Reading Guide
Giancoli PSE, 4th edition

Fall 2016

Contents

How to Read the Textbook

Here is what I want you to do before you come to class:

- Read the sections assigned on the syllabus. I recommend a close reading in which you read each sentence and see if it makes sense. When you run into something that doesn't make sense, try to formulate a question about it.
- Read carefully and work through each of the Examples in the assigned sections. Check each equation and see if you agree with it. Ideally, each step in the Example should make sense to you. If something doesn't make sense, try to formulate a question about it. Each Example has a follow-up question or problem in this Reading Guide. Please try to answer all of these follow-up questions. I will ask you about them in class.
- Do all of the Exercises. I will ask you about them in class.
- There are some extra questions in the Reading Guide for some sections. Please try to answer all of these questions. I will ask you about them in class.
- If there is anything else in the Reading Guide for the assigned sections, please read it or do it.
- For each class period, several people are assigned the task of coming up with a question related to the assigned reading for the day (or the most recently assigned reading if there is no reading assignment). You can ask a question based on confusion or curiosity. If there is something in the section that doesn't make sense, try to formulate a question about it. When it is your turn to produce a question, please send it to me electronically before 9:00 am on the day of class.

Chapter 1

Introduction, Measurement, Estimating

1.1 The Nature of Science

Question 1. Does the author think that theories are discovered or created?

1.2 Models, Theories, and Laws

Question 2. How can we be sure that a scientific law is true?

1.3 Measurement and Uncertainty; Significant Figures

Exercise A:

What do you think?

Conceptual Example 1-1: Significant figures.

- See Exercise B.

Exercise B:

What do you think?

Exercise C:

What do you think?

Exercise D:

What do you think?

Question 3. What is the difference between accuracy and precision?

Question 4. Give an example of how one could have high precision, but low accuracy.

1.4 Units, Standards, and the SI System

Question 5. What was the original definition of the meter?

Question 6. What is the current definition of the meter?

Question 7. About how long is a meter? Show with your hands.

Question 8. What is the current definition of the second?

Question 9. What is the current definition of the kilogram?

Question 10. Exciting changes are planned for the SI in the next few years. The BIPM (Bureau International des Poids Mesures, or International Bureau of Weights and Measures) is the international organization that administers the SI. Go to `www.bipm.org`, look under "MEASUREMENT UNITS", then "On the future revision of the SI". What is the planned future definition of the kilogram?

Question 11. I expect you to remember the abbreviations and values of the following metric prefixes: giga, mega, kilo, centi, milli, micro, nano. What are they?

1.5 Converting Units

Example 1-2: The 8000-m peaks.

- See Exercise E.

Exercise E:

What do you think?

Example 1-3: Apartment area.

- How many cubic centimeters are in a cubic meter?

Example 1-4: Speeds.

- The new speed limit on portions of the PA turnpike is 70 mph. What is this speed (a) in m/s and (b) in km/h?

Exercise F:

What do you think?

1.6 Order of Magnitude: Rapid Estimating

Example 1-5: Volume of a lake.

- Estimate the volume of LVC's main swimming pool. (If you haven't seen the pool, it's a 25-yard or 25-meter pool with about 5 lanes.)

Example 1-6: Thickness of a page.

- A roll of toilet paper has 1000 sheets. Estimate the thickness of a piece of toilet paper.

Example 1-7: Height by triangulation.

- The diameter of the moon is roughly 4000 km. If you hold your thumb up to the moon at the right distance from your eye, the width of your thumb matches the diameter of the moon. Make estimates for the width of your thumb and for your thumb-eye distance, then estimate the distance to the moon.

Example 1-8: Estimating the radius of Earth.

- If your feet are at sea level, and your eyes are 2 m above sea level, what is the farthest point of water you can see on the ocean?

Example 1-9: Total number of heartbeats.

- Estimate the total number of breaths a person takes in a lifetime.

1.7 Dimensions and Dimensional Analysis

Question 12. A *dimension* is different from a *unit*. Section 1-7 introduces two basic dimensions: length and time. There are many different units that can express the dimension of length. Similarly, there are many different units that can express the dimension of time. Below is a short list.

Dimension	Unit
Length [L]	meter (m), kilometer (km), foot, inch, etc.
Time [T]	second (s), minute, hour, day, year, etc.

The SI system has seven base units: the meter (m), second (s), kilogram (kg), ampere (A), kelvin (K), mole (mol), and candela (cd). What are the seven base *dimensions* of the SI system?

Example 1-10: Planck length.

- Can you find a combination of c, G, and h that has dimensions of time? This is the Planck time. Can you find it?

Remark 1. In Physics 111, which deals primarily with mechanics, we will only need the first three of the seven base dimensions that are defined in the SI system.

Base quantity	Symbol for dimension
Length	$[L]$
Time	$[T]$
Mass	$[M]$

The BIPM (Bureau International des Poids Mesures, or International Bureau of Weights and Measures) is the international organization that administers the SI. You can learn more about the SI system at `http://www.bipm.org/utils/common/pdf/si_brochure_8_en.pdf`.

Other quantities are derived quantities. The table below shows some derived quantities and their dimensions.

Quantity	Symbol for dimension
Pure number	$[1]$
Area	$[L^2]$
Volume	$[L^3]$
Frequency	$1/[T]$ or $[1/T]$
Velocity	$[L/T]$
Acceleration	$[L/T^2]$
Force	$[ML/T^2]$
Momentum	$[ML/T]$
Energy	$[ML^2/T^2]$
Power	$[ML^2/T^3]$
Angle	$[1]$
Angular acceleration	$[T]^{-2}$
Moment of Inertia	$[ML^2]$
Torque	$[ML^2/T^2]$
Angular momentum	$[ML^2/T]$
Mass density	$[ML^{-3}]$

Pure numbers (such as 4 or 49.6) are *dimensionless*. They have no dimension. I have indicated this with the symbol [1] in the table.

We have not talked about many of these quantities yet, so don't worry too much. You can refer back to this table after we learn about them.

The quantity of *angle* traditionally has no dimension. See the following remark.

How should we say the dimensions out loud when speaking? I find it cumbersome to say "mass over length squared" for the dimensions of acceleration, although that is perfectly correct. I recommend a shortened form in which we simply use the physical quantity name itself to talk about the dimension. So, if we are looking at an equation in which the symbol a appears, we might say that it has "dimensions of acceleration" or "the dimension of acceleration".

Torque and energy share the same dimension. This is curious and strange, because they are very different quantities. Is this a coincidence? I don't know.

The following tables are an attempt to lay out some of the dimensions of physical quantities in a visual form.

	$[1]$	$[L]$	$[L^2]$	$[L^3]$
$[T^{-2}]$	Angular acceleration	Acceleration		
$[T^{-1}]$	Frequency	Velocity		
$[1]$	Pure number, Angle	Length	Area	Volume
$[T]$	Time			

	$[M]$	$[ML]$	$[ML^2]$
$[T^{-3}]$			Power
$[T^{-2}]$		Force	Energy, Torque
$[T^{-1}]$		Momentum	Angular Momentum
$[1]$	Mass		Moment of Inertia

Remark 2. The quantity of *angle* traditionally has no dimension. This means the units degree, radian, revolution, etc. have no "home" dimension. This is an irritation sometimes. I will give an example later. It is an interesting question whether an additional base dimension could be added to the SI system to handle angle. Angle is a bit different from the other SI quantities in that it is purely geometrical rather than physical, so one could argue that it doesn't belong in the SI system to begin with. On the other hand, is angle any more "purely geometrical" than length? I believe angle deserves a dimension. What do you think?

Chapter 2

Describing Motion: Kinematics in One Dimension

Question 13. Chapter opening question with clickers.

2.1 Reference Frames and Displacement

Exercise A:

What do you think?

2.2 Average Velocity

Example 2-1: Runner's average velocity.

- What would the average velocity be if the trip took 4.00 s instead of 3.00 s?

Example 2-2: Distance a cyclist travels.

- See Exercise B.

Exercise B:

What do you think?

2.3 Instantaneous Velocity

Exercise C:

What do you think?

Example 2-3: Given x as a function of t.

- What units does the expression At have?

Question 14. What is wrong with the following sentence?

> The position of a small object is given by $x = 34 + 10t - 2t^3$.

Question 15. Suppose the position of a particle as a function of time is given by the following equation.

$$x = At^3 + Bt^2 + Ct + D$$

In this equation, the symbols A, B, C, and D are constants with appropriate units. Give an expression for the instantaneous velocity of the particle as a function of A, B, C, D, and t.

2.4 Acceleration

Remark 3. Example 2-7 gives the position of a particle with the following equation.

$$x = (2.10\ \mathrm{m/s^2})t^2 + (2.80\ \mathrm{m})$$

I will refer to this type of equation, in which units are explicitly supplied after the numbers 2.10 and 2.80, as an equation in *explicit unit form.* With explicit unit form, units for the variables x and t do not need to be given.

Chapter 2, Problem 8, by contrast, gives the position of a small object with the following equation.

$$x = 34 + 10t - 2t^3, \text{ where } t \text{ is in seconds and } x \text{ in meters.}$$

I will refer to this type of equation, in which units are not supplied after the numbers 34, 10, and 2, as an equation in *shorthand form.* With shorthand form, units for the variables x and t *must* be given explicitly in a sentence or phrase along with the equation. I do not recommend shorthand form, although Giancoli sometimes uses it. If the equation $x = 34 + 10t - 2t^3$ is written without any mention of units, this is ambiguous and hence just plain wrong.

Example 2-3 gives the position of a particle with the following equation.

$$x = At^2 + B$$

I will refer to this type of equation, in which symbols are used instead of numerical quantities, as an equation in *symbolic form.* With symbolic form, units for the variables x and t do not need to be given. Specific values for A and B may or may not be given. If they are given, they need to have units associated with them. Example 2-3 gives the values of A and B as $A = 2.10\ \mathrm{m/s^2}$ and $B = 2.80$ m.

The forms of equations are summarized in the table below.

$x = At^2 + B$	symbolic form	recommended
$x = (2.10\ \mathrm{m/s^2})t^2 + (2.80\ \mathrm{m})$	explicit unit form	recommended
$x = 2.10t^2 + 2.80$, where t is in seconds and x in meters.	shorthand form	not recommended
$x = 2.10t^2 + 2.80$	incorrect	don't use

Question 16. Chapter 2, Problem 16 gives an equation for position as a function of time. Write this equation in explicit unit form.

Question 17. One of the advantages of working with equations in symbolic form is that we can work at the level of *dimensions* rather than at the level of *units*. Consider, for example, the following equation.

$$x = At^2 + B$$

Suppose we know that the dimension of x is length [L] and the dimension of t is time [T]. What must be the dimensions of A and B? The meaning of this equation extends beyond a particular set of units. We can do a lot of analysis and learn a lot before we plug in any numbers. When we start using numbers, however, then we must commit to a set of units.

Example 2-4: Average acceleration.

- There is a song with the lyrics "zero to sixty in three point five". If we assume that this refers to a car, what is its average acceleration?

Conceptual Example 2-5: Velocity and acceleration.

- See Exercise D.

Exercise D:

What do you think?

Example 2-6: Car slowing down.

- What if the car's initial velocity is 20 m/s, with everything else the same as in the Example. What then is the car's average acceleration?

Question 18. Is deceleration the same as slowing down?

Question 19. Is deceleration the same as negative acceleration?

Remark 4. If the velocity and acceleration of an object are in the same direction, the object will speed up. If the velocity and acceleration of an object are in opposite directions, the object will slow down.

Exercise E:

What do you think?

Example 2-7: Acceleration given $x(t)$.

- Suppose the position of a particle as a function of time is given by the following equation.

$$x = At^3 + Bt^2 + Ct + D$$

  In this equation, the symbols A, B, C, and D are constants with appropriate units. Give an expression for the instantaneous acceleration of the particle as a function of A, B, C, D, and t.

Exercise F:

What do you think?

Conceptual Example 2-8: Analyzing with graphs.

- Which car has the greater average velocity?

2.5 Motion at Constant Acceleration

Remark 5. Most of the equations on our equation sheet are in symbolic form. (The same is true of most of the equations in the textbook.) As such, the symbols refer to quantities with particular dimensions, but not necessarily particular units. As an example, consider Equation (2-12a).

$$v = v_0 + at$$

Each symbol has a dimension, as shown in the table below.

Symbol	Dimension
v	$[L/T]$ (velocity)
v_0	$[L/T]$ (velocity)
a	$[L/T^2]$ (acceleration)
t	$[T]$ (time)

While Equation (2-12a) commits us to a particular *dimension* for each of the symbols, it does not commit us to a particular *unit* for each of the symbols. We *could* use the SI units for velocity, acceleration, and time. If we make this choice, then the symbols would have the following units.

Equation (2-12a) with choice of SI units

Symbol	Unit
v	m/s
v_0	m/s
a	m/s^2
t	s

An alternative choice would be to use miles per hour for v and v_0, miles per hour per second for a, and seconds for t. If we make this choice, then the symbols would have the following units.

Equation (2-12a) with alternative choice of units

Symbol	Unit
v	mi/hr
v_0	mi/hr
a	mi/hr/s
t	s

So, with a symbolic equation such as (2-12a), we have freedom to choose a unit for each symbol that goes along with the dimension of that symbol. However, we do need to use a *consistent* set of units. If we choose seconds for t and m/s^2 for a, then we must choose m/s for v_0, because we can only add numbers that have the same units. We must also choose m/s for v.

Question 20. Consider equation (2-12b).

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

Give the dimensions for the symbols x, x_0, v_0, a, and t.

Question 21. Dimensional analysis extends even to equations involving calculus. Consider the equation that says acceleration is the time-derivative of velocity.

$$a = \frac{dv}{dt}$$

Give the dimensions for the symbols a, v, and t.

Example 2-9: Runway design.

- What acceleration would the plane need to have in order to reach its takeoff speed in 150 m?

Exercise G:

What do you think?

2.6 Solving Problems

Example 2-10: Acceleration of a car.

- How fast will this car be going when it gets to the end of the intersection?

Example 2-11: Air bags.

- Redo the Example for a car traveling at 70 mph.

Example 2-12: Braking distances.

- What will the braking distance be if we take the reaction time to be 1.0 s and the deceleration to be 5 m/s^2, with everything else the same as in the Example?

Example 2-13: Two Moving Objects: Police and Speeder.

- What is the meaning of the point where the two lines cross in Figure 2-24(b).

2.7 Freely Falling Objects

Exercise H:

Chapter opening question, take two.

Example 2-14: Falling from a tower.

- When will the ball hit the ground?

Example 2-15: Thrown down from a tower.

- When will the ball hit the ground?

Example 2-16: Ball thrown upward, I.

- Redo the Example for an initial velocity of 20.0 m/s.

Conceptual Example 2-17: Two possible misconceptions.

- If the instantaneous velocity of an object is zero, that means it is not moving. But the instantaneous velocity of an object thrown upward is zero at its highest point. If it's not moving at its highest point, how can it fall down again?

Example 2-18: Ball thrown upward, II.

- Redo the Example for an initial velocity of 20.0 m/s.

Exercise I:

What do you think?

Example 2-19: Ball thrown upward, III; the quadratic formula.

- Redo the Example with an initial velocity of 20.0 m/s.

Example 2-20: Ball thrown upward at edge of cliff.

- Redo the Example with an initial velocity of 20.0 m/s.

Exercise J:

What do you think?

Question 22. Is the acceleration of gravity $a = 9.8$ m/s^2 or $a = -9.8$ m/s^2?

Question 23. What happens to an object whose acceleration and velocity are in opposite directions?

Question 24. When a ball thrown upward reaches its highest point, is its velocity zero? Is its acceleration zero?

Chapter 3

Kinematics in Two or Three Dimensions; Vectors

Question 25. Chapter opening question with clickers.

3.1 Vectors and Scalars

Question 26. Give some examples of physical quantities that are represented by vectors.

Question 27. Give some examples of physical quantities that are represented by scalars.

Question 28. What does it mean if we write $\vec{\mathbf{v}}$ (with an arrow over it)? What does it mean if we write v (without an arrow over it)?

3.2 Addition of Vectors - Graphical Methods

Question 29. Is 30 degrees north of east the same direction as 30 degrees east of north? Make a picture showing each.

Question 30. What is the meaning of the equation

$$\vec{\mathbf{D}}_R = \vec{\mathbf{D}}_1 + \vec{\mathbf{D}}_2?$$

What is the meaning of the equation

$$D_R = D_1 + D_2?$$

Question 31. Arrows on a page have a magnitude, a direction, and a location. Which of these three attributes do vectors have?

Exercise A:

What do you think?

Conceptual Example 3-1: Range of vector lengths.

- Slight modification: Suppose two vectors have lengths of 3 units and 2 units. What is the range of possible lengths for the vector representing the sum of the two?

Exercise B:

What do you think?

3.3 Subtraction of Vectors, and Multiplication of a Vector by a Scalar

Question 32. Is it possible for scalar multiplication to change the direction of a vector? If so, give an example. If not, why not?

Question 33. Is it possible for scalar multiplication to change the magnitude of a vector? If so, give an example. If not, why not?

Question 34. There is a vector with no direction. What is it?

Exercise C:

What do you think?

3.4 Adding Vectors by Components

Question 35. Are vector components independent of a coordinate system, or do they depend on the choice of a coordinate system?

Example 3-2: Mail carrier's displacement.

- How would the answer be different if the second displacement vector was 60.0° south of west for 47.0 km?

Example 3-3: Three short trips.

- How would the answer be different if the first leg was due west rather than due east?

Remark 6. Vectors are not inherently positive or negative (unlike integers or real numbers, which can be positive or negative). For this reason, try to avoid saying things like "the acceleration is negative". (It is clearer to use a word that specifies direction, such as "the acceleration is downward".) The *components* of a vector can be positive or negative. The value of a vector component (and the question of whether it is positive, zero, or negative) depends on the choice of coordinate system.

3.5 Unit Vectors

Example 3-4: Using unit vectors.

- Write the vector $\vec{\mathbf{D}}_1 - \vec{\mathbf{D}}_2$ in unit vector notation.

3.6 Vector Kinematics

Example 3-5: Position given as a function of time.

- Evaluate $\vec{\mathbf{v}}$ and $\vec{\mathbf{a}}$ at $t = 2.0$ s.

3.7 Projectile Motion

Exercise D:

Chapter opening question, take two.

Exercise D':

Allowing for the possibility that the helicopter might have any velocity when it drops the package, which of the trajectories shown are possible, and which are impossible? (Continue to ignore air resistance.)

3.8 Solving Problems Involving Projectile Motion

Example 3-6: Driving off a cliff.

- How fast must the motorcycle leave the cliff top to land 45.0 m from the base of the cliff?

Example 3-7: A kicked football.

- Give the answers to parts (d) and (e) in unit vector notation.

Exercise E:

What do you think?

Exercise E':

Which ball is thrown with greater speed?

Conceptual Example 3-8: Where does the apple land?

- Suppose, instead of a thrown apple, that a toy cannon is mounted on the wagon so that it points vertically upward. When a ball is shot from the cannon in a moving wagon, will the trajectory be essentially the same as the apple, or will it be different?

Conceptual Example 3-9: The wrong strategy.

- If v_0 in the picture is increased, what changes and what stays the same?

Example 3-10: Level horizontal range.

- Does the analysis in this example use a coordinate system in which y is positive upward or in which y is positive downward? There are two pieces of evidence that indicate the answer. Can you identify them?

Exercise F:

What do you think?

Exercise F':

At what speed was the projectile fired?

Example 3-11: A punt.

- Why was the quadratic formula required in this example, but not in Example 3-7?

Example 3-12: Rescue helicopter drops supplies.

- In part (b), use unit vector notation to write an expression for the velocity $\vec{\mathbf{v}}_0$ of the package just after it leaves the helicopter. Also use unit vector notation to write an expression for the velocity $\vec{\mathbf{v}}$ of the package just before it hits the ground. Finally, use unit vector notation to write an expression for the velocity at any time t that the package is in the air.

3.9 Relative Velocity

Conceptual Example 3-13: Crossing a river.

- Under what conditions would you aim your boat at 45° and arrive at a point directly across the shore from where you started?

Example 3-14: Heading upstream.

- Suppose the river current is 1.20 m/s and the boat's speed with respect to the water is 2.40 m/s. At what angle must the boat head in order to arrive at a point directly across the shore from where it started?

Example 3-15: Heading across the river.

- Give an expression for $\vec{\mathbf{r}}_{BS}$, the position of the boat with respect to the shore, as a function of time t, using unit vector notation.

Example 3-16: Car velocities at $90°$.

- Choose a coordinate system and express $\vec{\mathbf{v}}_{12}$ in unit vector notation.

Chapter 4

Dynamics: Newton's Law's of Motion

Question 36. First chapter opening question with clickers.

Question 37. Second chapter opening question with clickers.

4.1 Force

Question 38. Is force a vector or a scalar?

Question 39. What is *weight*?

4.2 Newton's First Law of Motion

Conceptual Example 4-1: Newton's first law.

- Think of another situation in which an object continues to move with no force applied.

4.3 Mass

Question 40. In what units do we measure mass?

4.4 Newton's Second Law of Motion

Question 41. In what units do we measure force?

Example 4-2: Force to accelerate a fast car.

- What is the approximate weight of a 100-g apple?

Example 4-3: Force to stop a car.

- Choose a coordinate system and express the net force in unit vector notation.

Exercise A:

What force pushes the cup off the dashboard?

4.5 Newton's Third Law of Motion

Conceptual Example 4-4: What exerts the force to move a car?

- In two words or less, what object exerts the force on the car?

Conceptual Example 4-5: Third law clarification.

- How many and which of the six forces shown in Figure 4-12 determine the acceleration of the sled?

Exercise B:

Clicker question.

Exercise C:

(a) Which vehicle experiences the greater force? (b) Which experiences the greater acceleration? (c) Which of Newton's law are useful?

Exercise D:

Does it always push back on you?

4.6 Weight—the Force of Gravity; and the Normal Force

Exercise E:

Second chapter opening question with clickers.

Example 4-6: Weight, normal force, and a box.

- If we push downward on the box with a force of 20 N, what is the normal force?

Example 4-7: Accelerating the box.

- Write the acceleration in unit vector notation.

Example 4-8: Apparent weight loss.

- If the scale displayed Newtons rather than kilograms, what would it read in parts (a) and (b)?

4.7 Solving Problems with Newton's Laws: Free-Body Diagrams

Example 4-9: Adding force vectors.

- Express $\vec{\mathbf{F}}_{\mathrm{R}}$ in unit vector notation.

Conceptual Example 4-10: The hockey puck.

- The magnitude of $\vec{\mathbf{F}}_{\mathrm{N}}$ is equal to the magnitude of $\vec{\mathbf{F}}_{\mathrm{G}}$. (a) Why? (b) Is it correct to write $\vec{\mathbf{F}}_{\mathrm{N}} = \vec{\mathbf{F}}_{\mathrm{G}}$? If not, what equation can be correctly written?

Example 4-11: Pulling the mystery box.

- Which of the following equations are correct?

    1. $F_{\mathrm{N}} = 78.0$ N

2. $F_{\text{N}} = 78.0\ \text{N}\ \hat{\mathbf{j}}$
3. $\vec{\mathbf{F}}_{\text{N}} = 78.0\ \text{N}$
4. $\vec{\mathbf{F}}_{\text{N}} = 78.0\ \text{N}\ \hat{\mathbf{j}}$

Exercise F:

What happens to the normal force if the applied force is doubled?

Exercise F':

If the applied force in Example 4-11 is doubled, what happens to the normal force (does it increase, decrease, or remain the same)?

Example 4-12: Two boxes connected by a cord.

- In this example, we did not need to apply Newton's second law in the y direction for either box. What would we learn if we did apply Newton's second law in the y direction?

Example 4-13: Elevator and counterweight (Atwood's machine).

- A slightly different way of solving this problem is to choose different coordinate systems for the elevator and the counterweight. The reason for doing this is that the downward acceleration of the elevator is equal to the upward acceleration of the counterweight. If we choose a coordinate system in which up is positive for the counterweight, and a coordinate system in which down is positive for the elevator, then we will have $a_{\text{C}} = a$ and $a_{\text{E}} = a$, without any minus signs. Write down Newton's second law for the elevator using a coordinate system in which down is positive. Is the equation mathematically equivalent to the corresponding equation from the textbook?

Conceptual Example 4-14: The advantage of a pulley.

- There are two pulleys in Figure 4-24. In order to get the mechanical advantage of 2, are both pulleys needed, or just one? If just one, which one?

Question 42. Figure 4-24 shows a free-body diagram for the pulley-piano combination. Draw separate free-body diagrams for the pulley and the piano.

Example 4-15: Accelerometer.

- Equation (3-2) from the Chapter 3 summary on page 74 says that

  $$V_x = V \cos\theta.$$

  In Example 4-15, the x component of tension is

  $$F_{\mathrm{T}x} = F_{\mathrm{T}} \sin\theta.$$

  Is this a contradiction? Why or why not?

Example 4-16: Box slides down an incline.

- Write the vector $\vec{\mathbf{g}}$ in terms of g, θ, $\hat{\mathbf{i}}$, and $\hat{\mathbf{j}}$. How does this expression simplify when $\theta = 0$?

4.8 Problem Solving—A General Approach

Question 43. What does Giancoli think is the most crucial part of solving a problem?

Chapter 5

Using Newton's Laws: Friction, Circular Motion, Drag Forces

We are going to explore two topics in chapter 5: friction and circular motion. Friction is the subject of section 5-1. Circular motion is the subject of sections 5-2, 5-3, and 5-4. These two topics will give us an opportunity to apply Newton's second law over and over again (more or less in every problem).

Question 44. Chapter opening question with clickers.

5.1 Applications of Newton's Laws Involving Friction

Example 5-1: Friction: static and kinetic.

- What would the graph in Figure 5-3 look like if both the coefficient of static friction and the coefficient of kinetic friction were 0.4?

Conceptual Example 5-2: A box against a wall.

- See Exercise A.

Exercise A:

What minimum force will keep the box from falling?

Exercise A':

If the coefficient of static friction is 0.2, what minimum force will keep the box from falling?

Example 5-3: Pulling against friction.

- See Exercise B.

Exercise B:

If $\mu_k F_N$ were greater than F_{Px}, what would you conclude?

Exercise B':

Suppose, in Example 5-3, that the coefficient of kinetic friction is 0.5 and the coefficient of static friction is 0.7. If the box starts from rest, find its acceleration and the force of friction on the box.

Conceptual Example 5-4: To push or to pull a sled?

- Suppose you were able to push horizontally instead of at a downward angle. Which requires less force: pushing horizontally or pulling at an angle $\theta > 0$, as shown in Figure 5-6(b)?

Example 5-5: Two boxes and a pulley.

- Suppose the boxes in this example start from rest. How big would the coefficient of static friction need to be to prevent the boxes from moving?

Question 45. In Example 5-5, write a symbolic equation for a in terms of m_A, m_B, g, and μ_k.

Question 46. In Example 5-5, suppose the mass of box A is very small. In the limit in which $m_A \to 0$, what do you expect (on physical grounds) the acceleration of box B to be? If you substitute $m_A = 0$ in the equation from the previous question, do you get what you expect?

Example 5-6: The skier.

- Explain how to figure out that $\sin\theta$ goes with the x component of the gravitational force and $\cos\theta$ goes with the y component, rather than the other way around.

Example 5-7: A ramp, a pulley, and two boxes.

- This example is sufficiently complicated, that we should go through it together in class.

Remark 7. Here is a summary of three types of resistive forces, including the two types of friction we studied in Section 5-1.

Type	Direction	Magnitude
Air resistance	Opposite the velocity	no equation
Kinetic friction	Opposite the velocity (and parallel to the surface)	$F_{\text{fr}} = \mu_{\text{k}} F_{\text{N}}$
Static friction	Parallel to surface (whatever direction will prevent motion)	no equation, but $F_{\text{fr}} \leq \mu_{\text{s}} F_{\text{N}}$

Question 47. Based on the summary table above, which type of resistive force is easiest to deal with? Why?

5.2 Uniform Circular Motion—Kinematics

Question 48. If you know that an object moves in a circle at constant speed, what can you say about the magnitude of its acceleration?

Question 49. If you know that an object moves in a circle at constant speed, what can you say about the direction of its acceleration?

Exercise C:

What do you think?

Example 5-8: Acceleration of a revolving ball.

- See Exercise D.

Exercise D:

What do you think?

Exercise D':

Figure out Exercise D symbolically by solving for the centripetal acceleration in terms of the radius and period. Then, using your equation, say what happens to the centripetal acceleration when you double the period, but keep the radius the same. This shows the power of solving for things symbolically. From a symbolic equation, you can see what happens when variables (like radius or period, in this case) change.

Example 5-9: Moon's centripetal acceleration.

- What is the frequency of the Moon's orbit?

Example 5-10: Ultracentrifuge.

- The centrifuge principle is also used in science fiction movies. We want to have a rotating space station that simulates Earth's gravity. Suppose the radius of rotation is r on the space station. Draw a picture, showing where a person could stand on the "ground". Come up with an equation for the period of rotation needed to simulate Earth's gravity in terms of the radius r. Then give a numerical result for the period if $r = 100$ m.

5.3 Dynamics of Uniform Circular Motion

Exercise E:

Chapter opening question, take two, with clickers.

Example 5-11: Force on revolving ball (horizontal).

- The second note gives a suggestion about how to include the weight of the ball in the calculation. Follow this suggestion, and calculate the x- and y-components of the tension. Then calculate the angle ϕ.

Example 5-12: Revolving ball (vertical circle).

- Suppose the ball of Example 5-12 has a speed of 4.64 m/s at the top of the circle and a speed of 8.05 m/s at the bottom of the circle. Find the tension in the cord at the top and at the bottom.

Exercise F:

What do you think?

Example 5-13: Conical pendulum.

- How long must the string on a conical pendulum be for it to have a period of 1 s if $\theta = 5°$. What if $\theta = 60°$?

5.4 Highway Curves: Banked and Unbanked

Example 5-14: Skidding on a curve.

- The condition for not slipping is that the centripetal force required for circular motion must be less than or equal to the maximum force of static friction. Using this idea, write a symbolic inequality in terms of μ_s, g, v, and r that needs to hold if no slipping is to occur. Try to simplify your inequality as much as possible.

Example 5-15: Banking angle.

- When solving a physics problem, we are free to choose whatever coordinate system we like. Sometimes we choose a coordinate system in which x is horizontal and y is vertical, and sometimes we choose a coordinate system in which x is "down the ramp" and y is perpendicular to the ramp (see, for example, Figure 5-8). Usually, we choose the coordinate system that makes the calculation easier, but the laws of physics will work in *any* coordinate system that we choose.

  Consider the free-body diagram shown in Figure 5-24. If we choose the coordinate system shown in that figure, and apply Newton's second law in the y direction, it seems we would conclude

$$F_N \cos\theta = mg.$$

Suppose instead that we choose a coordinate system in which x is "down the ramp" and y is perpendicular to the ramp. If we now apply Newton's second law in the y direction, it seems we would conclude

$$F_{\mathrm{N}} = mg\cos\theta.$$

Can both of these equation be correct? If not, what has gone wrong?

Exercise G:

What do you think?

Exercise H:

What do you think?

Chapter 6

Gravitation and Newton's Synthesis

Question 50. Chapter opening question with clickers.

6.1 Newton's Law of Universal Gravitation

Example 6-1: Can you attract another person gravitationally?

- Is the 10^{-6} N the force on the 50-kg person or the force on the 70-kg person?

Example 6-2: Spacecraft at $2r_\mathrm{E}$.

- Let m_E be the mass of the Earth, and r_E be the radius of the Earth. If you look up these values and plug them into

$$\frac{Gm_\mathrm{E}}{r_\mathrm{E}^2},$$

what do you think you will get? Why?

Example 6-3: Force on the Moon.

- What force would act on the moon if the Sun, Earth, and Moon were on a line with the Moon in the middle?

6.2 Vector Form of Newton's Law of Universal Gravitation

Question 51. Let $\vec{\mathbf{r}}_1$ be the position vector for particle 1, and let $\vec{\mathbf{r}}_2$ be the position vector for particle 2. One of the following equations is correct.

$$\vec{\mathbf{r}}_{21} = \vec{\mathbf{r}}_2 - \vec{\mathbf{r}}_1?$$
$$\vec{\mathbf{r}}_{21} = \vec{\mathbf{r}}_1 - \vec{\mathbf{r}}_2?$$

Which one? (Hint: Draw a picture showing particle 1, particle 2, and the origin of your coordinate system. Next, draw the three vectors $\vec{\mathbf{r}}_1$, $\vec{\mathbf{r}}_2$, and $\vec{\mathbf{r}}_{21}$. Based on the rules for adding vectors graphically, which two vectors add to make the third?)

For Giancoli, $\vec{\mathbf{r}}_{21}$ is the displacement vector from particle 2 to particle 1. Authors of physics textbooks do not agree on a convention for this. Some authors use $\vec{\mathbf{r}}_{21}$ to mean the displacement vector from particle 1 to particle 2. We will follow Giancoli's convention, although I may mess it up because I prefer the opposite convention. Please correct me if I fail to follow Giancoli's convention.

The unit vector $\vec{\mathbf{r}}_{21}$ is the first unit vector we've run into other than $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, and $\hat{\mathbf{k}}$. You need to have a coordinate system in order to be able to talk about $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, and $\hat{\mathbf{k}}$. The unit vector $\vec{\mathbf{r}}_{21}$, however, does not depend on a choice of coordinate system. It depends only on the relative locations of two particles.

6.3 Gravity Near the Earth's Surface; Geophysical Applications

Example 6-4: Gravity on Everest.

- Calculate "little g" for the Moon by looking up the mass and radius of the Moon.

Exercise A:

What do you think?

Example 6-5: Effect of Earth's rotation on g.

- Which is greater in magnitude: the weight of a person at the equator, or the normal force exerted by the ground on the person? Why?

6.4 Satellites and "Weightlessness"

Example 6-6: Geosynchronous satellite.

- Google tells me that the altitude of the International Space Station is 249 miles. Find its period.

Example 6-7: Catching a satellite.

- The Moon has a period of about a month and an altitude of 378,000 km (about 59 Earth radii). A geosynchronous satellite has a period of 24 hours and an altitude of about 36,000 km (about 6 Earth radii). We see that for satellites in circular orbit, as the altitude decreases, the period also decreases. Is there a minimum period, or can we make the period as small as we please if we are willing to make the altitude small enough? In answering this question, ignore Earth's atmosphere and the air resistance it provides. If there is a minimum period, what is it?

Exercise B:

What do you think?

Exercise C:

Chapter Opening Question, take two with clickers.

Exercise D:

What do you think?

6.5 Kepler's Laws and Newton's Synthesis

Example 6-8: Where is Mars?

- Halley's Comet orbits the Sun in a very elliptical orbit. Its eccentricity is 0.967 and its semimajor axis is 2.66×10^{12} m. Find the period of Halley's Comet.

Example 6-9: The Sun's mass determined.

- See Exercise E

Exercise E:

What is the period?

Example 6-10: Lagrange Point.

- We learned that the Earth-L1 distance is 0.01 of the Earth-Sun distance. The Moon-Earth system should have an L1 just like the Earth-Sun system has. The Moon-L1 distance is what fraction of the Moon-Earth distance?

6.6 Gravitational Field

You are not responsible for this section.

6.7 Types of Forces in Nature

Question 52. What are the four fundamental forces?

Question 53. Which of the fundamental forces describes the normal force?

Chapter 7

Work and Energy

Question 54. Chapter opening question with clickers.

7.1 Work Done by a Constant Force

Example 7-1: Work done on a crate.

- Can we tell, from the information given in this example, whether the crate will move at constant speed or not?

Exercise A:

What do you think?

Exercise B:

Chapter Opening Question, second time, with clickers.

Example 7-2: Work on a backpack.

- The magnitude of the displacement $\vec{\mathbf{d}}$ is never given in this example. How can we find the work done by the hiker without the displacement?

Example 7-3: Does the Earth do work on the Moon?

- Consider again Example 5-13, the conical pendulum. In that example, does the force of tension do work on the ball?

Question 55. Consider again Example 3-6. Does the force of gravity do work on the motorcycle?

7.2 Scalar Product of Two Vectors

Example 7-4: Using the dot product.

- Suppose a wagon experiences a constant force

  $$\vec{\mathbf{F}}_{\mathrm{P}} = (17\ \mathrm{N})\hat{\mathbf{i}} + (10\ \mathrm{N})\hat{\mathbf{j}}$$

  and undergoes a displacement

  $$\vec{\mathbf{d}} = (50\ \mathrm{m})\hat{\mathbf{i}} + (20\ \mathrm{m})\hat{\mathbf{j}}$$

  Find the work done by the force.

7.3 Work Done by a Varying Force

Question 56. Equation (7-8) says $F_{\mathrm{S}} = -kx$. Just before this equation is another equation that says $F_{\mathrm{P}} = kx$. Explain the difference between these two forces.

Example 7-5: Work done on a spring.

- (a) What is the work required to stretch this spring from 0 cm to 1 cm?
  (b) What is the work required to extend the spring from 1 cm to 2 cm?
  (c) What is the work required to extend the spring from 2 cm to 3 cm?
  (d) If we add these three works together, does it equal the work required to stretch the spring from 0 cm to 3 cm?

Example 7-6: Force as a function of x.

- A nonlinear spring has a force function

  $$F_{\mathrm{S}} = -kx - bx^3$$

  where $k = 2500$ N/m and $b = 1.2 \times 10^6$ N/m^3. What is the work required by a person to slowly extend this spring from $x = 0$ cm to $x = 3$ cm?

7.4 Kinetic Energy and the Work-Energy Principle

Example 7-7: Kinetic energy and work done on a baseball.

- Suppose the baseball traveling at 25 m/s hits the ground and bounces. After the bounce, the baseball's speed is 15 m/s. How much work was done by the ground on the baseball? (You may assume that the force of the ground is the only significant force that acts on the baseball during the bounce. Why is it important to know that you can make this assumption?)

Example 7-8: Work on a car, to increase its kinetic energy.

- See Exercise C.

Exercise C:

What do you think?

Conceptual Example 7-9: Work to stop a car.

- See Exercises D and E.

Exercise D:

What do you think?

Exercise E:

What do you think?

Example 7-10: A compressed spring.

- In part (c), what is the kinetic energy of the block when it separates from the spring?

Chapter 8

Conservation of Energy

Question 57. Chapter opening question with clickers.

8.1 Conservative and Nonconservative Forces

Question 58. There are two forces we have discussed so far in the course that are conservative. What are they?

8.2 Potential Energy

Example 8-1: Potential energy changes for a roller coaster.

- See Exercise A.

Exercise A:

What do you think?

Example 8-2: Determine F from U.

- Suppose
$$U(x) = \frac{a}{x},$$
where a is a constant. What is F as a function of x? What dimensions does the constant a have?

8.3 Mechanical Energy and Its Conservation

Question 59. What is the definition of mechanical energy?

Question 60. Consider a system with two objects, A and B, with masses m_A and m_B, respectively. If both of these objects are moving, then equation (8-11b) is not valid. Let $v_{\mathrm{A}1}$, $v_{\mathrm{B}1}$, and U_1 represent the speed of object A, the speed of object B, and the potential energy at one instant. Let $v_{\mathrm{A}2}$, $v_{\mathrm{B}2}$, and U_2 represent the speed of object A, the speed of object B, and the potential energy at a second instant. Write an equation to replace equation (8-11b) for the situation described here.

8.4 Problem Solving Using Conservation of Mechanical Energy

Example 8-3: Falling rock.

- See Exercise B.

Exercise B:

What do you think?

Example 8-4: Roller-coaster car speed using energy conservation.

- At the top of the hill, the car has all potential energy and no kinetic energy. At the bottom of the hill, the car has all kinetic energy and no potential energy. At what point does the car have half kinetic energy and half potential energy? What is the speed of car at this point?

Conceptual Example 8-5: Speeds on two water slides.

- What is the argument for why Kathleen makes it to the bottom first?

Exercise C:

What do you think?

Exercise C':

If the two balls are released at the same time, which ball reaches the floor first? Explain why.

Example 8-6: Pole vault.

- Could this calculation be done correctly choosing $y = 0$ to be the ground instead of the vaulter's center of mass?

Example 8-7: Toy dart gun.

- In Examples 8-3, 8-4, 8-5, and 8-6, the speed of the object does not depend on its mass. Does the final speed of the dart in this Example depend on its mass?

Example 8-8: Two kinds of potential energy.

- Redo Example 8-8 if the spring compresses 10.0 cm, and everything else is the same.

Question 61. In most problems that involve gravitational potential energy, we have a choice about where to locate $y = 0$. Do we have this choice in Example 8-8. Why or why not?

Question 62. In Example 8-6 with the pole vault, kinetic energy is transformed into elastic potential energy, and then into gravitational potential energy. Why do we not have to include elastic potential energy in this calculation?

Example 8-9: A swinging pendulum.

- Suppose the bob is released at angle of 60°. Give an expression for the magnitude of the tension at the bottom of the swing in terms of m and g.

8.5 The Law of Conservation of Energy

Question 63. What type of energy is *not* conserved when frictional forces are present and do work? What type of energy *is* conserved when frictional forces are present?

8.6 Energy Conservation with Dissipative Forces: Solving Problems

Exercise D:

Chapter Opening question, take two, with clickers.

Example 8-10: Friction on the roller-coaster car.

- Redo this Example assuming the car reaches a height of 20 m on the second hill, with everything else the same.

Example 8-11: Friction with a spring.

- What do you get for the coefficient of kinetic friction if $m = 10$ kg, $v_0 = 60$ cm/s, $k = 1.0 \times 10^4$ N/m, and $X = 2$ cm? Why is this result problematic? What is the reason for this result?

8.7 Gravitational Potential Energy and Escape Velocity

Example 8-12: Package dropped from high-speed rocket.

- Redo this Example, changing the position of the rocket to be the same distance from the Earth that the Moon is. (The rocket is not near the Moon, and is not orbiting the Earth like the Moon is.)

Example 8-13: Escaping the Earth or the Moon.

- Jupiter's moon Themisto has a diameter of 8 km and a mass of 6.9×10^{14} kg. Find the escape velocity from Themisto.

8.8 Power

Example 8-14: Stair-climbing power.

- Pretend that there are stairs on the Moon. Redo this Example with the same height of stairs and the same time, but on the Moon.

Example 8-15: Power needs of a car.

- A Ford Mustang can accelerate from 0 to 100 km/h in 4.8 s. It has a weight of 3500 lbs. Estimate the power requirement for this.

Chapter 9

Linear Momentum

Question 64. Chapter opening question with clickers.

9.1 Momentum and Its Relation to Force

Exercise A:

What do you think?

Example 9-1: Force of a tennis serve.

- What would the force on the ball be if the ball was in contact with the racket for 5 ms rather than 4 ms?

Example 9-2: Washing a car: momentum change and force.

- See Exercise B.

Exercise B:

What do you think?

9.2 Conservation of Momentum

Example 9-3: Railroad cars collide: momentum conserved.

- See Exercises C and D.

Exercise C:

What do you think?

Exercise D:

What do you think?

Example 9-4: Rifle recoil.

- Try Chapter 9, Problem 11.

Conceptual Example 9-5: Falling on or off a sled.

- See Exercise E.

Exercise E:

Chapter Opening questions, second time, with clickers.

9.3 Collisions and Impulse

Example 9-6: Karate blow.

- Redo the example for a hand speed of 12 m/s. This is 20% faster than the original example. Is the impulse delivered 20% more? Is the force delivered 20% more?

9.4 Conservation of Energy and Momentum in Collisions

Question 65. What is an elastic collision? What quantities are conserved in an elastic collision?

Question 66. What is an inelastic collision? What quantities are conserved in an inelastic collision?

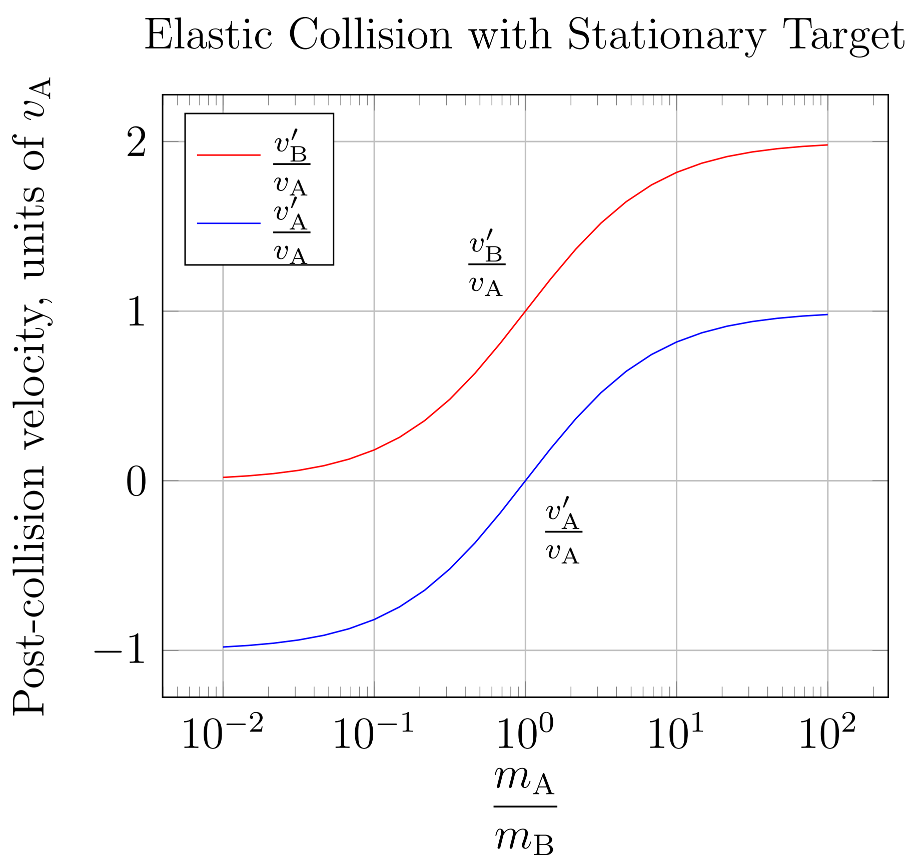
9.5 Elastic Collisions in One Dimension

Example 9-7: Equal masses.

- Ball A and ball B are identical. Ball A is moving at 2 m/s to the right and ball B is moving at 1 m/s to the left when they have an elastic collision. The collision takes place in one dimension. What are the velocities of each ball (magnitude and direction) after the collision?

Example 9-8: Unequal masses, target at rest.

- Here is a graph showing the results of Example 9-8.



Some things to notice about this graph:

1. What happens when $m_A = m_B$?

2. What happens when $m_A \ll m_B$?
3. What happens when $m_A \gg m_B$?
4. Why is $v'_B - v'_A$ the same for every mass ratio?
5. Under what conditions does object A bounce back?
6. Does object B (the target) ever move to the left?
7. How did I make this graph? Could you make a graph like this?

Let's do Chapter 9, Problem 40 together. I have one little bone to pick with the language used in Problem 40. The quantities v_A, v_B, v'_A, and v'_B are not *speeds*. They are one-dimensional velocities. What is the difference between speed and one-dimensional velocity?

Example 9-9: A nuclear collision.

- What would the final velocities be if the helium nucleus came in with the given initial velocity and the proton was initially at rest?

9.6 Inelastic Collisions

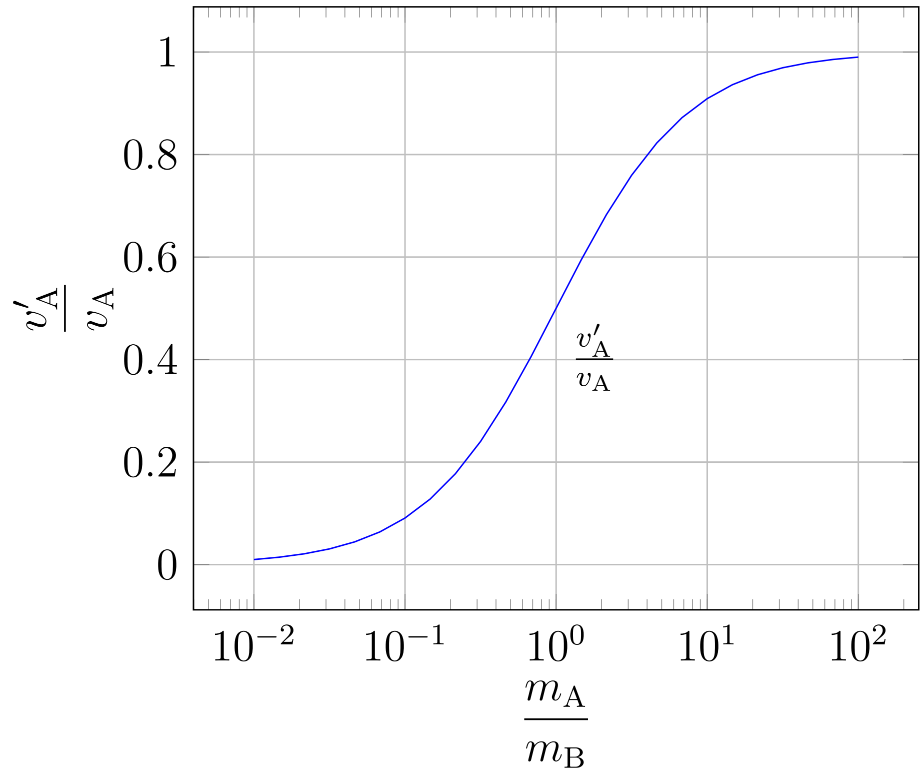
Example 9-10: Railroad cars again.

- In Exercise C, calculate how much of the initial kinetic energy is transformed to thermal or other forms of energy.

Question 67. In Chapter 9, Problem 40, we considered a one-dimensional *elastic* collision between object A (mass m_A, velocity v_A) and object B (mass m_B, velocity v_B). We derived the expressions at the bottom of page 224 of the textbook for v'_A and v'_B, the velocities after the collision. Let's redo that calculation for the case of a *completely inelastic* collision. Find expressions for v'_A and v'_B in terms of m_A, m_B, v_A, and v_B.

Question 68. Redo Example 9-8 for a completely inelastic collision instead of an elastic collision. Your results should be consistent with the graph below.

Completely Inelastic Collision with Stationary Target



Some things to notice about this graph:

1. What happens when $m_A = m_B$?
2. What happens when $m_A \ll m_B$?
3. What happens when $m_A \gg m_B$?
4. Why is v'_B not plotted on the graph?
5. Under what conditions does object A bounce back?
6. Does object B (the target) ever move to the left?
7. How did I make this graph? Could you make a graph like this?

Question 69. Give an expression in terms of m_{A} and m_{B} for the fraction of kinetic energy lost in a completely inelastic collision in which the target (object B) is at rest. What fraction do you get for the following special and limiting cases?

- $m_{\mathrm{A}} = m_{\mathrm{B}}$
- $m_{\mathrm{A}} \ll m_{\mathrm{B}}$
- $m_{\mathrm{A}} \gg m_{\mathrm{B}}$

Example 9-11: Ballistic pendulum.

- Consider a ballistic pendulum situation in which a 50-g bullet moving at 500 m/s embeds itself into a 10-kg block of wood. The block of wood is suspended by a 1-m string. How high will the block rise? What angle from the vertical will the string make at the block's highest point?

Question 70. Consider the ballistic pendulum, a system composed of a projectile and a block. Give an algebraic expression for the kinetic energy of the system before the collision. Give a second expression for the kinetic energy of the system after the collision. There are multiple correct expressions that you could give for each case (before and after collision). Try to come with expressions that make it clear that the kinetic energy after the collision is less than the kinetic energy before the collision.

Question 71. Both of the examples in section 9-6 deal with a *completely* inelastic collision, but this is not the only kind of inelastic collision. Suppose we have a collision between two equal-mass objects ($m_{\mathrm{A}} = m_{\mathrm{B}} = m$) in which the target is at rest ($v_{\mathrm{B}} = 0$). Suppose that after the collision, object A has a velocity of 1/4 its initial velocity, in the same direction ($v'_{\mathrm{A}} = v_{\mathrm{A}}/4$). Find the velocity of object B. What fraction of kinetic energy is lost in this collision? (It should be less than half, which is the fraction that would be lost in a completely inelastic collision.)

Question 72. Let's do Chapter 9 Problem 49 together. This problem introduces the *coefficient of restitution*.

9.7 Collisions in Two or Three Dimensions

Example 9-12: Billiard ball collision in 2-D.

- Find the kinetic energy lost in this collision. Was the collision elastic, inelastic, or completely inelastic?

Remark 8. Earlier I noted that I did not approve of the term "speed" applied in Chapter 9, Problem 40, to the variables v_{A}, v_{B}, v'_{A}, and v'_{B}. In one-dimensional collision problems, these variables are one-dimensional velocities. They can be positive, negative, or zero. A negative value means motion in the negative direction (usually to the left).

In Section 9-7, where we begin to consider collisions in two dimensions, Giancoli now begins to use the same variables, v_{A}, v_{B}, v'_{A}, and v'_{B}, as speeds. These variables cannot be negative. The direction is specified by angles θ'_{A} and θ'_{B}.

In summary, for 1-D collisions, the v's can be negative; for 2-D collisions, the v's cannot be negative.

Example 9-13: Proton-proton collision.

- In equations (i), (ii), and (iii), which three variables are we trying to solve for? After the sneaky squaring and trig identity, which variable have we gotten rid of?

9.8 Center of Mass

Example 9-14: CM of three guys on a raft.

- See Exercise F.

Exercise F:

What do you think?

Example 9-15: Three particles in 2-D.

- Let's generalize this example by letting the mass be m rather than 2.50 kg (still the same for all three particles), letting the horizontal distance be a rather than 2.00 m, and letting the vertical distance be b rather than 1.50 m. Give expressions for x_{CM} and y_{CM}. Also give an expression for $\vec{\mathbf{r}}_{\text{CM}}$ using unit vector notation.

Exercise G:

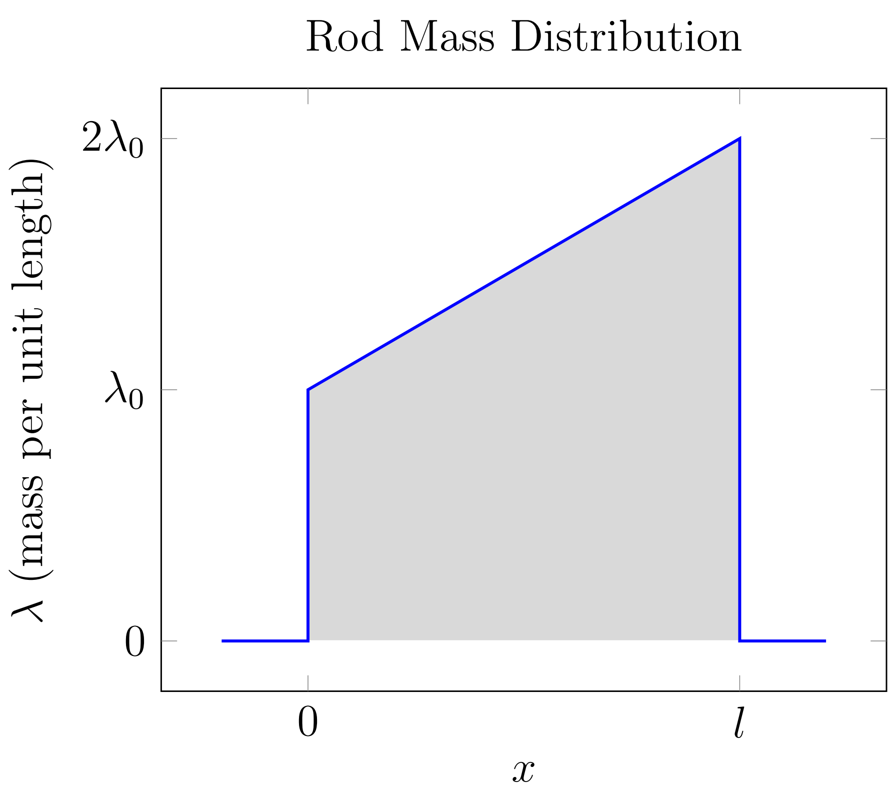
What do you think?

Example 9-16: CM of a thin rod.

- In part (b), why can we not stop with the result

$$x_{\text{CM}} = \frac{5}{6}\frac{\lambda_0}{M}l^2?$$

It's because the three parameters given in this Example, l, M, and λ_0, are not independent. The graph below shows the mass per unit length λ as a function of position x along the rod. The shaded area under the curve represents the total mass M of the rod.

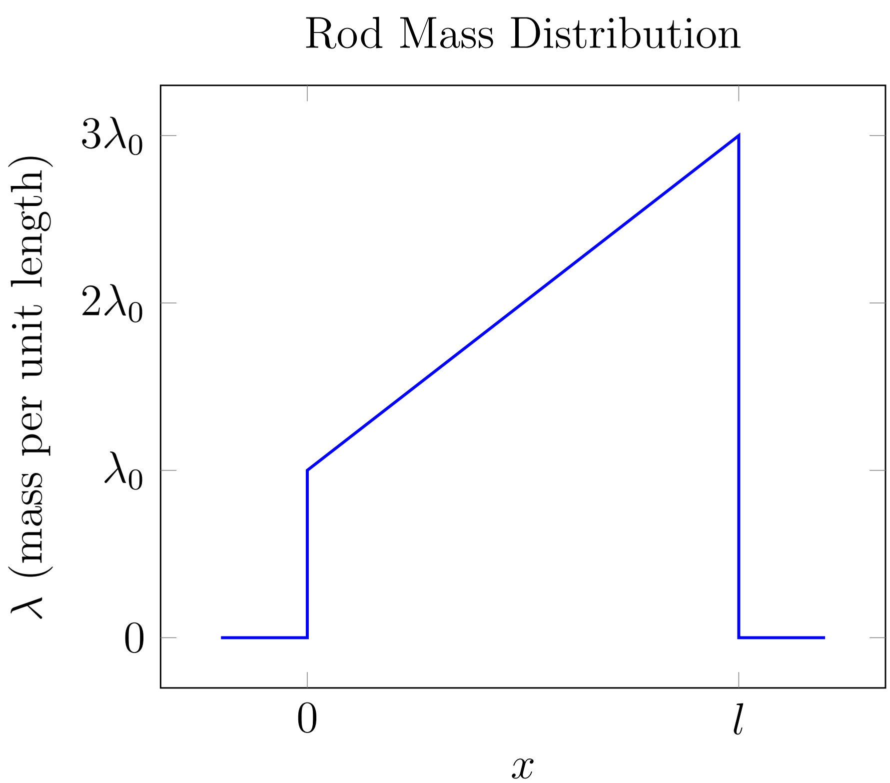


Even without calculus, using the formulas for the areas of a triangle and a rectangle, we can obtain an expression for M.

$$M = \frac{1}{2}\lambda_0 l + \lambda_0 l = \frac{3}{2}\lambda_0 l$$

Because $M = \frac{3}{2}\lambda_0 l$, we should attempt to express the result in terms of only two of the parameters l, M, and λ_0. In the end, it turns out that x_{CM} depends only on l.

Question 73. Find x_{CM} for a rod with the mass distribution shown below.



Example 9-17: CM of L-shaped flat object.

- We should get the same center of mass if we divide the L-shaped object into two rectangles in a different way. Instead of including the upper right corner of the L in the top rectangle, let's include it in the bottom rectangle.

(a) Rectangle A' is 1.86 m horizontally and 0.20 m vertically. Find the x and y coordinates for the center of mass of rectangle A', using the coordinate system in Figure 9-29.

(b) Rectangle B' is 0.20 m horizontally and 1.68 m vertically. Find the x and y coordinates for the center of mass of rectangle B', using the coordinate system in Figure 9-29.

(c) Find the CM of the L-shaped object using the CMs of rectangles A' and B'. You should get the same result as in Example 9-17.

9.9 Center of Mass and Translational Motion

Conceptual Example 9-18: A two-stage rocket.

- See Exercise H.

Exercise H:

What do you think?

Chapter 10

Rotational Motion

Question 74. Chapter opening question with clickers.

10.1 Angular Quantities

Example 10-1: Birds of prey—in radians.

- Redo part (b) of the Example if the bird can distinguish objects that subtend an angle of $0.17°$.

Question 75. Does a positive value of ω indicate clockwise or counterclockwise rotation?

Conceptual Example 10-2: Is the lion faster than the horse?

- DVDs store a fixed amount of data (in bytes, say) per cm of arc length. The DVD player needs to read a fixed amount of data per unit time. In order to do this, the player will need to use a different angular velocity for data read near the outer edge of the DVD compared with data read near the center of the DVD. Is the angular velocity required to read data at the outer edge bigger or smaller than the that for data at the center?

Example 10-3: Angular and linear velocities and accelerations.

- Repeat parts (a)-(e) at time $t = 4.0$ s.

Exercise A:

What do you think?

Example 10-4: Hard drive.

- Repeat this Example for a 5400-rpm hard drive.

Example 10-5: Given ω as function of time.

- Repeat this Example for

$$\omega = 3.2 \text{ rad/s} + (2.4 \text{ rad/s}^2)t + (0.8 \text{ rad/s}^3)t^2.$$

Remark 9. Earlier I said that for most of the equations in the book, each symbol was committed to having a particular dimension, but that any units with that dimension could be used, as long as the units were consistent. (See Remark 5.) There are exceptions to this rule, unfortunately. Consider Equation (10-1b).

$$l = R\theta$$

The symbol θ is dimensionless. We could write its dimension as [1]. This is the dimension for pure numbers and angles. But angle can be measured in degrees, radians, or revolutions. Does it matter which we choose? Yes. Does the SI system help us choose? No. The answer is that this particular equation is only good if θ is in radians. If we use degrees or revolutions, we will end up with something wrong. This is an example of what I referred to in Remark 2 as an irritation. We simply must remember that in this equation, θ must be in radians.

A similar example is Equation (10-4).

$$v = R\omega$$

Here, ω should be in rad/s. (Actually, there are some other options, but not for the angle part. We need radians.)

Challenge Question 1. Equation (10-1a) in the textbook is only correct if θ is measured in radians. Can you write an analogous equation with the angle in degrees? In other words, what is the relationship between radius, arc length, and angle if the angle (let's call it ϕ) is measured in degrees?

10.2 Vector Nature of Angular Quantities

Question 76. Consider an analog clock on a wall. The angular velocity vector $\vec{\omega}$ of the minute hand points in which direction? (Toward the left, toward the right, up the wall, down the wall, into the wall, or out of the wall?)

10.3 Constant Angular Acceleration

Example 10-6: Centrifuge acceleration.

- Repeat this Example for a centrifuge that can accelerate from rest to 20,000 rpm in 20 s.

Question 77. Chapter 10, Problem 22 gives an equation for angle as a function of time. This equation is given in shorthand form. Write the equation in explicit unit form.

Question 78. Chapter 10, Problem 23 gives an equation for angular acceleration as a function of time. This equation is given in shorthand form. Write the equation in explicit unit form.

10.4 Torque

Example 10-7: Torque on a compound wheel.

- In Figure 10-15, it looks the angle between $\vec{\mathbf{F}}_{\mathrm{B}}$ and R_{B} is 120°. The example uses $\theta = 60°$. Would it be OK to use 120° for θ instead of 60°?

Exercise B:

What do you think?

10.5 Rotational Dynamics; Torque and Rotational Inertia

Example 10-8: Two weights on a bar: different axis, different I.

- Calculate the moment of inertia about a third axis, parallel to the two considered in the Example, but passing through the 7.0-kg mass.

10.6 Solving Problems in Rotational Dynamics

Example 10-9: A heavy pulley.

- Suppose the pulley is a hollow cylinder with outer radius 33.0 cm. What is the inner radius?

Example 10-10: Pulley and bucket.

- What is the tension in the rope?

Example 10-11: Rotating rod.

- Let us generalize this Example a bit. Suppose a point mass m is attached to the tip of the rod of mass M. At the moment of release, determine (a) the angular acceleration of the system and (b) the linear acceleration of the tip. Find a general solution, then examine the limiting cases (i) $m \ll M$ and (ii) $m \gg M$.

Question 79. Try Chapter 10, Problem 51. We'll work on this in class.

10.7 Determining Moments of Inertia

Example 10-12: Cylinder, solid or hollow.

- Following the procedure in this Example, show that the moment of inertia of a rod about its end is $I = \frac{1}{3}Ml^2$ (item (g) in Figure 10-20). Example 9-16 may also help you set this up as well.

Question 80. Consider the rod described in Example 9-16 part (b). Determine the moment of inertia for this rod about an axis perpendicular to the rod passing through its left end.

Question 81. Consider the rod described in Example 9-16 part (b). Determine the moment of inertia for this rod about an axis perpendicular to the rod passing through its right end.

Example 10-13: Parallel axis.

- See Exercise C.

Exercise C:

What do you think?

Question 82. Use the perpendicular-axis theorem to derive the moment of inertia in Figure 10-20(h).

Super Extra Challenge Problem 1. Show that the moment of inertia for a solid spherical ball of radius r_0 and mass M about an axis through its center is $I = \frac{2}{5}Mr_0^2$ (item (e) in Figure 10-20).

Super Extra Challenge Problem 2. Determine the moment of inertia of a hollow sphere with inner radius r_1, outer radius r_2, and mass M. Assume the axis of rotation is through the center of the sphere. Look at limiting cases to find the moment of inertia for a solid ball (Figure 10-20(e)) and the moment of inertia for a thin hollow sphere.

10.8 Rotational Kinetic Energy

Question 83. The equation for translational kinetic energy is $K = \frac{1}{2}mv^2$. What is the equation for rotational kinetic energy about a fixed axis?

Remark 10. I'm not entirely happy with the derivation of equation (10-21). I don't have any trouble with the result, $P = \tau\omega$. My trouble is that I don't know how to interpret the equation

$$P = \frac{dW}{dt}$$

that occurs at the beginning of (10-21). In order to make sense of that equation, W should be a function of t. Then we could take the derivative of W with respect to t in the usual way. If you have any ideas about how to make sense of this, please let me know.

Example 10-14: Flywheel.

- How could we get the flywheel described in this Example to store more energy? Think of at least two changes that could be made to the situation described that would allow the flywheel to store more energy.

Example 10-15: Rotating rod.

- Let us generalize this Example a bit, as we did with Example 10-11. Suppose a point mass m is attached to the tip of the rod of mass M. Determine the angular velocity of the rod when it reaches the vertical position, and the speed of the rod's tip at this moment. Find a general solution, then examine the limiting cases (i) $m \ll M$ and (ii) $m \gg M$.

Exercise D:

What do you think?

10.9 Rotational Plus Translational Motion; Rolling

Example 10-16: Sphere rolling down an incline.

- Repeat this Example for a solid cylinder of mass M and radius R_0.

Conceptual Example 10-17: Which is fastest?

- A solid sphere and a hollow sphere roll down a ramp without slipping. Which reaches the bottom first? Why?

Exercise E:

Chapter opening question, take two, with clickers.

Example 10-18: Analysis of a sphere on an incline using forces.

- Consider a solid cylinder instead of a sphere. What is the friction force?

Example 10-19: A falling yo-yo.

- See Exercise F.

Exercise F:

Find the acceleration.

Example 10-20: What if a rolling ball slips?

- Calculate the work done by friction, the ball's kinetic energy just after release, and the ball's kinetic energy when it is rolling without slipping. Is the work-energy principle satisfied?

Chapter 11

Angular Momentum; General Rotation

Question 84. Chapter opening question with clickers.

11.1 Angular Momentum—Objects Rotating About a Fixed Axis

Example 11-1: Object rotating on a string of changing length.

- First, find the initial angular velocity ω_1. If the radius decreases from 0.80 m to 0.40 m (gets cut in half), what happens to the angular velocity? What happens to the speed of the mass?

Example 11-2: Clutch.

- Part (c) of this Example is a rotational collision. Do you think this collision is elastic, inelastic, or completely inelastic?

Example 11-3: Neutron star.

- What would the rotation frequency be if the star had a mass 4.0 times that of the Sun?

Example 11-4: Running on a circular platform.

- What is the moment of inertia of the person? What is the angular velocity of the person running (with respect to the Earth)?

Conceptual Example 11-5: Spinning bicycle wheel.

- See Exercises A–C.

Exercise A:

What do you think?

Exercise B:

Chapter opening question, take two.

Exercise C:

What do you think? (Clickers)

11.2 Vector Cross Product; Torque as a Vector

Exercise D:

What do you think?

Example 11-6: Torque vector.

- See Exercise E.

Exercise E:

What do you think?

Question 85. Do Chapter 11, Problem 24.

11.3 Angular Momentum of a Particle

Conceptual Example 11-7: A particle's angular momentum.

- Suppose the circular motion in this example is parallel to the xy plane, with radius R, centered at the point $a\hat{\mathbf{k}}$, where a is a constant with dimensions of length. Using these coordinates, the position of the particle can be given as function of time.

  $$\vec{\mathbf{r}} = R\cos\omega t\hat{\mathbf{i}} + R\sin\omega t\hat{\mathbf{j}} + a\hat{\mathbf{k}}$$

  In this equation, $\omega = v/R$. By taking a time derivative, we can find the particle's velocity as a function of time.

  $$\vec{\mathbf{v}} = -R\omega\sin\omega t\hat{\mathbf{i}} + R\omega\cos\omega t\hat{\mathbf{j}}$$

  By multiplying by m, we can find the the particle's momentum as a function of time.

  $$\vec{\mathbf{p}} = -mR\omega\sin\omega t\hat{\mathbf{i}} + mR\omega\cos\omega t\hat{\mathbf{j}}$$

  After you get a general expression for angular momentum, set $a = 0$ to see if you recover the result from the Example.

11.4 Angular Momentum and Torque for a System of Particles; General Motion

Question 86. Giancoli writes in the third paragraph, "Hence the sum of all internal torques adds to zero". This is not obvious, and he has not shown it. Let us see if we can convince ourselves that the sum of the internal torques really does add to zero. Consider two particles in the system. They could be any two particles, but let's call them particle 1 and particle 2. We will denote the positions of these particles by $\vec{\mathbf{r}}_1$ and $\vec{\mathbf{r}}_2$. The internal force exerted on particle 1 by particle 2 is denoted $\vec{\mathbf{F}}_{12}$. The internal force exerted on particle 2 by particle 1 is denoted $\vec{\mathbf{F}}_{21}$. By Newton's third law, $\vec{\mathbf{F}}_{21} = -\vec{\mathbf{F}}_{12}$. The internal torque exerted on particle 1 by particle 2 is

$$\vec{\boldsymbol{\tau}}_{12} = \vec{\mathbf{r}}_1 \times \vec{\mathbf{F}}_{12}.$$

The internal torque exerted on particle 2 by particle 1 is

$$\vec{\boldsymbol{\tau}}_{21} = \vec{\mathbf{r}}_2 \times \vec{\mathbf{F}}_{21}.$$

We would like to show that the internal torques all cancel in pairs. In symbols, we want to show that $\vec{\boldsymbol{\tau}}_{12} + \vec{\boldsymbol{\tau}}_{21} = 0$.

$$\begin{aligned} \vec{\boldsymbol{\tau}}_{12} + \vec{\boldsymbol{\tau}}_{21} &= \vec{\mathbf{r}}_1 \times \vec{\mathbf{F}}_{12} + \vec{\mathbf{r}}_2 \times \vec{\mathbf{F}}_{21} \\ &= \vec{\mathbf{r}}_1 \times \vec{\mathbf{F}}_{12} - \vec{\mathbf{r}}_2 \times \vec{\mathbf{F}}_{12} \\ &= (\vec{\mathbf{r}}_1 - \vec{\mathbf{r}}_2) \times \vec{\mathbf{F}}_{12} \end{aligned}$$

Can you think of a reason that this should be zero? (Hint: Giancoli notes parenthetically that something stronger than Newton's third law holds here. In addition to $\vec{\mathbf{F}}_{12}$ and $\vec{\mathbf{F}}_{21}$ being equal and opposite, they act along the same line, namely the line that joins the two particles.)

Remark 11. I will not hold you responsible for the derivation presented in the starred subsection. It is interesting, and it's well written, so read it if you are interested. If you're struggling to get the main points, skip it. In any case, don't forget to read the short Summary subsection at the end.

11.5 Angular Momentum and Torque for a Rigid Object

Example 11-8: Atwood's machine.

- How large does the moment of inertia of the pulley need to be so that the acceleration of the masses is half what it would be for a massless pulley?

Conceptual Example 11-9: Bicycle wheel.

- What would happen if everything else was the same in this Example, but the wheel was spinning the other way? What is the direction of the angular momentum? What is the direction of the torque? What happens to the wheel?

Remark 12. Let's skip the starred subsection on Rotational Imbalance.

11.6 Conservation of Angular Momentum

Example 11-11: Kepler's second law derived.

- Where do we get the equation

$$dA = \frac{1}{2}(r)(v\,dt\sin\theta)$$

  from?

Example 11-12: Bullet strikes cylinder edge.

- Write an expression for the angular momentum of the system before the collision. Write an expression for the angular momentum of the system after the collision.

Appendix A

Mathematical Formulas

A.1 Quadratic Formula

You should memorize the quadratic formula. You will need it and it will not be on the equation sheet. If you are a hard-core non-memorizer, I can show you how to derive it by completing the square.

A.2 Binomial Expansion

I do not expect you to remember the formulas in this section.

A.3 Other Expansions

I do not expect you to remember the formulas in this section.

A.4 Exponents

I expect you to know these rules. I regard them as part of algebra.

A.5 Areas and Volumes

You should know the circumference and area of a circle. You should know the surface area and volume of a sphere. You should know the volume of a cylinder.

A.6 Plane Geometry

You should know this stuff.

A.7 Logarithms

I regard the ability to work with logarithms as part of algebra that you need to know and be able to apply.

A.8 Vectors

Section 3-3 covers scalar multiplication. Section 7-2 covers the dot product. Section 11-2 covers the cross product. These topics are on the syllabus. It's fine if you don't know about them yet.

A.9 Trigonometric Functions and Identities

You need to know the definitions of the trigonometric functions. You need to be aware that there are a bunch of trigonometric identities out there, including the ones in this section, that can be used to simplify expressions. You should remember the following identity.

$$\sin^2\theta + \cos^2\theta = 1$$

It is really a restatement of the Pythagorean theorem. (Can you see why?)

Appendix B

Derivatives and Integrals

Calculus I is a co-requisite for this course. Some of you will will be taking calculus simultaneously with this course. Others will have already completed calculus. I have also given permission for some people to take this course who are not yet taking calculus. Furthermore, for the people who are taking calculus simultaneously with this course, the time at which we need to use topics from calculus does not always align well with the time at which those topics are taught in the calculus course.

Motivated by this situation of people with a range of experience with calculus, I will attempt to introduce the parts of calculus we need most in a gentle way.

We will need to learn what *derivatives* and *integrals* are and how to calculate them. Appendix B does not teach calculus. It is merely a two-page table of derivatives and integrals. Derivatives will appear in the textbook for the first time in Section 2-3 on Instantaneous Velocity. The definition of a derivative, in the context of velocity, is given in Section 2-3. Integrals first appear in the textbook in Section 7-3, Work Done by a Varying Force. (They also appear in the starred Section 2-8, which we are going to skip.)

It would not hurt for you to learn how to calculate derivatives and integrals before we get to those sections.

B.1 Derivatives: General Rules

The rules in this section are ones that people internalize as they get more and more practice calculating derivatives. For example, the third rule says that the derivative of a sum is the sum of the derivatives. Once you calculate a bunch of derivatives, you will apply this rule automatically. You won't have any need to look it up.

If you already know calculus, you already know these rules. If you are learning calculus (which is everyone that does not already know calculus, whether you are enrolled in a calculus course or not), these rules are not the place to start. It's better to start with examples.

Consequently, glance quickly at these rules and move on.

B.2 Derivatives: Particular Functions

I will put these rules on the equation sheet that I supply with exams.

Check out this web page:

`http://web.mit.edu/wwmath/calculus/differentiation/polynomials.html`

- If you already know calculus, skip to the Exercises at the bottom of the page and do them. Feel free to read anything else on the page that is helpful. Then find someone in the class who is learning calculus and see if you can be of service to them.

- If you are learning calculus (which is everybody else), read the whole page (it's not very long). Pay particular attention to the examples, and don't get hung up on the theory. When you are ready, do the Exercises at the bottom of the page. At the top of the page, there is a link to "Definition of differentiation" which you can check out if you want to. If you get lost or stuck, find someone in the class that already knows calculus and see if they can help you.

B.3 Indefinite Integrals: General Rules

These general rules are again rules that you will internalize as you learn calculus. Look at them quickly and move on.

B.4 Indefinite Integrals: Particular Functions

I will put some of these rules on the equation sheet that I supply with exams. No need to memorize these.

B.5 A Few Definite Integrals

I will put these rules on the equation sheet if we need them. No need to memorize these.

Appendix C

More on Dimensional Analysis

This is a cool appendix that builds on Section 1-7, and includes some "secret tricks" that make people look like physics wizards. It's not an official part of our reading list, but it's cool.