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Real-World Motion: Analyzing Physics and Physiology with Vernier Video Analysis®

Experiments

Projectile Motion

Introduction to Weight Lifting

Workshop Presenter

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SCIENCE EDUCATION

Projectile Motion

Introduction

Up to this point it is likely that you have examined the motion of an object in one dimension only—either falling vertically under the influence of Earth's gravity or on a horizontal or inclined surface.

In this experiment, you will examine the behavior of a projectile—an object moving in space due to some initial launching force. Such an object can undergo motion in two dimensions simultaneously. Using the Vernier Video Analysis app, you will compare features of the position *vs*. time and velocity *vs*. time graphs with those of one-dimensional motion.

Objectives

In this experiment, you will

- Use video analysis techniques to obtain position, velocity, and time data for a projectile.
- Analyze the position *vs*. time and velocity *vs*. time graphs for both the horizontal and vertical components of the projectile's motion.
- Create and analyze your own video of an object undergoing projectile motion.

Materials

Vernier Video Analysis app in a web browser on a computer, Chromebook, **or** mobile device
camera capable of recording digital video (e.g., the camera on a phone or tablet)
tripod or other equipment to support the device used to record the video
meter stick or some other object to provide scale
projectile: a brightly-colored ball works well
video editing software (optional)

Pre-Lab Investigation

Your instructor will launch a projectile. Observe its motion carefully, then discuss its position *vs*. time and velocity *vs*. time behavior. Sketch a graph of the projectile's horizontal velocity *vs*. time, and sketch another graph of vertical velocity *vs*. time. Share your sketched graphs with your group or with the class.

Investigation

Part 1 Analysis of an existing video

1. Launch Vernier Video Analysis. Import the movie "Basketball Shot." Play the movie once so you can be familiar with the motion.

2. Add sufficient points to the basketball shot to show the basketball's motion graphically.

3. Apply a scale to the video and decide where to put the origin of the axes.

4. Adjust your graph to display only the *x* position data.

5. Do Part 1 of the Analysis, and then return to continue with Part 2 of the investigation.

Part 2 Production and analysis of your own video

For this part, you need a device capable of recording video such as a digital camera or smartphone; it can be the same device you used in Part 1 for Vernier Video Analysis. Keep the following tips in mind when you shoot your video.

- It is best to have a plain background that provides sufficient contrast with the object you are investigating. Good lighting is essential; recording outside on a cloudy day will provide better light than recording inside.
- Set up the device on a tripod so that it is pointed squarely at the background, and so that the plane of motion is perpendicular to the view.
- Position the camera as far from the plane of motion as is practical in order to reduce problems with scaling and parallax. Use the zoom feature to fill the screen with the motion.
- The object used for scaling must be in the same plane as the motion of the projectile (see Figure 1).

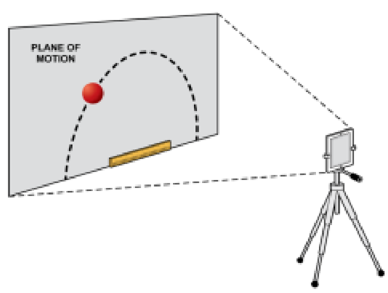

Figure 1

- Once you have captured your video, transfer the video to the device you will use for the analysis, if necessary. Optional: If you have captured more video than you need, trim the video to contain just the motion you plan to analyze.

6. Capture video of your object undergoing projectile motion, and import your movie into Vernier Video Analysis.

7. Add sufficient points to the basketball shot to show the projectile's motion graphically. Then, apply a scale to the video and decide where to put the origin of the axes.

8. Adjust your graph to display only the *x* position data, and complete the analysis.

Analysis

Part 1 Analysis of an existing video

1. Examine the graph of *x* position *vs*. time. If it appears to be linear, fit a straight line to your data. If the slope of the graph appears to change abruptly, select each segment, one at a time, and fit separate straight lines to each portion of the graph that appears to be linear.

   a. Click-and-drag or touch-and-drag across the graph to select the portion of the graph that appears linear.

   b. Click or tap Graph Tools, choose Apply Curve Fit, and apply a linear curve fit.

   c. Repeat Steps a and b for additional linear regions of the graph, if desired.

2. Write the equation that describes the *x* position *vs*. time behavior of the ball in each segment; be sure to include units.

3. Based on what you have learned in previous experiments, write a description of the horizontal component of the motion of the projectile. Note when any change in the horizontal component of the motion occurs.

4. Now, examine the graph of *y* position (Y) *vs*. time.

   a. Click or tap the vertical axis label to open the Plot Manager. Turn on the *y* position and turn off *x* position.

   b. Fit an appropriate curve to this graph (or to each portion of the graph). To do this, click or tap Graph Tools, choose Apply Curve Fit. Select the curve fit model that best fits your data, and apply the curve fit.

   c. Write the equation that describes the *y* position *vs*. time behavior of the ball in the first segment; be sure to include units.

5. Based on what you have learned in previous experiments, write a description of the vertical component of the position of the projectile.

6. Now, to test your analysis in Step 5, examine the graph of *y* velocity *vs*. time.

   a. Click or tap the vertical axis label to open the Plot Manager. Turn on *y* velocity (Y Velocity) and turn off *y* position.

   b. Click-and-drag or touch-and-drag across the graph to select the portion of the graph that appears linear.

   c. Click or tap Graph Tools, choose Apply Curve Fit, and apply a linear curve fit. Fit a straight line to the first portion of the graph only, if there are multiple linear regions.

   d. Repeat Steps b and c for additional regions of the graph, if desired.

7. What can you say about the rate of change of the *y* velocity as a function of time? How does the value of the slope of the linear fit compare to the acceleration of a freely falling object? Summarize in a sentence or two.

8. Compare the a and b parameters (including values and units) of the curve fits you performed in Step 4 to the slope and intercept of the linear fit you performed in Step 6.

9. Explain the differences in the horizontal and vertical components of the velocity of the projectile in terms of the force(s) acting on the projectile after it was launched.

10. Display the velocity vectors for the motion of the projectile, and then explain how the vectors correspond to the motion of the projectile in the vertical and horizontal directions. To display the velocity vectors, follow these steps:

    a. Use View, ⊞, to display the video if it is hidden.

    b. Click or tap Vectors, ↗, to add a vector display. (Click or tap Add, +, if the Vectors option is not visible.)

    c. Enable the velocity vectors only. To do this, click or tap the visibility toggle next to Velocity until Components, ⮡, is displayed.

    d. Adjust the Scale Factor and Vector Frequency so you can clearly see the vectors.

    e. Explain how the displayed vectors correspond to the motion of the projectile in the vertical and horizontal directions that you have also described with graphs and equations.

Part 2 Production and analysis of your own video

11. Perform the analysis of your movie as you did with the video provided to you in Part 1.

Extensions

1. Suppose that, in the shooting of your video, you placed the meter stick used for scaling against the wall you used for your background. However, the plane of the ball's motion was 0.50 m in front of the wall. The distance between the camera and the wall was 5.0 m. Would this error result in a value for the acceleration of gravity in your analysis of the *y* velocity *vs*. time graph that was smaller or larger than the accepted value? By what factor would this value differ from the expected value? Explain using a diagram.

2. Repeat the production and video analysis of a projectile, but this time use an extended body (i.e., an object that cannot be readily modeled by a point-particle). Consider carefully how best to mark the position of such an object during its motion. Interpret your position *vs*. time and velocity *vs*. time graphs as you did for Part 1.

3. Using either the analysis of the basketball shot sample video or the analysis of the video you created, model the vertical motion based on ideal conditions. Create a new calculated column and use the initial upward velocity of the object and the acceleration of gravity to calculate the ideal vertical velocity. Use the graph to compare the video-based velocities with the model-based velocities. Suggest reasons for any discrepancies.

   Note: Instructions for creating a calculated column are found in the Vernier Video Analysis User Manual, **http://www2.vernier.com/manuals/video-analysis-manual.pdf**

Introduction to Weight Lifting

Introduction

Strength training is a complex physiological process, but the basic result is that weight lifting causes the muscles to change and grow over time making the subject stronger. In weight lifting, the subject moves a known weight against gravity. One of the simplest forms of weight lifting involves using a bar loaded with weights. The loaded bar is moved through a range of motion that works the chosen muscle group. For example, during a squat, the bar rests on the subject's shoulders. The subject lowers into a squatting position and then straightens the legs so they are standing again. One full phase of motion is called a repetition (rep). Without resting, the subject repeats the motion a certain number of times to complete a set. A standard weight training routine might consist of 3 sets of 8–10 reps of a given lift or exercise.

Different weight lifting programs are used to build different types of muscle. Weight lifting that focuses on using lighter weights with lots of sets and repetitions tends to build lean muscle that is resistant to fatigue. Weight lifting that focuses on lifting heavy loads with fewer repetitions tends to build explosive and powerful muscles. Athletes will use different weight lifting programs that are designed for the sport or activity in which they engage.

One of the most common lifts is the bench press, which exercises the muscles of the chest and arms. The bench press resembles an inverted push up. The subject lies supine (flat on their back) on a weight bench, with the arms outstretched (fully extended) and the hands oriented so that the palms face the feet. A bar with a set of weights is placed into the subject's hands; the bar is grasped with the hands and is then lowered in a controlled fashion to the chest and then pushed back up until the arms are again fully extended. Using the weight of the loaded bar and the vertical motion data associated with the rising phase of the lift, you can determine several factors that are important for weight training, including the lift force, work, and power required for the lift.

In this experiment, you will use the Vernier Video Analysis app to examine the motion of a single test subject performing a bench press under two conditions. First, you will analyze a slow bench press, where the subject makes a conscious effort to move the weight at a constant speed through the lift. Next, you will analyze a rapid bench press, where the subject pushes the bar up as fast as they can. Using the analysis features in the app, you will compare the vertical displacement, duration, and velocity of the bar during the rising phase of each lift. You will use this information to calculate the lifting force, work, and power generated during the rising phase of each lift. As time permits (or as required by your instructor), you can complete one or more of the extensions or design your own investigation using videos of lifts that you record.

Objectives

In this experiment, you will

- Use video analysis techniques to obtain position, velocity, and time data for a human subject performing the bench press.
- Analyze the position and velocity *vs*. time graphs for the vertical motion of the bar as it is raised during the slow and fast press.
- Calculate the net force and lift force for the rising phase of the lift.
- Calculate work and power for the rising phase of the lift.
- [Extensions] Create and analyze your own videos of a person lifting in different ways.

Materials

Vernier Video Analysis app in a web browser on a computer, Chromebook, or mobile device

"Lift-Slow" video file

"Lift-Fast" video file

Pre-Lab Investigation

Using either student volunteers or a video, observe a few repetitions of a person performing a bench press. If using student volunteers, one person will perform a bench press while another acts as a spotter. Observe from a position that will allow you to see one end of the bar as it descends and rises during the lift. Watch the motion of the lift carefully; you will sketch graphs of the motion after the demonstration.

The motion of the bench press can be divided into four distinct phases: the preparatory phase where the subject holds the loaded bar aloft with the arms extended, the descent phase where the subject allows the bar to descend in a controlled fashion to the chest, the pause phase where the bar is held still just above or resting on the chest, and the rising phase where the bar is pushed back up as the arms fully extend.

Sketch position *vs*. time and velocity *vs*. time graphs that show the *y* direction (vertical) motion of the bar. Include all four phases of the lift. Compare your graphs with those created by your lab partner and other lab groups.

Investigation

Part 1 Slow Lift

1. Launch Vernier Video Analysis and import the "Lift-Slow" movie. Play the movie once or twice so you are familiar with the motion.

2. Advance the movie to the frame where the bar is at the bottom of the lift and just begins to move up. This is the beginning of the upward push or rising phase of lift.

3. Apply a scale to the video and place the origin of the axes. **Note**: The red bar in the video is 2.0 m long and should be parallel to the horizontal axis of your axes system. For best results, place the origin at the center of the yellow dot located at the end of the bar when the bar is positioned as described in Step 2.

4. Mark the location of the bar through the rising phase of the lift. You can use autotracking or you can mark the position of the bar manually.

5. Create a graph of position *vs*. time for the vertical motion of the lift.

6. Do Part 1 of the Analysis, then return to continue with Part 2 of the investigation.

Part 2 Fast Lift

In this part, you will analyze a video that shows the same subject performing a fast lift. The bar has the same mass as the bar in the slow lift video.

7. Click or tap File, , choose New Experiment, and import the "Lift-Fast" movie. Play the movie once or twice so you are familiar with the motion.

8. Repeat Steps 2–5 from part 1 to analyze the fast lift video.

9. Complete Part 2 of the Analysis.

Analysis

Part 1 Slow Lift

1. Examine the graph of *y* position (Y) *vs*. time.

   a. Would you use a straight line to model this data? What does that say about the motion of the lift?
   b. Click or tap Graph Tools, , choose Apply Curve Fit, and apply a linear curve fit to your data. Record the slope of the line, then close the Curve Fit details box. What does the slope tell you about the lift?
   c. Determine the duration of the rising phase of the lift as well as the distance the bar traveled:
      i. Click or tap Graph Tools, , and select View Statistics.
      ii. Record the value of Δx. This is the duration of the segment of the rising phase of the lift in seconds.
      iii. Record the value of Δy. This is the distance the bar traveled for the rising phase of the lift in meters.
      iv. Close the Statistics details box.

2. Examine the graph of *y* velocity (Y Velocity) *vs*. time.

   a. Click or tap the vertical axis label on the graph to open the Plot Manager. Turn off the Y column and turn on the Y Velocity column so only *y* velocity *vs*. time is plotted.

b. Click or tap Graph Tools, , and select View Statistics. Record the mean, standard deviation, minimum, and maximum velocity. How does the mean velocity value compare to the slope you found in Step 1b?

In order to do further analysis on the lift, we need to determine the lift force (F_{lift}) the test subject is exerting on the bar during the lift. You will use data from your motion analysis to determine the value. In order to do that, you will use the following relationships in your analysis:

$$\Sigma F = ma \qquad\qquad \Sigma F = F_{\text{lift}} + F_{\text{weight}}$$

3. To find the lift force, you need additional information about the bar and weights used in the video. The bar the subject is lifting has two 25 lb weights attached. The bar without the weights weighs 15 lbs.

   a. Calculate the mass of the loaded bar (bar plus weights) the subject is lifting.
   Note: 1.0 kg = 2.2 lbs

   b. Calculate the weight of the loaded bar in newtons. **Note**: $F_{\text{weight}} = mg$

4. Create a calculated column to find the *y* acceleration of the bar during the lift.

   a. Use View, , to add the data table to your display.

   b. In the data table, click or tap Column Options, , for Y Velocity and choose Add Calculated Column.

   c. Enter **Y Acceleration** as the name of the column and **m/s^2** as the units.

   d. Select Insert Expression. Choose 1st Derivative (Y, X).

   e. Verify that Y Velocity has been selected for the Column Y box and that Time has been selected for the Column X box.

   f. Click or tap Apply.

5. Examine the graph of *y* acceleration *vs*. time.

   a. Use View, , to remove the data table from your display.

   b. Click or tap the vertical axis label on the graph to open the Plot Manager. Turn on the Y Acceleration column and turn off all other columns so only *y* acceleration *vs*. time is plotted.

   c. Click or tap Graph Tools, , and select View Statistics. Record the average Y Acceleration of the bar during the lift. Is this value what you expected? Explain.

   d. Record the standard deviation, the minimum and maximum acceleration of the bar, and then dismiss the statistics box.

6. Create a calculated column to find the net force (ΣF) acting on the bar during the lift.
   Note: $\Sigma F = ma$

   a. Use View, , to add the data table to your display.

   b. In the data table, click or tap Column Options, , for Y Acceleration and choose Add Calculated Column.

   c. Enter **F_net** as the name of the column and **N** as the units.

   d. Select Insert Expression. Choose A*X+B.

   e. For Parameter A, enter the mass of the loaded bar you found in Step 3a. Verify that Y Acceleration has been selected for the Column X box, and change the value of Parameter B to **0**.
   f. Click or tap Apply.

7. Create a calculated column to find the Lift Force (F_{lift}) applied during the lift. The net force represents the sum of all forces acting on the bar at any point in the lift. **Note**: $\Sigma F = F_{lift} + F_{weight}$
   a. In the data table, click or tap Column Options, ⊡, for F_net and choose Add Calculated Column.
   b. Enter **F_lift** as the name of the column and **N** as the units.
   c. Select Insert Expression. Choose X+A.
   d. Verify that F_net has been selected for Column X. For Parameter A, enter the magnitude of the weight of the bar (from Step 3b).
   e. Explain why it is appropriate to add (and not subtract) the magnitude of the weight to the F_net in this expression. Use a force diagram to help justify your answer.
   f. Click or tap Apply.
8. Examine the graph of Lift Force (F_lift) *vs*. *y* position (Y)
   a. Use View, ⊞, to remove the data table from your display.
   b. Click or tap the vertical axis label on the graph to open the Plot Manager. Turn on the F_lift column, and turn off all other columns so only lift force *vs*. time is plotted.
   c. Click or tap the horizontal axis label on the graph. Select Y (m) to display a graph of lift force (F_lift) *vs*. *y* position (Y).
   d. Click or tap Graph Tools, 📈, and select Edit Graph Options. Enter **0** for the Bottom of the *y* axis range, and then dismiss the Graph Options.
   e. Click or tap Graph Tools, 📈, and select View Statistics. Record the mean F_lift value. How does this value compare to the weight of the bar? Is that what you expected? Explain your reasoning.
   f. Close the Statistics details box. Click or tap Graph Tools, 📈, and select View Integral. Record the value of the integral, and then dismiss the Integral details box. What do you think this area represents?
9. Calculate work done during the lift.
   a. Calculate the work (W) done assuming the bar rises at constant velocity. Use the formula $W=F_{avg}\Delta y$, where F_{avg} is the average lift force and Δy is the distance the bar moved vertically during the rising phase of the lift (see Step 1c).
   b. The area under the force *vs*. *y* position graph is another way to determine work. Do the data support this? Compare the value for the integral (Step 8f) and the value you calculated in Step 9a. Are they similar?
   c. Use the formula for gravitational potential energy to calculate the change in potential energy of the bar when it is raised to its peak position of the lift. Use the formula $\Delta U = mg\Delta y$. In this case m is the mass of the loaded bar, g is the acceleration due to gravity, and Δy is the distance the bar traveled vertically during the rising phase of the lift.

d. How does the change in potential energy of the bar compare to the work done when lifting the bar? Why do you think this is so?

10. Calculate the power (P) of the lift.

    a. Use the formula $P = W/\Delta t$ where W is the work done in lifting the bar (Step 9) and Δt is the duration of the rising phase of the lift in seconds (from Step 1c).

    b. The subject in the video was asked to complete the slow, constant-speed lift over a 3-second count period (i.e., 1 one thousand, 2 one thousand, 3 one thousand). If the lifter had used a 6-second count, how do you think this would change the work and power generated for the lift? Explain your reasoning.

    c. Which lift do you think would fatigue the subject faster, a set of 3-second count lifts or a set of 6-second count lifts (assume the same number of reps for each set)? Explain your reasoning.

11. Save your Video Analysis file.

Part 2 Fast Lift

12. Examine the graph of y position (Y) *vs*. time.

    a. Would you use a line to model this data? What does that say about the motion of the fast lift compared to the slow lift?

    b. Do you see regions of the graph where the bar is accelerating or decelerating? Do you see regions of the graph where the bar is moving at near constant speed? Note these regions.

    c. If it is displayed, close the Curve Fit details box. Click or tap Graph Tools, , and select View Statistics.

       i. Record the value of Δx. This is the duration of the segment of the rising phase of the lift in seconds.

       ii. Record the value of Δy. This is the distance the bar traveled for the rising phase of the lift in meters.

       iii. How do these values for the fast lift compare to those found for the slow lift (Step 1c)? Does that make sense for these videos? Explain your reasoning.

       iv. Close the Statistics details box.

13. Examine the graph of y velocity (Y Velocity) *vs*. time.

    a. Click or tap the vertical axis label on the graph to open the Plot Manager. Turn off the Y column and turn on the Y Velocity column so only y velocity *vs*. time is plotted.

    b. Click or tap Graph Tools, , and select View Statistics. Record the mean, standard deviation, minimum, and maximum velocity.

    c. Compare the average velocity of the fast lift to that of the slow lift you found in Step 2b. How many times faster is the fast lift?

    d. Compare the standard deviation and the minimum and maximum velocity for the fast lift to the same parameters you found in Step 2b.

    e. Click or tap the point on the graph that corresponds to the maximum velocity. Drag the Examine line back and forth around the maximum velocity. Observe and note what is happening in the video just as the bar reaches peak velocity.

14. Create a calculated column to find the *y* acceleration of the bar during the fast lift.
    a. Use View, ▦, to add the data table to your display.
    b. In the data table, click or tap Column Options, ⊡, for Y Velocity and choose Add Calculated Column.
    c. Enter **Y Acceleration** as the name of the column and **m/s^2** as the units.
    d. Select Insert Expression. Choose 1st Derivative (Y, X).
    e. Verify that Y Velocity has been selected for the Column Y box and that Time has been selected for the Column X box.
    f. Click or tap Apply.
15. Examine the graph of *y* acceleration *vs*. time.
    a. Use View, ▦, to remove the data table from your display.
    b. Click or tap the vertical axis label on the graph to open the Plot Manager. Turn on the Y Acceleration column and turn off all other columns so only *y* acceleration *vs*. time is plotted.
    c. Click or tap Graph Tools, 📈, and select View Statistics. Record the mean, maximum, and minimum accelerations of the bar, then dismiss the Statistics details box.
    d. Compare the acceleration parameters for the fast and slow lift.
16. Create a calculated column to find the net force (ΣF) acting on the bar during the lift. **Note**: $\Sigma F = ma$
    a. Use View, ▦, to add the data table to your display.
    b. In the data table, click or tap Column Options, ⊡, for Y Acceleration and choose Add Calculated Column.
    c. Enter **F_net** as the name of the column and **N** as the units.
    d. Select Insert Expression. Choose A*X+B.
    e. Enter the mass of the loaded bar you found in Step 3a for Parameter A.
    f. Verify that Y Acceleration has been selected for Column X and change the value of Parameter B to **0**.
    g. Click or tap Apply.
17. Create a calculated column to find the lift force (F_{lift}) applied during the lift. The net force represents the sum of all forces acting on the bar at any point in the lift. **Note**: $\Sigma F = F_{lift} + F_{weight}$
    a. In the data table, click or tap Column Options, ⊡, for F_net and choose Add Calculated Column.
    b. Enter **F_lift** as the name of the column and **N** as the units.
    c. Select Insert Expression. Choose A*X+B.
    d. Verify that Parameter A is 1 and F_net has been selected for the Column X box. For Parameter B, enter the magnitude of the weight of the bar (from Step 3b).
    e. Click or tap Apply.

18. Examine the graph of lift force *vs*. *y* position (Y).

    a. Use View, ⊞, to remove the data table from your display.

    b. Click or tap the vertical axis label on the graph to open the Plot Manager. Turn on the F_lift column, and turn off any other columns so only lift force *vs*. time is plotted.

    c. Click or tap the horizontal axis label on the graph. Select Y (m) to display a graph of lift force (F_lift) *vs*. *y* position (Y).

    d. Click or tap Graph Tools, 📈, and select Edit Graph Options. Enter **0** for the Bottom of the *y* axis range, then dismiss the Graph Options.

    e. Click or tap Graph Tools, 📈, and select View Statistics.

       i. Record the mean F_lift. How does this value compare to the weight of the loaded bar? Is that what you expected? Explain your reasoning.

       ii. Record the maximum F_lift value. By how much is this force greater than the weight of the loaded bar?

       iii. Record the minimum F_lift value. By how much is this force less than the weight of the loaded bar?

       iv. Close the Statistics details box.

    f. Click or tap Graph Tools, 📈, and select View Integral. Record the value of the integral. Then dismiss the Integral details box. Do you think this area represents work done? Explain your reasoning.

19. Calculate work done on the bar during the lift.

    a. Calculate the work done on the bar assuming a force equal to the average lift force was applied to the bar throughout the lift. Use the formula $W=F_{avg}\Delta y$, where F_{avg} is the average lift force and Δy is the distance the bar moved vertically during the rising phase of the lift (see Step 12c).

    b. The area under the force *vs*. *y* position graph should still represent work. Do the data support this? Compare the value for the integral (Step 18f) and the value you calculated in Step 19a. Are they similar?

    c. Use the formula for gravitational potential energy to calculate the change in potential energy of the bar when it is raised to its peak position of the lift. Use the formula $\Delta U = mg\Delta y$. In this case the m is the mass of the loaded bar, g is the acceleration due to gravity, and Δy is the distance the bar traveled vertically during the rising phase of the lift.

    d. How does the change in potential energy of the bar compare to the work done when lifting the bar? Why do you think this is so?

20. Calculate the power of the lift.

    a. Use the formula $P = W/\Delta t$ where W is the work done in lifting the bar (Step 19) and Δt is the duration of the rising phase of the lift in seconds (Step 12c).

    b. How does the power for the fast lift compare to the power for the slow lift you found in Step 11a? Is this what you expected? Explain your reasoning.

Extensions

1. Analyze the descent phase of the "Lift-Slow" movie and compare it to the results from Part 1. When analyzing the video, be sure to use the video range tools, ▲, to restrict the video to only show the descent phase of the lift when you play the video. Use the first frame of the descent portion of the video when positioning the origin at the center of the bar. (Note that this will make the *y* position values negative for this analysis.)

For the following extensions, you will record and analyze your own videos. Tips for recording useful videos are found after the Extensions.

2. Record and analyze your own bench press video. Analyze a slow and fast lift, or investigate constant velocity lifts done on 3-, 6-, and 12-second counts. Always use proper lifting technique and employ a spotter. The bar should be loaded so the subject can move the bar smoothly through the entire range of motion.

3. Analyze videos of different types of lifts. Focus on lifts with vertical range of motion. Good examples would be the military press, squat, and dumbbell row. Always use proper lifting technique and employ a spotter. Make sure the subject can perform the lift in a slow and controlled fashion through the entire range of motion of the lift.

4. Analyze videos of strength training exercises that don't use weights. Focus on motion that moves vertically. Good examples would be pull ups and dips. Always use proper technique.

5. Analyze videos of a lift through an entire set. The bench press would work fine for this extension. Determine if you can use the data to detect when the subject begins to fatigue.

Production and analysis of your own video

You will need either a digital camera or some other device capable of recording video; it can be the same device that is running Vernier Video Analysis. Ask your instructor for additional tips for making your own videos. Your instructor can find these in Appendices A and B of this book.

- Once the subject has been selected, have them practice performing the bench press a couple of times. You may need an exercise bench and a bar with weights. Always use clamps to hold the weights in place on each end of the bar.
- The subject should be able to move the bar smoothly through the range of motion. The weight of the bar is not critical.
- For best results with the bench press, have the subject start with arms extended. Have the subject bring the bar down slowly to the chest while counting to three. Then, have the subject raise the bar slowly while counting to three. This should all be done as one smooth continuous motion.
- Make sure the subject uses proper technique when lifting and always employ a spotter. This should be done even if the subject is able to lift the weight with ease. Dumbbells can also be used instead of a bar.
- Verify that the full range of motion of the bench press or exercise can be captured on video.