Lab Solutions Table of Contents

Ballistic pendulum Lab Solution

Question 1

Momentum is conserved during the collision. There are no external horizontal forces acting on the system during the collision. There are vertical forces (string tension and gravity) but they nearly cancel out, and they act over a very short time.

Kinetic energy is never conserved in totally inelastic collisions where objects collide and stick together.

Other Questions

From the final height, solve the second equation for the velocity of the pendulum plus ball immediately after the collision.

$$V = \sqrt{2gh}$$

Solve for the initial velocity of the fast-moving ball.

$$v = \frac{m+M}{m}V = \frac{m+M}{m}\sqrt{2gh}$$

As discussed above, kinetic energy is NOT conserved, and consequently, mechanical energy is not conserved throughout the experiment.

There could be some friction in the pendulum support, which results in a loss of mechanical energy. Air resistance also could rob the system of mechanical energy. Some mechanical energy is also dissipated in the form of sound and heat.

Ballistics cart Lab Solution

Question 1: The ball will land back in the cart.

Question 2: The ball will land back in the constant velocity cart over a range of initial conditions.

Question 3: Horizontal and vertical motion are independent, and the ball and cart start and end with the same horizontal component of velocity, so the ball lands back in the cart.

Question 4: The ballistic cart might not fire straight up relative to itself. Or friction in the wheels might slow down the cart, or air resistance might affect the horizontal movement of the ball and cart differently.

Question 5: The ballistic cart might not fire straight up relative to itself, so the initial horizontal velocities may differ. Or friction in the wheels might slow down the cart, or air resistance might affect the horizontal movement of the ball and cart differently, so later horizontal velocities may differ.

Question 6: The ball will land behind the cart because the cart accelerates horizontally, whereas the ball does not.

Question 7: The ball will land inside the cart because both the ball and cart have the same acceleration parallel to the surface of the inclined planeCathode ray tube Lab Solution
Question 1: The horseshoe magnet will change the path of the electrons. Magnetic fields exert force on charged particles.

Seen from the observer's perspective, assume the electron beam goes from left to right. If a horseshoe magnet is positioned so that the north magnetic pole is placed closer to the observer and the south magnetic pole is on the far side of the tube, then the electron beam will bend DOWN toward the earth.

Explanation: Velocity is left to right. Magnetic field emerges from the north pole, so it points away from the observer. The vector v cross B points up by the right hand rule, but the magnetic force on the electron, qv cross B, points DOWN because the charge is negative.

Collision Apparatus Lab Solution

Experiment 1: Elastic Collision of Objects—Equal Mass

Question

When two carts of equal mass collide head-on and rebound on spring bumpers, how does the momentum of each cart before the collision compare with the momentum of each cart after the collision? How about the kinetic energy?

If the two speeds are equal, then the two momentums are equal and opposite, the momentum is zero, and the 2 carts will collide and rebound back the way they came, with the exact same speed. The net momentum afterward should be the same as it was before the collision.

If the two speeds are unequal, then each cart will change direction, and they will exchange speeds, so that the cart that came in at a slower speed will rebound at a higher speed, and the originally faster cart will rebound at a lower speed. The net momentum afterward should be the same as it was before the collision.

If the spring bumpers allowed for a perfectly elastic collision, then the kinetic energy before and after would be exactly the same.

Experiment 2: Elastic Collision of Objects—Unequal Mass

Question

When two carts of unequal mass collide and rebound on spring bumpers, how does the momentum of each cart before the collision compare with the momentum of each cart after the collision? How about the kinetic energy?

If the two initial speeds are equal, then the two carts will collide and rebound back the way they came. The more massive cart will rebound at a slower speed than it came in with, and the less massive cart will rebound at a higher speed than it came in with. The net momentum afterward should be the same as it was before the collision.

If the spring bumpers allowed for a perfectly elastic collision, then the kinetic energy before and after would be exactly the same.

Experiment 3: Inelastic Collision of Objects—Unequal Mass

Question

When two carts of unequal mass collide head-on and stick together, how does the momentum of each cart before the collision compare with the momentum of each cart after the collision? How about the kinetic energy?

The two carts stick and move together in such a way that the momentum of the system is the same. There must be less kinetic energy after the collision; anytime objects stick together after a collision ("totally inelastic collision"), KE is lost.

DC Circuits Lab Solution

Exercise 1: Design, Build, and Analyze a Series Circuit

Does the same amount of current flow through components connected in series?
yes

Or is it a function of the resistance of the component?
No, it is always the same current regardless of component resistance.

Is the potential difference measured across each of the components going to be the same when they are connected in series? Or is it a function of the resistance of the component?
Not in general. However, if the series components all have the same resistance, then since the current is the same, the potential difference measured across each of them will be the same.

Is the power consumption the same for each of the components connected in series? Or is it a function of the resistance of the component?

Not in general. However, if the series components all have the same resistance, then since the current is the same, the power consumed by each of them will be the same.

How does the total power consumed by all the components compare to the total power supplied by the battery?
By conservation of energy, the total power consumed by the components equals the total power supplied by the battery.

How is the resistance of each of the components related to the overall, equivalent resistance of the series combination? Explain.
The overall series resistance is equal to the sum of the individual resistances. Please consult the textbook for a derivation of this result.

In every experiment there are potential sources of error and/or instances of a lack of accuracy and precision. Explain what sources of error or lack of accuracy and precision might be in this lab.
The multimeters have limited precision and accuracy, and round-off errors accumulate. The wires and switches do not have zero resistance, so they dissipate some power.

Exercise 2: Design, Build, and Analyze a Parallel Circuit

Does the same amount of current flow through components connected in parallel? Or is it a function of the resistance of the component?
Not in general. However, if the parallel components all have the same resistance, then since the voltage across each of them is the same, the current flow through each of them will be the same.

Is the potential difference measured across each of the components going to be the same when they are connected in parallel?
Yes, always.
Or is it a function of the resistance of the component?
No, it is always the same voltage regardless of component resistance.

Is the power consumption the same for each of the components connected in parallel? Or is it a function of the resistance of the component?
Not in general. However, if the parallel components all have the same resistance, then since the voltage across each of them is the same, the power consumed by each of them will be the same.

How does the total power consumed by all the components compare to the total power supplied by the battery?
By conservation of energy, the total power consumed by the components equals the total power supplied by the battery.

How is the resistance of each of the components related to the overall, equivalent resistance of the parallel combination? Explain.

The reciprocal of the overall series resistance is equal to the sum of reciprocals of the individual resistances. Please consult the textbook for a derivation of this result.

Discharge tube Lab Solution

Question 1: The spectrum will consist of discrete, separated narrow emission lines.

Question 2:

Here are some of the expected lines for hydrogen, in units of angstroms:

3835
3889
3970
4102
4340
4861
6563

Question 3: Yes, the spectrum depends on the gas. The lines are a result of the quantized nature of the energy levels of the electrons. Different elements have electron energy levels at different places, so the spectrum depends on that. The eye perceives different energies of photons as different colors.

Dynamics apparatus Lab Solution

Question

If different amounts of force are applied to an object of constant mass, will the acceleration be affected?

A larger force will result in a larger acceleration when the mass is held constant.

Question

Why should the graph of velocity vs. time be a straight line? What is the interpretation of the slope?

The acceleration of the cart is constant, and with the assumption of constant acceleration, a graph of velocity is a straight line. The slope is the rate at which the cart's velocity is changing, or its acceleration.

Electrostatics Lab Solution

1. The glass rod and the rubber rod have opposite charges and will attract each other.

2. The glass rods have the same charge and will repel each other. The same comment applies to the two charged rubber rods.

3. When a charged glass rod is placed near the electroscope's ball, the leaves will separate. As the rod moves closer, the leaves will separate more, and as the rod moves farther away, the leaves will move closer together.

4. The same effect will be noted with a rubber rod. The magnitude of the charges depends on the intensity and duration with which the glass and rubber rods were rubbed, so no general statement can be made.

5. An extremely charged rod will have a larger effect on the leaves at the same distance from the electroscope's ball, compared to one that is moderately charged.

6. A magnet will have no effect on a gold-leaf electroscope.

Friction Block Lab Solution

Experiment 1
For contact between wood and the table surface, would you expect K to be approximately independent of the normal force and the speed?
Yes.

Experiment 2
Would you expect K to be approximately independent of contact area?
Yes.

Experiment 3
For contact between felt and the table surface, would you expect K to be larger or smaller than between wood and the table surface?
We expect it to be larger, as it feels "rougher."

Experiment 4
You can use a friction block on an inclined plane to calculate the coefficient of static friction between two materials. As the plane is inclined more and more from the horizontal, at some point the block just begins to slide. At that moment, what is the relationship between the static friction coefficient and the angle of inclination of the plane from the horizontal?
The tangent of the angle of inclination of the plane is the coefficient of static friction.

Lenses Lab Solution

1. As the object distance approaches infinity, the value of $1/d_o$ approaches zero.

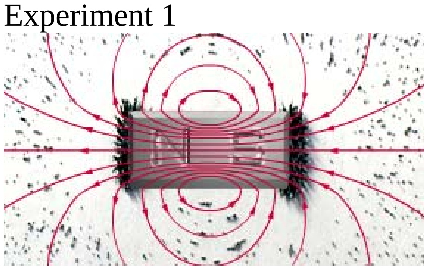
2. The image is real because it is being projected onto a screen. Also, the image distance is a positive number.

3. Some sources of error in the lens experiment include the fact that no lens can bring all colors to a focus at the same point, so the image distance is ill-defined. Also, different students may disagree on exactly when an image is in sharp focus, leading to uncertainty in the measurement of image distance. Finally, due to the finite thickness of the object, the object distance is also not sharply defined.

4. Students may obtain slightly different values for the magnification depending on whether they used the heights or the distances. Sources of error include the ones mentioned above, plus the uncertainty in the length measurements. Since the object and image heights are generally smaller than the object and image distances, any uncertainty in the height measurement is a greater percentage of the "actual" value than it would be for the distance measurements, and this may result in greater uncertainty.

Magnetic Fields Lab Solution

Experiment 1

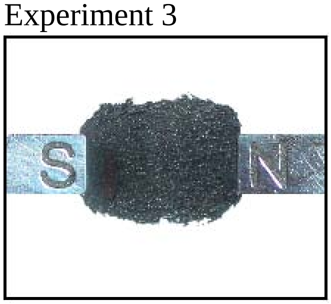


Experiment 2

Can you tell what direction the magnet is facing from the pattern of the filings?

No, the pattern appears identical no matter which way the magnet is facing.

Experiment 3



If you see this pattern and know what one of the poles of one magnet is, can you determine what the orientation of the other magnet is? No, the pattern is symmetric.

Experiment 4

If you see this pattern and know what one of the poles of one magnet is, can you determine what the orientation of the other magnet is? Yes, this pattern is created by two identical magnetic poles.

Experiment 5

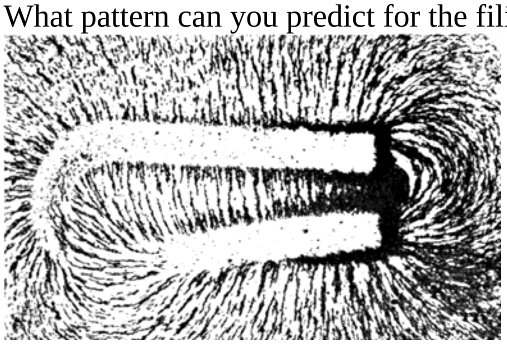
The pattern with two north poles near each other will be the same as the one with two south poles near each other.

Experiment 6

Place two bar magnets on the table next to and parallel to each other, with the north pole of one magnet next to the north pole of the other. You may have to tape the magnets together, as they will tend to repel each other.
What pattern do you predict for the filings?
The pattern will be similar to that for a single bar magnet, only the field will be stronger everywhere.

Experiment 7

What pattern can you predict for the filings?



http://commons.wikimedia.org/wiki/File:Magnetic_field_of_horseshoe_magnet.png

Experiment 8

Place a magnetic compass on the table, far from any other magnets. Tap it gently so that the needle is free to reach equilibrium. Which way does the needle point?
The needle points roughly toward geographic north. Magnetic declination is the angle between magnetic north (the direction the compass needle points) and true north.
Now bring the south pole of a bar magnet near the compass and move it around. Write down your observations about the behavior of the compass needle.

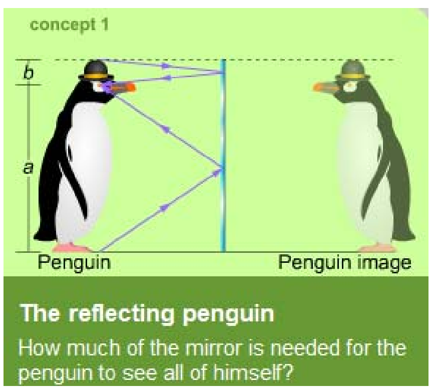
The needle points toward the south pole of the bar magnet.
Based on your previous observation, predict what kind of magnetic pole (N or S) is found near the Earth's geographic north pole.
The geographic north pole is associated with a magnetic south pole.

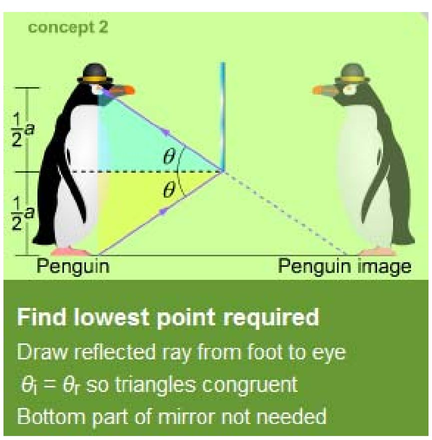
Mirrors Lab Solution

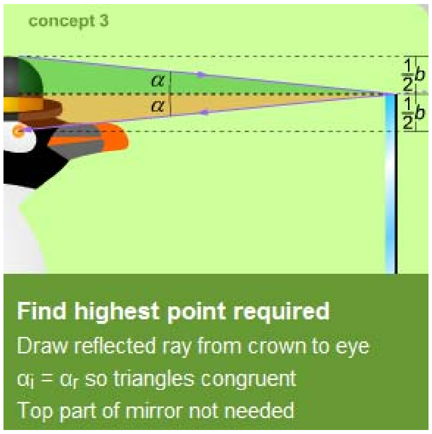
Plane Mirrors

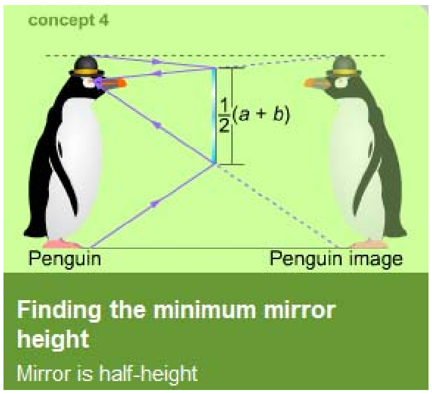
1. When you stand in front of a plane mirror, the image is the same distance from the mirror that you are, but it is "behind" the mirror. In other words, the image is twice as far away from you as the mirror is. This is a virtual image because if a screen were to be placed behind the mirror, no image would be projected onto the screen (there are no converging light rays at that location).

2. The distance between the two pieces of masking tape should be half of your total height, and that is how tall a mirror needs to be so that you can see your entire body. Here are some ray diagrams explaining it.









Motion Sensor Lab Solution

Experiment 1: A toy moving at constant velocity

If a small wind-up toy moves at constant velocity, what will its position vs. time graph look like? What about its velocity vs. time graph? What about its acceleration vs. time graph?

Its position vs. time graph looks like a straight line, going either upward (positive velocity) or downward (negative velocity).

Its velocity vs. time graph will be a straight horizontal line either at a positive value (positive velocity) or a negative value (negative velocity).

Its acceleration vs. time graph will be a straight horizontal line at a = 0.

Experiment 2: A toy moving with constant acceleration

If a small toy car moves with constant acceleration, what will its position vs. time graph look like? What about its velocity vs. time graph? What about its acceleration vs. time graph?

Its position vs. time graph looks like a parabola, either opening upward (positive acceleration) or downward (negative acceleration).

Its velocity vs. time graph will be a straight line, going either upward (positive acceleration) or downward (negative acceleration).

Its acceleration vs. time graph will be a straight horizontal line either at a positive value (positive acceleration) or a negative value (negative acceleration).

If the plane is inclined at an angle of θ off the horizontal, what is the expected acceleration of the toy car down the plane? Assume that it moves just like a frictionless object sliding down the inclined plane.

The expected acceleration down the plane will be $a = g \sin \theta$, where g is the acceleration due to gravity. This value of "a" will be the slope of the velocity vs. time graph, and twice the coefficient of "t squared" in the parabolic fit to the position vs. time data.

Observing Thermal Energy Transfer Lab Solution

Observing the Transfer of Thermal Energy

Question

Which methods of thermal energy transfer can be observed in solids, liquids, and gases?

Thermal energy is transferred by conduction, convection, or radiation.

Sunlit window: dominant mode is radiation, with some convection (air currents flowing above it) and some conduction (from hotter surface below).

Fan: dominant mode is convection, with some conduction and radiation.

Putting objects in warm water: dominant mode is conduction, with some convection and radiation.

Putting objects in microwave: dominant mode is radiation, with some convection and conduction.

Pendulum Lab Solution

Question
Re-arrange the equation to show that the square of the period is proportional to the length of the pendulum. What is the constant of proportionality?
$4\pi^2/g$

Question
Does the period depend on the mass?
No

Question
Design an experiment to prove your hypothesis.
Change the mass and try it, making sure that you measure L correctly.

Uncertainty in measured data
For a single value of L, have one lab partner measure T with a stopwatch, for one back and forth swing of the pendulum. Then have the other lab partners do the same thing. Is there a relatively large “spread” in the results? To quantify the “spread”, calculate the standard deviation of the different measurements. Record your results below.
There will be a relatively larger standard deviation of the results.

Identify the causes of the uncertainty in your measured data. What are some reasons that the lab partners got different results? Didn’t you all measure the same thing?
Human reaction time is the main cause of the uncertainty, as well as the fact that the stopwatches might not be identically calibrated.

Identify the effects of the uncertainty in your measured data. If you use the lowest value of T in the equation that relates T, L, and g, what value of g do you obtain? What happens if you use the highest value of T that your group measured?
You will obtain a large and a small value of g, respectively.

Quantify the causes of the uncertainty in your measured data. How confident are you in the result of the experiment of measuring the time for one back and forth swing? Are you sure that your result is accurate to within, say, 1 second? How about 0.5 seconds? (Hint: you may want to do some experiments regarding human reaction time.)
Human reaction time is on the order of tenths of seconds.

For the same value of L, now have one lab partner measure T with a stopwatch, for 10 back and forth swings of the pendulum (and then dividing the total time by 10). Then have the other lab partners do the same thing. Is there a smaller “spread” in the results? To quantify the “spread”, calculate the standard deviation of the different measurements.
There is a smaller spread (by roughly a factor of 3).

Now that you each have measured T using 10 complete swings, if you use the lowest value of T in the equation that relates T, L, and g, what value of g do you obtain? What happens if you use the highest value of T that your group measured? Record your results below, and comment on the advantages and disadvantages of making measurements of 10 periods vs. making just one. The experiment takes longer overall if you measure 10 periods, but the increased accuracy is worth it!

Can you design a new experiment to measure T that can eliminate or reduce some of the uncertainties that you have encountered?
Use a photogate that will tell you the time between interruptions of the light beam, for a more precise and accurate experiment.

Polarized light Lab Solution

Experiment 1:

If you place a linear polarizer in front of unpolarized light, it is half as intense on the other side. What do you think will happen to the brightness if the linear polarizer is rotated? Will the intensity change?

No, the intensity will stay the same. There is no preferred direction for the transmission axis; all directions that are perpendicular to the direction of wave travel will give the same result.

Experiment 2:

If initially unpolarized light passes through one polarizer, and then a second one whose transmission axis is *parallel* to that of the first one, what will be the final intensity of the light?

Half as much as it was initially. If you place a linear polarizer in front of unpolarized light, it is half as intense on the other side. The second polarizer does nothing because it is aligned with the first. It is analogous to passing a rope through 2 consecutive picket fences whose pickets are aligned. The second fence does nothing to reduce the energy transmitted along the rope.

If initially unpolarized light passes through one polarizer, and then a second one whose transmission axis is *perpendicular* to that of the first one, what will be the final intensity of the light?

The final intensity will be zero. It is analogous to passing a rope through 2 consecutive picket fences where the transmission axis of the first is vertical, but that of the second is horizontal. All transverse motion in the rope will be eliminated.

Prism Lab Solution

Question

When white light hits a prism, the different wavelengths are refracted at different angles, resulting in a rainbow of colors. Look at how the colors of light are ordered on the other side of the prism. Do you think that blue light is bent ("refracted") more when it enters the glass from air, or do you think that red light is bent more? If light of a certain color bends more, then glass has a relatively large index of refraction for that color.

The index of refraction for glass is generally greater for waves of shorter wavelength, so indigo and violet light will refract more than red or orange light will refract.

Question

If you place a prism in front of pure red light, what do you think will happen on the other side? Will the intensity change? Will the color change?

This experiment proves that the prism was not coloring the light. The second collimating slit only lets one color go through. If it was the prism that was coloring the light, the red light should come out a different color, but it passes through unchanged by the second prism.

Question

If white light hits a prism and is spread into its component colors, and then you place a second prism "upside down" behind the first prism, what will happen?

Sir Isaac Newton famously used a pair of prisms to separate white sunlight into colors, and to recombine the colors into white light again. That is what you will observe too!

Radiation monitor Lab Solution

Experiment 1: Geiger Plateau
The details of the graph will depend on the construction of your GM tube, and you should check the owner's manual. 750 volts is typical for a GM tube about the size of the inner cardboard tube in a roll of toilet paper.

Experiment 2: Background Radiation
The background count will vary depending on your altitude and environment.

Experiment 3: Measuring Shelf Ratios

The shelf ratios will vary depending on the construction of your GM tube and tube stand. Because the source is often fairly close to the admittance window of the GM tube, the inverse square law will not be strictly followed.

If you have time, measure the shelf ratios for another radioactive source. Did it depend upon the identity of the sample used?
Variations in shelf ratios can occur between samples because, for example, alpha and beta radiation are absorbed by air.

Experiment 4: Absorption of Beta Particles

Plot corrected activity (cpm) on semilog graph paper vs. absorber thickness (in mass thickness units, i.e., mass per unit area). You will get roughly a straight line.

Ripple and wave generator Lab Solution

Ripple tanks and wave generator

Experiment 1:
For a fixed water depth, the product of frequency and wavelength is a constant, the wave speed.

Experiment 2:
When the water wave reflects, the angle of incidence equals the angle of reflection.

Experiment 3:
How is the angle at which the waves spread out related to the width of the single slit (i.e., the distance between the barriers)? The narrower the slit is, the greater the spread of the wave after it passes through the slit (i.e., the spreading angle is larger).

How is the angle at which the waves spread out related to the wavelength (i.e., the distance between the wave fronts)? The longer the wavelength, the greater the spread of the wave after it passes through the slit (i.e., the spreading angle is larger).
How is the angle at which the waves spread out related to the frequency? The lower the frequency, the greater the spread of the wave after it passes through the slit (i.e., the spreading angle is larger).

Experiment 4:
How is the angle at which the waves spread out related to the distance between the slits? The smaller the distance between the 2 slits, the greater the spread of the wave after it passes through the slits (i.e., the spreading angle is larger).

When the frequency increases (and wavelength decreases), what happens to way in which the waves spread out after passing through the slits? As the wave frequency increases, the spread of the wave after it passes through the slits decreases (i.e., the spreading angle is smaller).

Sound Lab Solution

The speed of sound is approximately 343 m/s. It varies by temperature. A thermometer may be handy to have.

Students should multiply the wavelength they observe by the frequency shown on the tuning fork. They must use meters for wavelength for the answer to come out in m/s.

An acoustic wave will constructively interfere with a closed air column at specific fractions of its wavelength, namely at 1/4, 3/4, and 5/4, etc. of its wavelength. When the air column's length equals these fractions of the sound's wavelength, the sound produced by a tuning fork held above such an air column will become louder.

Consequently, the wavelength is four times the length of the air column for the first harmonic, 4/3 the length of the air column for the second harmonic, or 4/5 the length of the air column for the third harmonic. (We are using the reciprocals of 1/4, 3/4, and 5/4, respectively).

Question 1: The product of frequency and wavelength for a sound wave is expected to be constant, since it equals the wave speed.

Question 2: What might be some sources of error in the lab (comparing your measured speed of sound to the standard value for the speed of sound, as reported in the textbook)?
One specific source of error is that the speed of sound varies with temperature and altitude. Of course, there are the usual experimental uncertainties in measuring the length of the air column and determining exactly when the sound produced by the tuning fork is loudest.

Trajectory apparatus Lab Solution

Question

What is the acceleration a, when considering the horizontal motion? What about vertical motion?

The acceleration in the horizontal direction should be zero (neglecting air resistance). In the vertical, it should have a magnitude of g, 9.8 m/s^2, and be directed downward.

Question

Make a graph of x versus t and do a straight line fit. Why should this be a straight line? What is the interpretation of the slope?

The acceleration in the horizontal direction is zero (neglecting air resistance), so the velocity is constant and the ball covers equal horizontal steps in equal time intervals. That is a straight line on a graph of position vs. time.

Question

Make a plot of v_y vs. t and do a straight line fit. Why should this be a straight line? What is the interpretation of the slope? Can you check the slope of your line and find the percentage deviation from a “true value”?

The acceleration in the vertical direction should have a magnitude of g, 9.8 m/s^2, and be directed downward. With the assumption of constant acceleration, a graph of velocity is a straight line. The slope is the rate at which the velocity is changing, or the acceleration. Therefore, the magnitude of the slope should be equal to g.

Wave essentials Lab Solution

Question 1: The two types of waves are longitudinal (shake the end of the slinky toward and away from your partner at the other end) and transverse (shake up and down or left and right).

Question 2: Power is proportional to the square of the frequency. Students cannot determine this mathematically in this lab, but they should get the sense that power increases significantly with the frequency.

Question 3: Amplitude and frequency are not related.

Question 4: Wave speed is the product of frequency and wavelength. For a wave of a given speed, as frequency increases, wavelength must decrease. Students may also see frequency increasing as wavelength stays constant or increases—in these cases, they should note that wave speed increases.

Question 5: When waves interfere, they can interfere destructively (peak meets trough) or constructively (peak meets peak, or trough meets trough). Since two students shaking the rope should impart more energy than just one, there will be constructive interference on the waves at points. Students should note destructive interference as well.