Workbook

ActivPhysics 1

VERSION 1.1

For Macintosh and Windows
CD-ROM
Inside

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ActivPhysics 1
Workbook

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ADDISON-WESLEY

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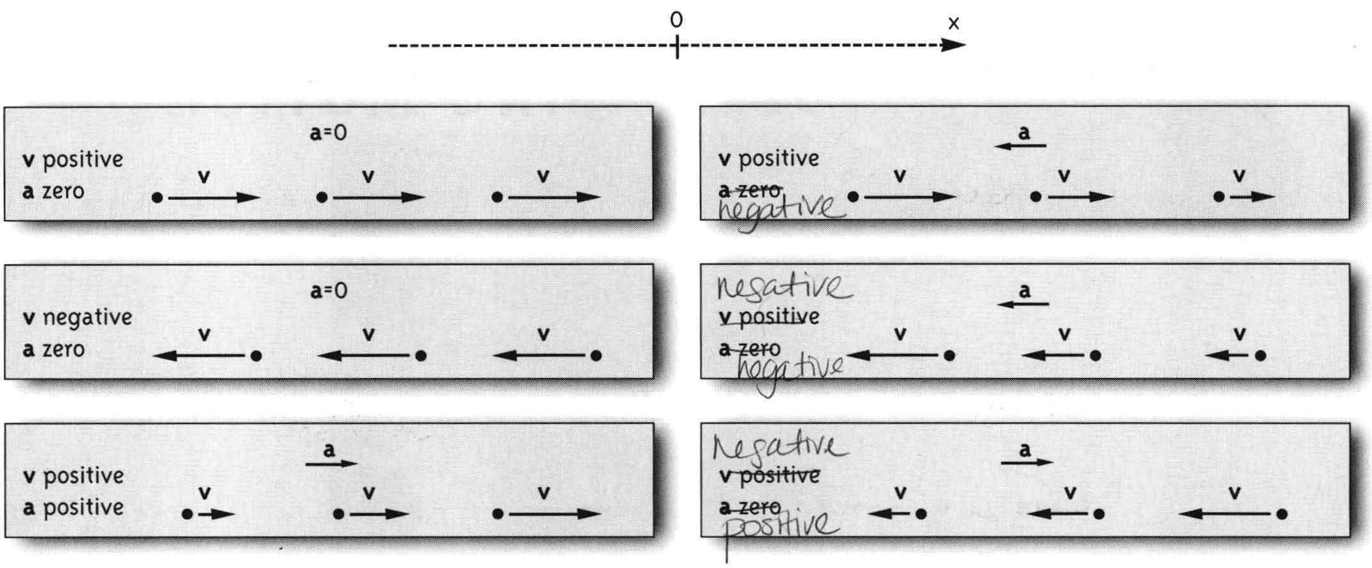
Motion Diagrams: Their Construction and Interpretation

A motion diagram uses a series of dots and arrows to represent the changing position, velocity, and acceleration of an object.

Advantages of Motion Diagrams:

- They help you develop mental images and intuition about the meaning of the kinematics quantities used to describe motion.
- They help you understand the signs of these quantities, especially when the quantities have negative signs.
- They are useful for checking the values of kinematics quantities when you are solving problems.

Examples of Motion Diagrams for Constant Acceleration (positive direction toward the right):



Rules for Constructing Motion Diagrams:

- The position dots indicate the location of the object at equal time intervals.
- The separation of adjacent position dots indicates roughly the speed of the object.
- $a = \Delta v/\Delta t$, and the direction of the acceleration arrow represents the change in the velocity Δv from one position to the next.
- The sign of the velocity or acceleration depends on the direction of the arrow relative to the coordinate axis (the positive direction is toward the right in these examples).

1. DESCRIBING MOTION

2. FORCES AND MOTION

3. PROJECTILE MOTION

4. CIRCULAR MOTION

5. WORK AND ENERGY

6. MOMENTUM

7. ROTATIONAL MOTION AND STATICS

Torques and Statics

7. ROTATIONAL MOTION AND STATICS (Continued)

Rotational Kinematics and Dynamics

Rotational Energy

Angular Momentum Conservation

8. THERMODYNAMICS

9. VIBRATIONS

10. WAVES

Question 1 — Meaning of x_0 : Set the initial velocity and acceleration sliders to zero and try different initial position settings. What is the meaning of x_0?

The start position of the car. The position of subject.

Question 2 — Meaning of v_0: Set the initial position and acceleration sliders to zero and try different initial velocity settings. What is the meaning of v_0 and v?

V_0 the car is moving at 7 m/s constantly, unchanging

Question 3 — Meaning of a: Set the initial position to -48 m and the initial velocity to zero. Try different positive acceleration settings. How does the change in velocity each second relate to the acceleration?

the displacment is getting bigger. the velocity is increasing. Acceleration is constant but velocity increasing

Question 4 — Acceleration and Time: Set the initial position to -48 m and the initial velocity to + 12 m/s. Try different negative accelerations starting at - 1.0 m/s². Predict the time interval needed to stop the car.

12 seconds. We were right it took 12 seconds to stop the car.
@ $-3.0 m/s^2$ it would stop 4 seconds to stop.

Question 5 — Meaning of Negative a if v Is Negative: Set the initial position to +48 m and the initial velocity to zero. Try different negative accelerations. What does negative a imply about the motion if the object has a negative velocity? Start with a = 1.0 m/s².

They are going in the same direction, back.

Question 6 — Meaning of Positive a if v is Negative : Set the initial position to +48 m and the initial velocity to -12.0 m/s. Try different positive accelerations. Predict the time interval needed for the car to stop.

4 seconds?
As acceleration increases it takes a shorter amount of time for the car to stop.

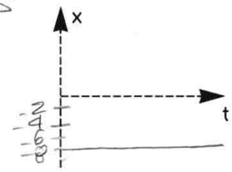
The motion of a car is represented by motion diagrams and graphs. You can choose the motion by adjusting sliders for

- the initial position x_o
- the initial velocity v_o
- the acceleration

Answer the following questions and check your work by adjusting the sliders and running the simulation. The graphs that you are asked to draw are qualitative — don't worry about the detailed numbers.

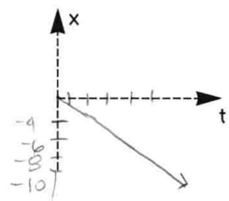
Question 1— Initial Position: Describe in words the meaning of the quantity "initial position x_o." Draw an x-vs-t graph for x_o = −8 m, v_o = 0, and a = 0.

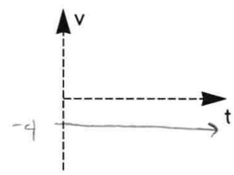
Initial position is the place where the objects starts at.



Question 2 — Velocity and Changing Value of x: Draw x-vs-t and v-vs-t graphs for x_o = 0, v_o = −4 m/s and a = 0. Predict the position x readings at t = 0 s, 1 s, 2 s, and 3 s.

t=0s X_0 = 0 m/s
t=1s X_0 = -4 m/s
t=2s X_0 = -8 m/s
t=3s X_0 = -12 m/s

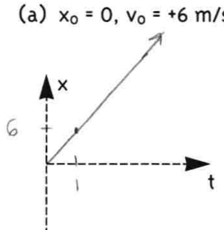


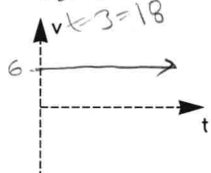


Velocity and Position-Versus-Time Graph: Draw the following x-vs-t and v-vs-t graphs.

(a) x_o = 0, v_o = +6 m/s, a = 0

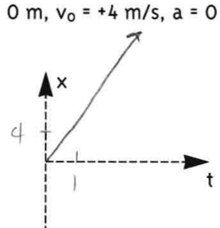
Predict
t=0 X = 0
t=1 X_0 = 6
t2 X_0 = 12
t=3 = 18

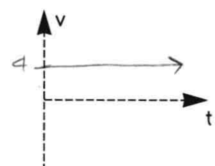




(b) x_o = 0 m, v_o = +4 m/s, a = 0

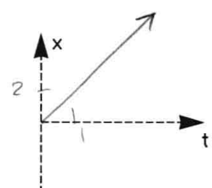
t=0 X_0 = 4
t1 X_0 = 8
t=2 X_0 = 12

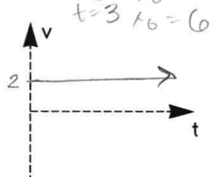




(c) x_o = 0, v_o = +2 m/s, a = 0

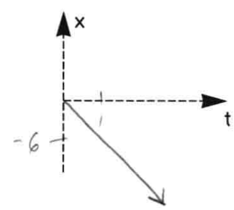
t=1 X_0 = 2
t=2 X_0 = 4
t=3 X_0 = 6

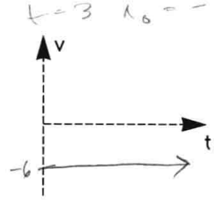




(d) x_o = 0 m, v_o = -6 m/s, a = 0

t=1 X_0 = -6
t=2 X_0 = -12
t=3 X_0 = -18





How is the slope of the x-versus-t graph related to the velocity?

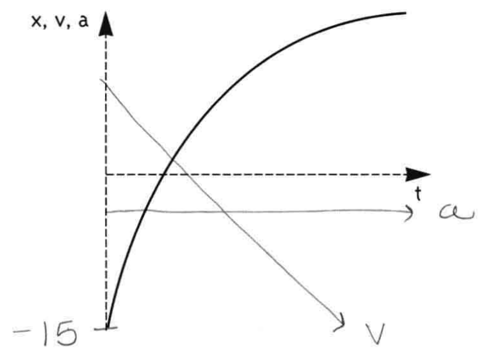
the slope is the velocity

In each of the following five questions, you are first given a position-versus-time graph. From the graph, you are to construct a motion diagram that is qualitatively consistent with the graph. After making the motion diagram, add velocity-versus-time and acceleration-versus-time kinematics graph lines to the position-versus-time graph. (Don't worry about the numbers for the graphs—just the general shapes.) The acceleration is constant.

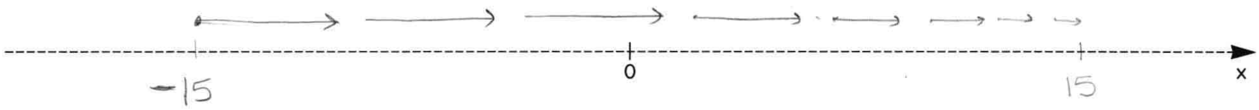
Question 1:

(a) Construct a qualitative motion diagram that is consistent with the x-vs-t graph.

(b) Construct v-vs-t and a-vs-t graphs that are consistent with the x-vs-t graph.



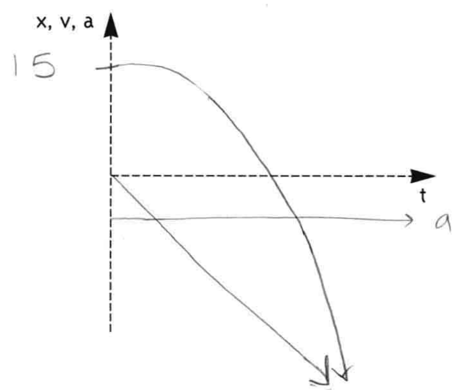
Predicted motion diagram:



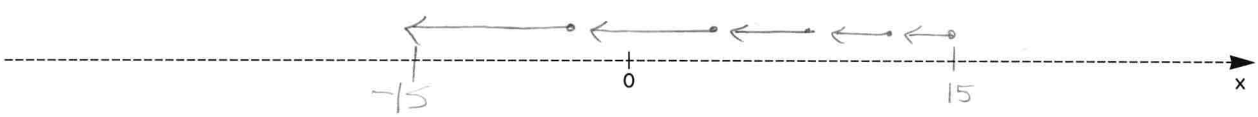
Question 2:

(a) Construct a qualitative motion diagram that is consistent with the x-vs-t graph.

(b) Construct v-vs-t and a-vs-t graphs that are consistent with the x-vs-t graph.



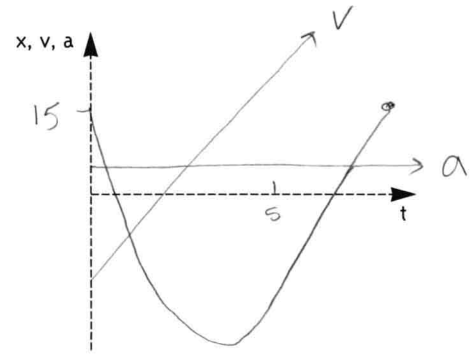
Predicted motion diagram:



Question 5:

(a) Construct a qualitative motion diagram that is consistent with the x-vs-t graph.

(b) Construct v-vs-t and a-vs-t graphs that are consistent with the x-vs-t graph. For your motion diagram, place the dots above the horizontal axis if the object is moving right and below if moving left.



Describe the motion:

The graph slopes quickly downwards stops and speeds upward again.
The car goes backwards fast, slows down; stops, and starts to go forward again at a fast speed.

Kinematics equations describe motion. The equation used in this activity

$x = x_0 + v_0 t + (1/2) a t^2$

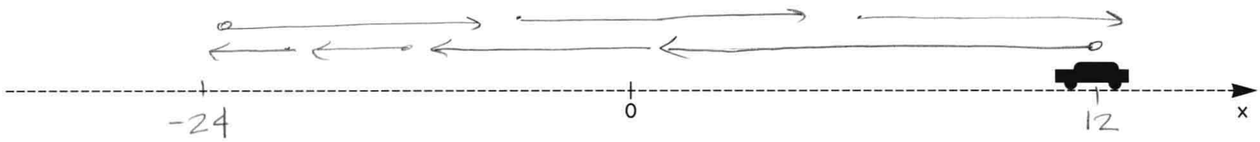
describes the changing position of an object moving along a straight line with constant acceleration. The questions test your ability to identify the values of x_0, v_0, and a.

Question 1: Run the simulation. You see a car, an equation and a white dot whose motion is described by the equation. Adjust the sliders to make the car move with the same motion as the dot — on the first try.

x_0 $v_0 t$ a

$x = + 12.0\ m + (- 12.0\ m/s) + 0.5\,(+ 2.0\ m/s^2)\,t^2$

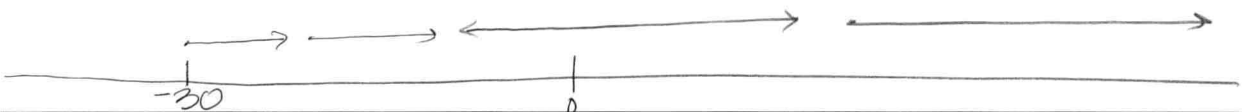
$x_0 = 12$ $v = -12\ m/s$ $a = 2.0\ m/s^2$



Question 2: Run the simulation. You see an equation and a white dot whose motion is described by the equation. Adjust the sliders to make the car move with the same motion as the dot — on the first try.

$x = -30.0\ m + (0.0\ m/s) \cdot t + (3.0\ m/s^2) \cdot t^2/2$

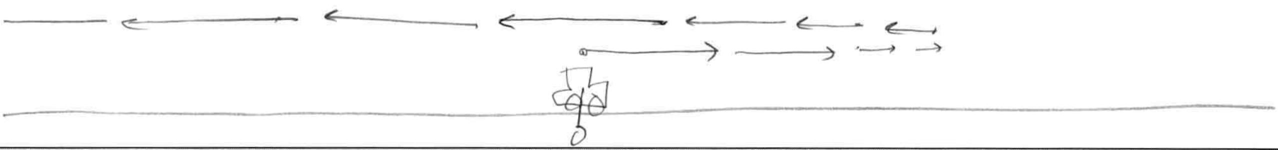
$x_0 = -30\ m$ $v = 0.0\ m/s$ $a = 3\ m/s^2$



Question 3: Run the simulation. You see an equation and a white dot whose motion is described by the equation. Adjust the sliders to make the car move with the same motion as the dot — on the first try.

$x = 0.0\ m + (10.0\ m/s) \cdot t + (-2.0\ m/s^2) \cdot t^2/2$

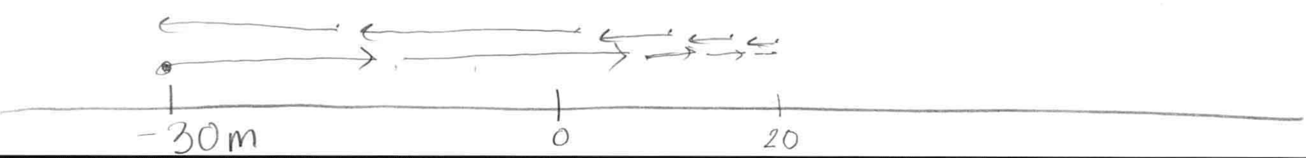
$x_0 = 0$ $v_0 = 10\ m/s$ $a = -2.0\ m/s^2$



Question 4: Run the simulation. You see an equation and a white dot whose motion is described by the equation. Adjust the sliders to make the car move with the same motion as the dot — on the first try.

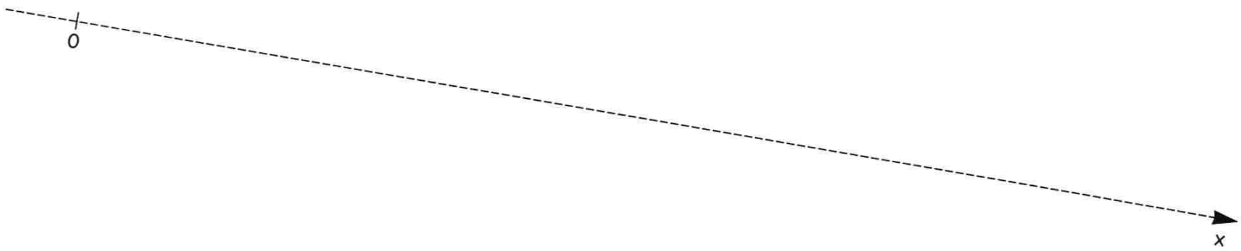
$x = -30.0\ m + (10.0\ m/s)\,t + (-1.0\ m/s^2) \cdot t^2/2$

$x_0 = -30$ $v_0 = 10.0\ m/s$ $a = -1.0\ m/s^2$

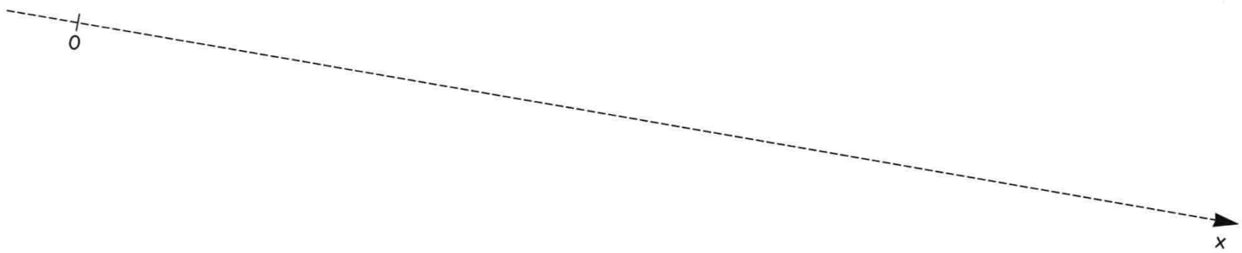


A skier travels 200 m to a finish line, a pole at the last tree. She starts at rest and her speed at the finish line is 31.7 m/s. Describe the process using a pictorial description, a motion diagram, kinematics graphs, and equations. Then determine the time interval needed for the trip and her constant acceleration. (Complete the descriptions below to answer Question 1.)

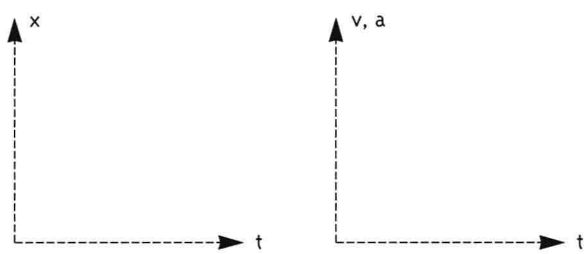
Pictorial Description: Include a sketch, axis, symbols, and values.



Motion Diagram: Compare directions of arrows to the signs of quantities in your pictorial description.



Graphs: Construct the graphs.

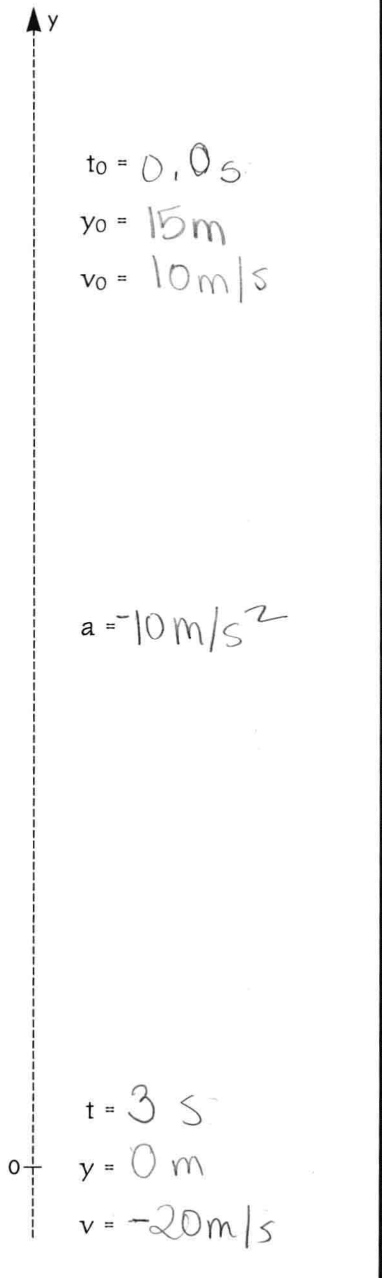


Equations: Solve for the answer.

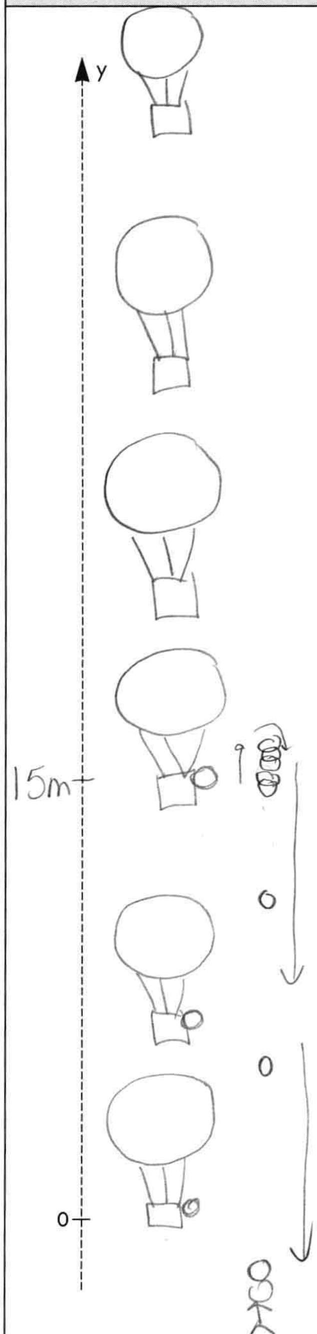
- Move the slider so that the time reads 10.1 s. Note the skier's speed at that time: ______________. Also note the skier's acceleration: ______________. Relying only on the meaning of acceleration and without using any equations, predict her speed at time 12.7 s.
- After moving the slider to 12.7 s, predict the skier's velocity at 3.0 s. Check your prediction by moving the slider back so the meter reads 3.0 s.

A balloonist ascending at a constant speed of 10 m/s accidentally releases a cup of lemonade when 15 m above the head of a crew person directly below the balloon. Determine the time interval that the crew person has to dodge the lemonade. Assume that the gravitational constant is 10 m/s².

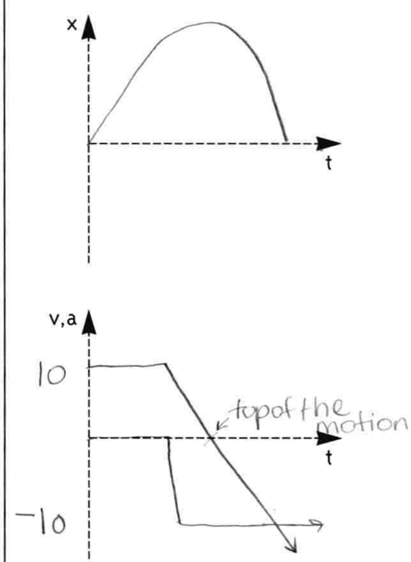
Question 1 — Pictorial Description:



Question 4 — Motion Diagram:



Question 5 — Graphs:



Question 6 — Equations and Solution

$V = V_0 + at$

$-10 = 10 + (-10)(t)$

$-20 = -10t$

$2 = t$ top sec

$-10 = 0 + (-10)(t)$

$-10 = -10t$

$1 = t$ bottom sec

$2 + 1 = 3$ sec

$V = 10 + (-10)(-3)$

$V = 10 - 30$

$V = -20$ m/s

1.1 Analyzing Motion Using Diagrams continued

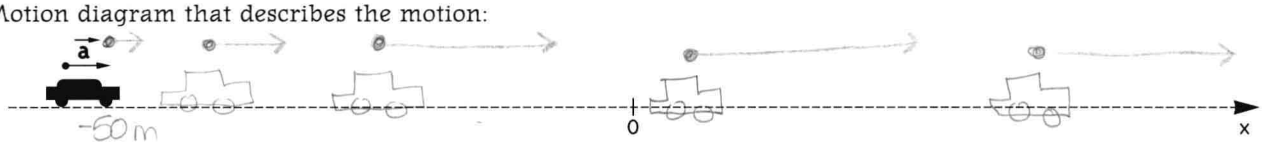
For each problem in Question 7, first run the simulation. Then adjust the initial position, the initial velocity, and the acceleration sliders so that the car has the same motion as the white dot. You should get the signs of the quantities correct on the first try but may need to experiment to get the exact values correct. After matching the motion, draw a motion diagram as a reminder of the motion that occurred.

Problem 1:

Initial slider-setting predictions:
x_0 = −50m
v_0 = 1 m/s
a = 3 m/s²

Slider settings that matched motion:
x_0 = −50m
v_0 = 0
a = 2 m/s²

Motion diagram that describes the motion:

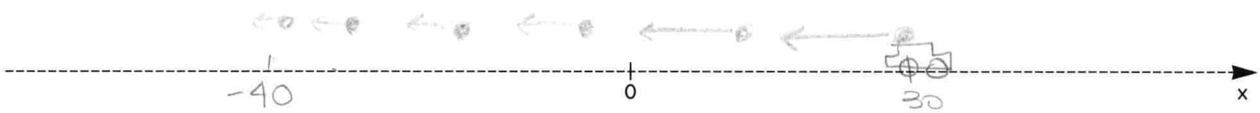


Problem 2:

Initial slider-setting predictions:
x_0 = 30 m
v_0 = −5 m/s
a = 0.0 m/s²

Slider settings that matched motion:
x_0 = 30 m
v_0 = −12.0 m/s
a = 1.0 m/s²

Motion diagram that describes the motion:

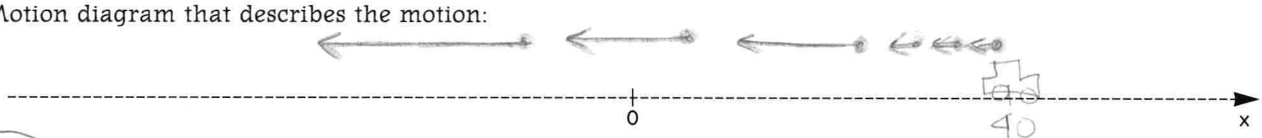


Problem 3:

Initial slider-setting predictions:
x_0 = ~~0 m~~ 40 m
v_0 = 2 m/s
a = −2 m/s

Slider settings that matched motion:
x_0 = ~~0 m~~
v_0 = 0 m/s
a = −2.0 m/s²

Motion diagram that describes the motion:

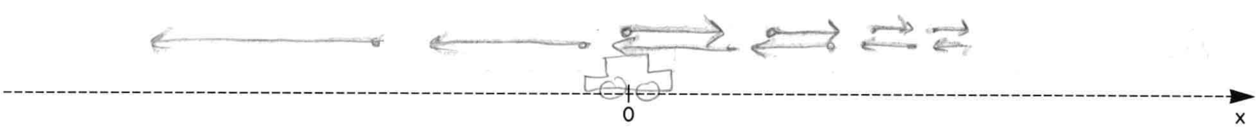


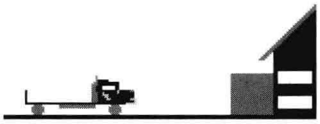
Problem 4:

Initial slider-setting predictions:
x_0 = 0m
v_0 = 10m/s
a = −2.0 m/s²

Slider settings that matched motion:
x_0 = 0m
v_0 = 12 m/s
a = −3.0 m/s²

Motion diagram that describes the motion:





Question 1: A truck traveling at 10 m/s (about 22 mph) runs into a very thick bush and stops uniformly in a distance of 1.0 m. Determine the average acceleration of the truck during the collision.

(a) Pictorial description:

(b) Motion diagram:

(C) Equations and solution:

Question 2: Repeat your calculation, but this time determine the acceleration if the initial speed is 20 m/s. After completing your work, adjust the speed slider in the simulation to 20 m/s and check your answer.

Question 3: You doubled the initial speed from 10 m/s to 20 m/s. Qualitatively,why did the acceleration quadruple instead of double, assuming the same stopping distance?

Question 4: **Why wear seat belts?** The crate on the flat bed of the truck simulates a person wearing no seat belt. Observe very carefully the acceleration of the crate when it hits the hard surface at the back of the truck's cab. Based on the maximum acceleration of the crate, estimate its stopping distance.