty times more force than concrete. Hands and feet can withstand even more than that due to the skin, muscles and ligaments which absorb much of the impact. Despite possessing these "natural shock absorbers", breaking wood, concrete or bricks should not be attempted without proper training. Such training would include toughening up the hand and knowing exactly how and where to hit the object with maximum speed. Over time the knife edge of the hand, called the "shuto", develops a callous which acts to absorb the collision force. As well, experts know to only hit things that can actually be broken. Sihak Henry Cho, a grand master at the Karate Institute in Manhattan sums it up nicely: "Being good at karate is a lot like being good at telling a joke. It's not what you break; it's how you break it" (Rist, 2000).

Questions

1. Why is it important to hit a concrete slab quickly when attempting to break it?

2. Karate black belts often advise beginners before their first attempt at breaking, not to try to break the board, but to aim for the floor underneath the board. How would this advice help?

3. Research: Karate practitioners usually yell "Kiai" when striking an object. Research the meaning of this term?

References

Rist, Curtis. (2000). The physics of karate: Breaking boards. Discover, 21.

Chananie, Jon. (1999). The physics of karate strikes. Journal of How Things Work, 1, 1-4.

Karate. Available: http://www.pbs.org/ktca/newtons/12/karate.htm.

Nowikow, I., & Heimbecker, B. (2001). Physics: Concepts and connections. Toronto: Irwin Publishing Ltd.

Physics 142. Karate chop. Available: http://www-class.un1.edu/phys142/Labs/L50/L50_Karate_chop_-_142_w_02.htm.

Pushy Air. Available:
http://www.schools.ash.org.au/paa/downloads/actbook.pdf

Wilk, S.R., et al. (1983). The physics of karate. American Journal of Physics, 51, 783-790.

Activities

Activity 1: How Much Weight does it take to break a board?

Materials: ● masses (2 kg) ● supports (bricks)
● board ● meter stick

Procedure:
Design a procedure to see how much weight must be placed on the board in order to get the board to break. As the weight is added to the board, measure how far the board bends.

Analysis:
1. Graph applied force (y-axis) versus bending distance (x-axis).
2. Find the slope of your graph. Describe how the applied force is related to the bending distance.
3. Recall that work can be done to a system to change the energy of the system. The work done by a force F can be determined by finding the area under the curve of a force versus distance graph. From your data determine the work that was done to break the board.

Activities

Activity 2: Pretzel

Purpose: To use pretzel sticks to better understand what causes materials to break.

Materials:
● pretzel sticks of varying thickness ● paper cup
● pieces of uncooked spaghetti ● empty plastic film container
● rolls of 50 pennies each, plus 50 loose pennies ● scissors or craft knife
● thick string or wire about 6 cm long ● tweezers

Procedure:

1. Build a pretzel strength-testing machine. Start by cutting a large hole in the bottom of the paper cup. Set the cup on the table, bottom side up. Rest a pretzel stick across the center of the cup.

2. Next create a weight bucket to hang on the pretzel. Take the empty plastic film container and make two holes about 1 cm from the top rim and directly across from each other. Thread the string or wire through the holes and tie the end at each hole. The bucket should hang on the pretzel without touching the table.

3. Begin testing. With the bucket hanging on the pretzel stick begin adding pennies. See how many pennies the pretzel can hold without breaking. Find the average number of pennies one type of pretzel stick can hold.

4. Gaining momentum: Test to see if it makes a difference if you drop the pennies in the bucket or you place them in gently using the tweezers.

5. Breaking point: Test to see if the weakest point of the pretzel is really at the center.

6. Length and width test: Try pretzels of various lengths and widths to see what size and length hold the most and least pennies.

7. Compare with other materials: Do you think a pretzel or an uncooked piece of spaghetti is stronger when bent? Try testing uncooked spaghetti to see how it holds up in comparison to the pretzel sticks.

Questions:

1. Look at the ends of a broken pretzel with a magnifying glass. Does its structure tell you anything about its bending strength?
2. Can you figure out a way to spread weight out across the entire length of the pretzel? Can it hold more weight when the weight is distributed over a larger area?

(Activity designed by Jane Copes, Science Museum of Minnesota and adapted from Newton's Apple Teacher's Guide: Karate)

Activities

Activity 3: (taken from Pushing Air located at http://www.schools.ash.org.au/paa/downloads/actbook.pdf)

Purpose: To relate a successful karate chop to air pressure.

Materials:
- sheet of newspaper
- ruler

Procedure:
1. Place a ruler or flat stick on a bench top with about a quarter of its length overhanging.
2. Give the overhanging part of the ruler a quick karate chop from above.
3. Repeat the above steps with a piece of newspaper covering the nonoverhanging part of the ruler.

Questions:
1. Why do you think the ruler snaps during the second part of the experiment?

Explanation:
Air is all around us pushing on everything. It pushes on our skin and on the bench top. The ruler has a small surface area, so the air pushing down on it is not enough to hold the ruler in place when you hit it. The newspaper has a large surface area. The force of the air acts over the whole area. The result is that air holds down the paper which holds the ruler in place. Unable to lift quickly enough when the overhanging part of the ruler is struck, the ruler has no option but to snap.

Appendix B

When an object vibrates back and forth over the same path, its motion is ***periodic***. The simplest example of this is a uniform coil spring. (Wave motion in Physics 2104 C will involve this concept also.) It is assumed that the mass is mounted horizontally as in Figure 9.43 of your text. The object of mass *m* slides without friction on the horizontal surface. A spring has a length at which it exerts no force on the mass. This position of the mass is called the ***equilibrium position***. If the mass is moved to the left (the spring is compressed) or the right (the spring is stretched), the spring exerts a force on the mass that acts in a direction to return the mass to the equilibrium position. The restoring force (*F*) is always in a direction opposite to the displacement (*x*).

If the spring is compressed at a distance x = -A (Figure 1) and then released, it moves toward the equilibrium position (Figure 2) and because it has been accelerated by a force, continues to move past that position until it reaches x = A (Figure 3) where it stops momentarily and then reverses direction back past the equilibrium point to x = -A, where it again stops momentarily and then moves again.

The maximum displacement from the equilibrium point is called the amplitude (*A*). One cycle refer to the complete to and from motion from some x = -A to x = + A and back to x = -A. The period (*T*) is the time (in seconds) for a complete cycle. The frequency, *f*, Is the number of cycles per second (units of Hertz i.e cycles per second or s^{-1}).

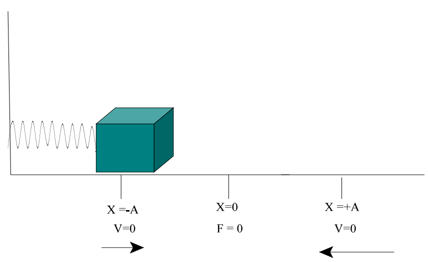


Figure 7: Spring at x = -A

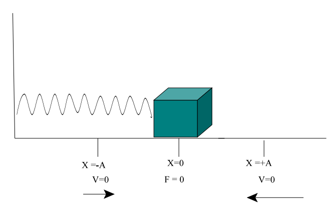


Figure 6: Spring at x =0

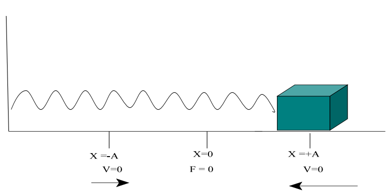


Figure 8: Spring at x =A