Physics Lesson 1 to Prepare for UIL Physics Portion of Science Test

Lesson Plan Title: Free-Body Diagram Lesson Plan

Physics EOC (End of Course) objective 2D – The student demonstrates an understanding of the relationship of force and motion in one and two dimensions. The student is expected to develop and interpret free-body diagram for force analysis.

Subject: Regular/Pre AP Physics

Goal of Lesson: The student will be able to draw and label correctly a free-body diagram representing situations where forces are being applied to an object.

Materials needed: 15-cm length 2x4-board, mass hanger plus masses totaling 100-g, 1-m length string capable of holding at least 20N, protractor, 3 cylindrical shaped spring scales each capable of measuring 20N.

Overview of Lesson:
Hang the mass hanger plus masses from a support with a spring scale between the mass hanger and the support.
Attach a piece of string to the part of the string connecting the mass hanger to the weight scale currently measuring the weight of the hanging mass. Pull the string at different angles and show that the spring scale measures different values for the weight of the hanging mass.

Procedure and Activities:

The teacher will –
>   (1) Define what force is. (*anything that pushes or pulls on something else*).   Tell the students that forces are vectors (because they have magnitude as well as direction) and basically come in two forms: those that are in contact and those that are not in contact – sometimes called field forces. Give examples of contact forces (i.e. friction, normal, tension, etc.) and field forces (i.e. magnetic, electric, weak, (maybe call these two the electroweak force); and GRAVITY).
>   (2) Point to the hanging mass and tell the students that the spring scale reads around 10 Newtons. Tell the students that there is a force that is attracting the hanging mass downward. It's a field force and we call it gravity. You should also tell them that the units we use in the metric system to stand for forces are called Newtons. You don't really have to define a Newton now; just tell the students it is the unit we are going to use.
>   (3) Have a volunteer student pick up one of the other spring scales and attach one end to the string that is currently dangling from the string holding up the hanging mass. Have the student pull on the string parallel to the floor and tell the class what the original spring scale now reads along with what the spring scale they are holding currently reads and record these values on the chalk/marker board. Have another student take a protractor and measure the angle between the two strings above and below the knot where the two strings are tied as well as record the readings on the two spring scales.
>   (4) Now have the volunteer student take the string he/she is holding and pull the string so that it now makes some angle **above** the line parallel to the ground. Have another student take a protractor and measure the angle between the two strings above and below the knot where the two strings are tied as well as record the readings on the two spring scales.

(5) Now have the volunteer student take the string he/she is holding and pull the string so that it now makes some angle **below** the line parallel to the ground. Have another student take a protractor and measure the angle between the two strings above and below the knot where the two strings are tied as well as record the readings on the two spring scales.

(6) Remind students that vectors are used to help find certain quantities that involve magnitude and direction. Tell the students that to solve problems where forces are acting on an object, a diagram, called a free-body diagram, is often used to help visualize the forces involved.

(7) On the marker/chalk board draw a Cartesian plane and label the horizontal axis x and the vertical axis y.

(8) Tell the students that we are going to draw all vectors starting at the origin. Also tell the students to determine the point where all forces appear to be acting on in the problem. Tell the students that is where we are going to locate our origin for drawing vectors representing the various forces.

(9) On the Cartesian plane we are going to draw vectors representing the first situation we visited. First ask the students to say how many forces are acting with the mass and single string holding up the mass. (*two*) These two forces are the gravitational force (we normally call it weight) and the string tension force.

(10) Ask the students which direction they should draw a vector representing the gravity force. (*down*) Ask the students which direction they should draw the vector representing the string tension force. (*up*)

(11) Tell the students to draw the vectors to lengths that are proportional and appropriate. Note that since the hanging mass is just hanging and still, the tension force and the weight force are equal in magnitude but opposite in direction. This means the vector arrows representing the two forces should be the same length pointing in opposite direction – say along the y-axis. Also tell the students to label the vectors with unambiguous words/values. (gravity force, weight force, tension force, 12 N, etc.) Tell the students that when angles are involved in the vector diagram it is important to label the angles as well.

(12) Now tell the students to draw two more free-body diagrams representing the other two situations whereby the volunteer pulled up on a second string above the horizontal axis and downward below the x-axis. In each case ask the class, before drawing the free-body diagram, how many forces are acting in the problem. (*three*) Have the students draw the weight vector straight down along the negative y-axis and then using the angles measured, draw the other two vectors in the appropriate direction, the approximate proportionate length and the appropriate angles labeled. You can also state that as long as the vector magnitudes are labeled correctly proportional length is not a big deal.

(13) Now attach another piece of string to the 2x4 board and hang the board to the other spring string and record its weight.

(14) Now place the board on a table and pull with a force (holding on to the spring scale and keeping the string parallel to the table) so that the board does NOT move. When the board is about to move, note the scale reading and write down that value.

(15) Now tell the students to draw another free-body diagram representing the 2x4 being pulled situation. First ask the class, before drawing the free-body diagram, how many forces are acting in the problem. (*four*) Have the students draw the weight vector straight down along the negative y-axis and the string tension force vector along either x-axis. Ask the students what are the other two vectors. (*Normal and friction forces*) Ask the students how would they draw the friction force vector. (*same length as tension vector but along opposite x-axis*) Ask the students how they would draw the normal force vector. (*same length as weight vector but along the +y-axis*)

(16) For extension the concept of resolving vectors into x and y components in order to come up with a sum (resultant) would be useful, especially if free-body diagrams involve forces at an angle to the x or y -axis. In addition there are classic problems whereby objects are pulled up or let down inclined planes. I have found (from experience) that having students place the normal force along the +y-axis and drawing the other forces (note that the weight force is no longer along the negative y-axis) accordingly makes the problem solving process easier.

Performance Assessment:
(1) A worksheet with various drawings showing objects being pushed or pulled by two to four forces. Some forces might be at angles to the horizontal. Some questions might be entirely conceptual with answers represented by free-body diagrams only. Some problems could be numerical in nature, where a resultant force is to be determined, but care should be taken that concepts related to vector components have been thoroughly discussed prior.

Free-Body Diagram Assessment

Directions: Draw a free-body diagram for the problems listed below.

(1)

50 N   60 N

(2)

100 Kg

(3)

F₂

F₁

130°

110°

100 N
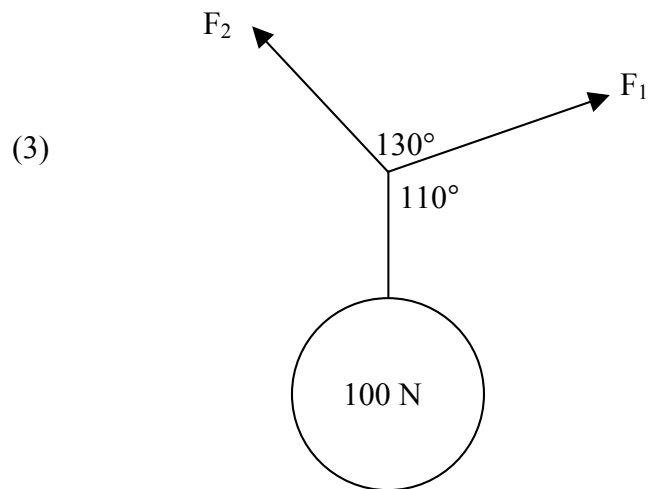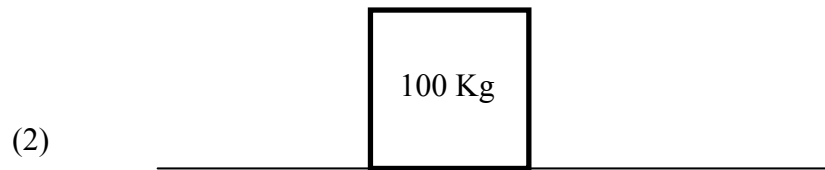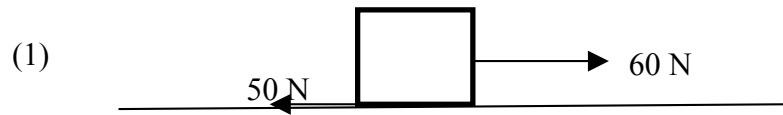
(4) Andy kicks a block of wood that has a mass of 0.100 kg across a level floor. After traveling for 2 meters the block comes to a rest. (A) How many forces are acting on the block while its is moving? (B) Draw a free-body diagram of the forces acting on the block.

4A)

4B)

(5)	Which of the free body-drawings below is drawn correctly for the problem drawn below? 5) _____

A)	T_A ← T_B ↗ 30°

B)	T_B ← T_A ↗ 30°

C)	T_B ← T_A ↗ 30° , 150 N ↓

D)	150 N ↑ , T_B ← T_A ↗ 30°


T_A T_B 30°   150 N
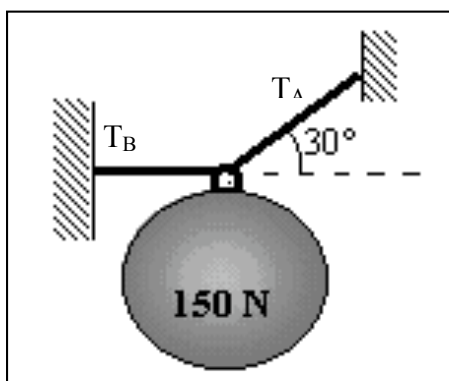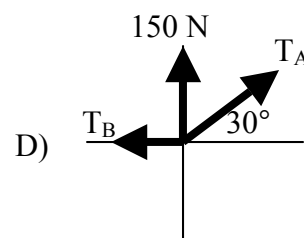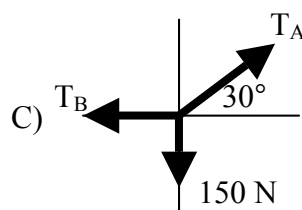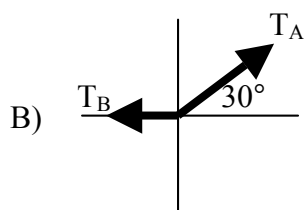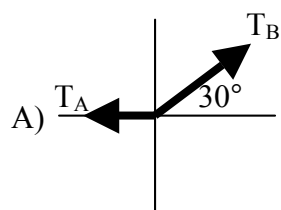
(6)	Genny is sitting on a swing when Andy grabs her foot and pulls her with a force of 110 N, parallel to the ground, causing the swing rope to make an angle of 40° with the vertical. Genny weighs 450 N. Draw a free-body diagram representing this situation.
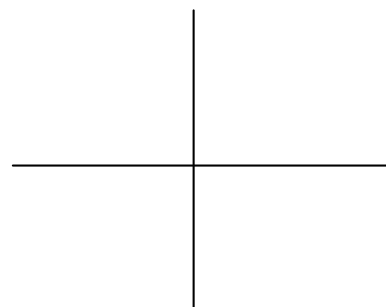
*(7)	A car that weighs 5000 N is parked on a hill that makes an angle of 12° with the vertical.
(A) How many forces are acting on the parked car? (B) Draw a free-body diagram of this situation.
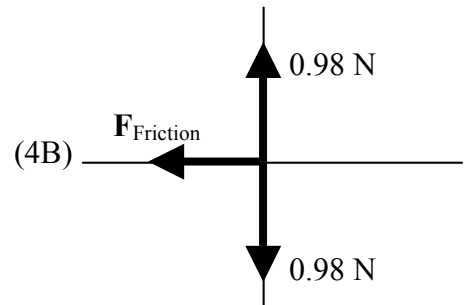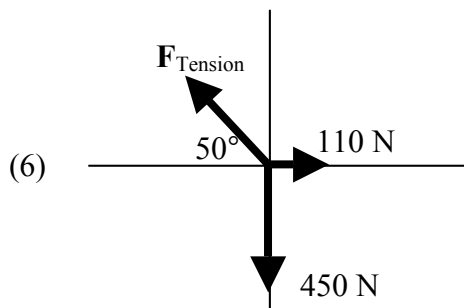
7A)	_____

7B)
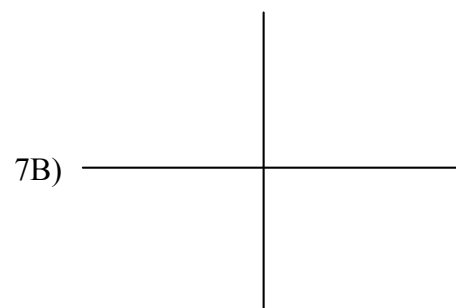
Answers

Note that unless specific directions are given in a problem, all diagrams are direction independent. Normally we draw weight forces straight down along the negative y-axis. But your students may draw some forces to the left/right along the x-axis while you draw the forces to the right/left along the x-axis. Sometimes I specify that north is along the positive y-axis and 0° is along the positive x-axis. Sometimes this helps me not have to worry about different looking graphs when grading the student papers.

(1)   50 N   60 N

(2)   980 N   980 N

(3)   F₂   F₁   30°   20°   100 N
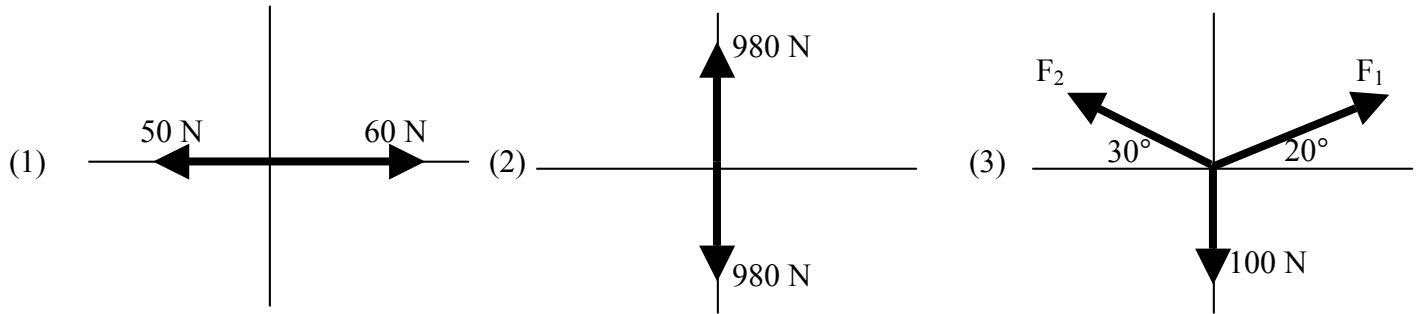
(4A)   3 – Friction, Normal and Weight forces.

(4B)   0.98 N   **F**Friction   0.98 N

(5)   C

(6)   **F**Tension   50°   110 N   450 N

(7A)   3 – Weight, Normal, and Friction forces.
Note: I drew the normal force vector along the positive y-axis and because of the geometry of the problem the weight of the car is consequently drawn 12° from the negative y-axis.

(7B)   **F**Normal   **F**Friction   30°   5000 N
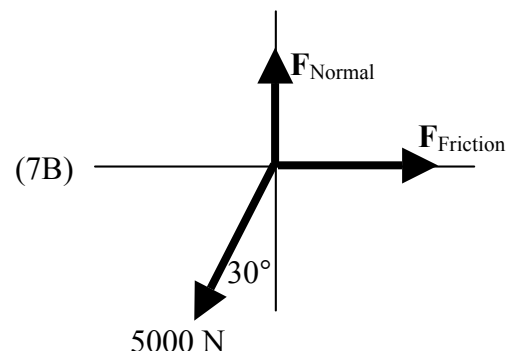
Lesson Plan Title: Projectile Motion Lesson Plan

Physics EOC objective 2B – The student demonstrates an understanding of the relationship of force and motion in one and two dimensions.   The student is expected to analyze examples of uniform and accelerated motion including linear, projectile and circular motion.

Subject: Regular/Pre AP Physics

Goal of Lesson: The student will be able to state the reason the horizontal and vertical components of projectile motion are independent of each other.

Materials needed: Two identical coins or two metal washers; one 30-cm ruler or flexible strip of wood/metal similar in shape to the ruler; two timers; one meter stick or tape measure with metric units.

Overview of Lesson:
Launch two coins/metal washers from a height ≥ 1 meter and have students observe the time the two objects hit the floor.

Procedure and Activities:

The teacher will –
        (1) Review concept of linear acceleration. Talk about gravity being a force and that net forces cause accelerations. This is also the time to start using terminology related to the concept of vectors. You might mention that for this topic we are only going to be concerned with motion in two dimensions.
        (2) Drop a coin/metal washer from one hand to the other – demonstrating the acceleration of the object.Point out that the object in hand has no initial velocity until released and then the object has some velocity when caught – indicating that a change in velocity occurred, hence there was acceleration.
        (3) Define the term projectile motion – **A projectile is any body that is given an initial velocity and then follows a path determined by the effect of the gravitational force and by air resistance**. Mention that for now we are going to disregard the effects of air friction. Also mention that projectile motion involves parabolic shaped paths.
        (4) Place two coins/metal washers on an elevated surface, preferably higher than one meter above the floor, at the edge of the surface. Make sure the two objects are at least 25 cm apart.
        (5) Place a ruler/ flexible metal strip on its edge next to the objects and parallel to the elevated surface edge so that when the ruler is pulled back and released it will strike the two objects at the same time causing them to leave the elevated surface at the same time. You must hold one end of the ruler still with one hand while pulling back, with the other hand, on the other end to bend the ruler. Before you release the ruler ask the questions to the class: (1) Will the coins/washers leave with the same velocity when struck by the ruler?(*No - the coin/washer farthest away from the fixed end should get hit harder!*) (2) Which coin/washer will hit the floor first? Will it be the coin/washer that lands farther away or closer? (*They should hit at the same time.*)   Tell the class to be extra quiet to hear the sound of the coins/washer hit the floor. You may need to perform this step a few times to get the coins/washers to leave at the same time.

A little practice before class starts never hurts. In addition the extra attempts should reinforce the concept that the horizontal velocity does not influence the time the coins/washers are in the air.

(6) Now place one of the coins/washers at the same launch location and ask a couple of students to determine the time it takes for the coin/washer to drop straight down to the floor. Do this a couple of times and write down the average of the two times on marker/chalk board.

(7) Now place one of the coins/washers at the same launch location and ask a couple of students to determine the time it takes for the coin/washer to be launched across the floor, as in step #5. Do this a couple of times and write down the average of the two times on marker/chalk board. This is trickier since you are asking the students to closely watch the impact of the ruler on the launched objects and determine the object's time in the air. You might ask the students to listen to the impact sounds. Again do this a couple of times and write down the average of the two times on marker/chalk board.

(8) Ask the class if the flight times (the time the coin/washer is in the air) are much different for the object dropped or launched from the same height above the ground. (*They should not be!*)

(9) Now ask the class if the time of flight **depends** on the horizontal component of the projectile's velocity. (*It does not.*)

(10) Ask the class why the time of flight does not depend on the horizontal velocity. (*Disregarding air friction the net force acting on the coin/washer in flight is only gravity which acts straight down.*)

(11) For extension, if you have time, you might write down the equation that allows one to calculate the distance covered during uniform acceleration: $d = v_i t + \dfrac{1}{2} a t^2$. You should have already covered this equation and its uses before; but, you might point out that the "*a*" in this equation is "*g*" – the acceleration due to gravity. You might also point out that when you dropped the coin/washer the "v_i" is zero. This fact allows one to calculate the time the coin/washer is in the air. Using that equation:

$$t = \sqrt{\frac{2d}{g}}$$ and the height (*d*) used you might have the class compare the predicted time

and the time measured by the class. You could also point out that since there is no net force in the horizontal direction, there is no acceleration in that direction and the horizontal distance covered by the coin/washer is just: $d = v_i \times t$.
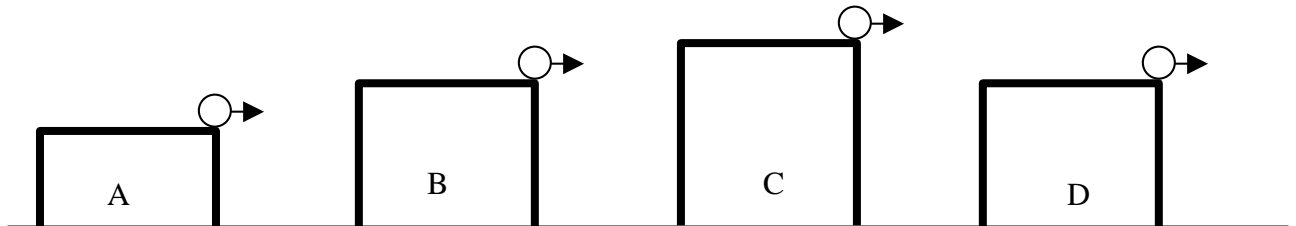
Performance Assessment:
(1) A worksheet with various drawings showing objects being launched from different heights as well as different initial velocities. Some questions might be entirely conceptual with answers such as longer horizontal distance or longer times. Some questions might be numerical in nature using the two formulas mentioned in step #11.

Projectile Motion Assessment

(1)   In the illustration to the right marble A
is traveling at a speed of 4.5 m/s and
marble B is traveling at a speed of 2.4 m/s.
If both marbles leave the table at the same
time, which marble hits the floor first?

A = 4.5 m/s

B = 2.4 m/s

1.2 m

     A) Marble A
     B) Marble B
     C) Both marbles hit the floor at the same time.
   D) Cannot tell without more information.
     1) _____
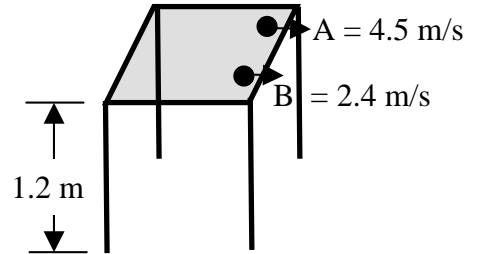
(2)   In the figures below a marble leaves the different tables at the same speed. In which
situation will the marble travel the farthest horizontal distance? All table heights are
2) _____
drawn to scale.

A

B

C

D

(3)   In the figures below a marble leaves the different tables at the different speeds. In which
situation will the marble travel twice as far horizontally? All table heights are drawn to
3) _____
scale.

     A) C and B   B) D and B   C) D and A   D) C
and A

2 m/s

1 m/s

1 m/s

2 m/s

A

B

C

D
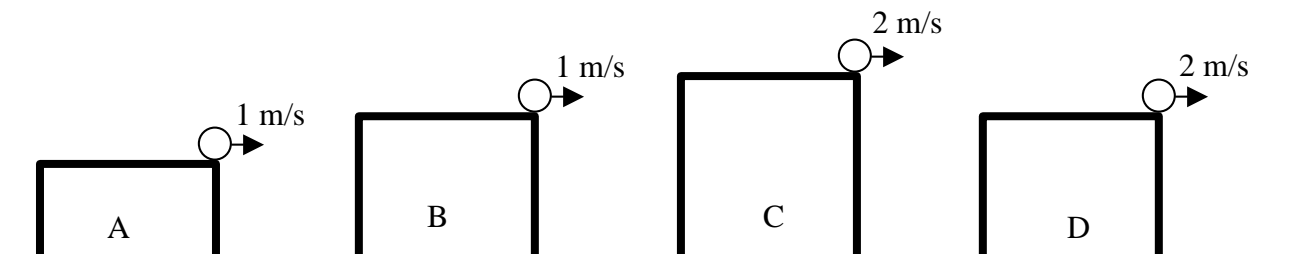
(4)   Andy and Mike run off a diving platform that is 3 meters above a swimming pool at the same time side by side. Andy leaves with a horizontal speed of 2 m/s, while Mike leaves with a horizontal speed of 3 m/s. Who hits the water first?
A) Mike
B) Andy
C) Cannot tell with the information given.
D) They hit the water at the same time.   4) _____

(5)   A marble leaves a 1 meter tall table at a speed of 2.0 m/s. A) How long is the marble in the air?
B) How far away horizontally from the table's edge does the marble land?

                                                                    5A) _____

                                                                    5B) _____

(6)   Two marbles leaves a table that is 1 meter tall at the same time. One marble is traveling at a speed of 3.0 m/s and the other marble is traveling at a speed of 6.0 m/s. How far apart are the two marbles when they land on the floor?

                                                                    6) _____

(7)   Genny leans over the top of the stadium and drops a marble. 2.25 seconds later the marble hit the ground below. How tall is the stadium where Genny dropped the marble?

                                                                    7) _____

Answers

(1) **C** – Since the two marbles leave from the same vertical height they take the same time to hit the floor.

(2) **C** – Table C is taller which means the marble will take longest to hit the floor and since the marble in each situation is traveling with the same horizontal speed the marble leaving table C will travel the farthest.

(3) **B** – Table B and D are of the same vertical height. Since the marble at table D is traveling twice as fast the marble at table B, that marble will travel twice as far as the marble leaving table B.

(4) **D** – Since the vertical distance determines the time in the air, and since they leave at the same time, they hit the water at the same time.

(5A) $t = \sqrt{\dfrac{2(1)}{9.8}} = \textbf{0.45 seconds}$ (5B) distance $= (2.0 \text{ m/s}) \times (0.45 \text{ sec}) = \textbf{0.90 m}$

(6) $t = \sqrt{\dfrac{2(1)}{9.8}} = 0.45$ seconds $d = (0.45 \text{ sec}) \times (6.0 \text{ m} - 3.0 \text{ m}) = \textbf{1.4 meters}$

(7) $d = \left(\dfrac{1}{2}\right)(9.8)(2.25)^2 = \textbf{25 meters}$