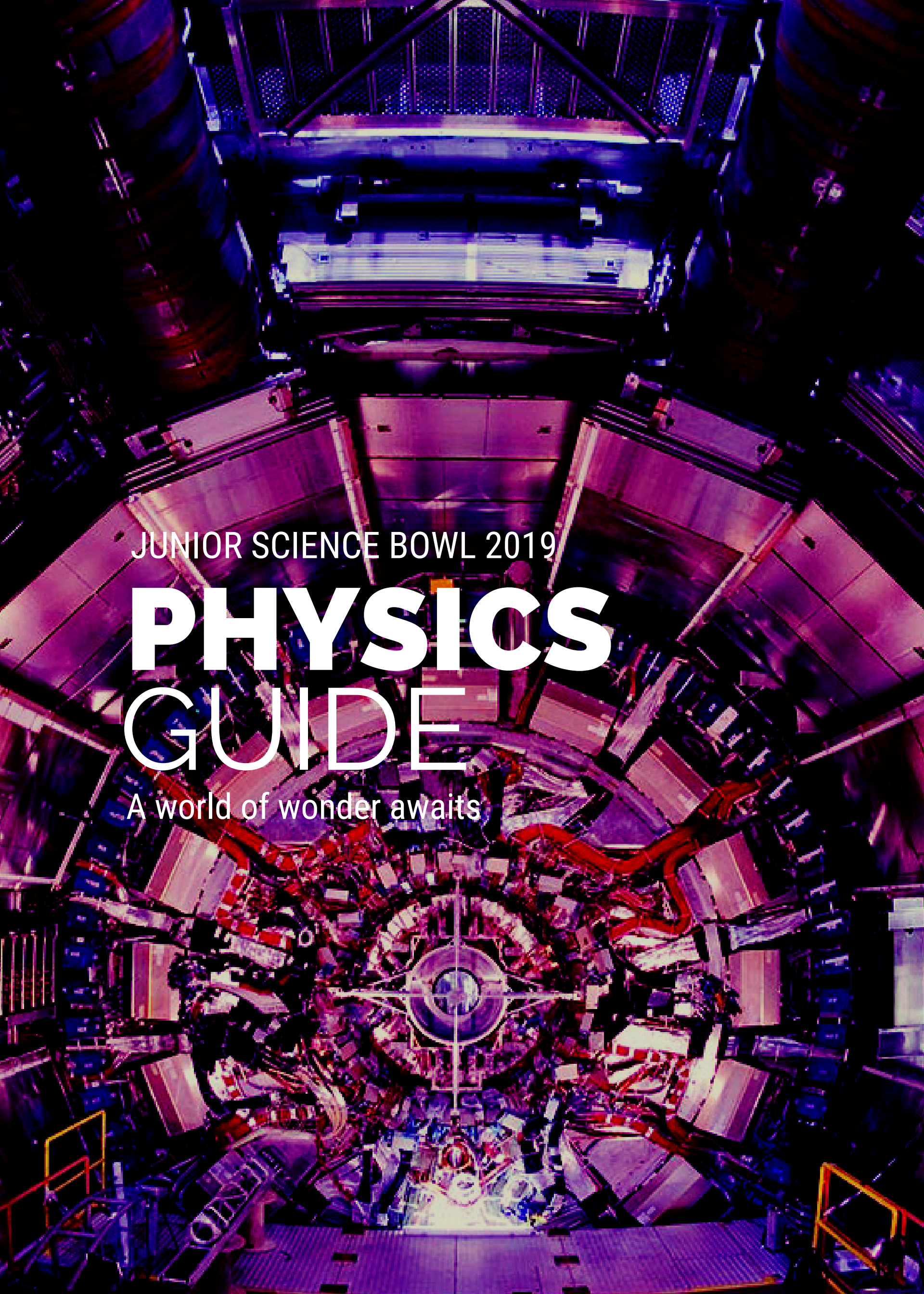


JUNIOR SCIENCE BOWL 2019

PHYSICS GUIDE

A world of wonder awaits

TYPES OF MEASUREMENT

Scalar - only have the **magnitude** and **units**

- Location (x): location of the object
- Distance (d or Δx): length of path that the object moves
- Speed (v): rate of change in distance, $v = d/t = \Delta x/t$

Vector - have magnitude, units, and direction. Arrow is drawn over symbols for vector quantities to indicate that they have direction.

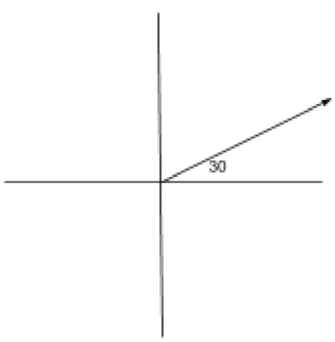
Position ($\vec{x}$): distance of an object relative to a reference point

- Displacement ($\vec{d}$ or $\Delta\vec{x}$): change in position relative to reference point (Δ means the difference between final and initial (Δ = final - initial)
- Velocity ($\vec{v}$): rate of change in displacement, $\vec{v} = \Delta\vec{d}/t$ or $\vec{x}/t$

VECTORS

To state the direction of vectors, use one of the 3 major methods

Compass- use abbreviated forms for North [nt or N], South [st or S], East [et or E], and West [wt or W]. To indicate non major compass directions, follow the example below:



Assume this is 30° above the x-axis. Using compass directions, we can state this direction as

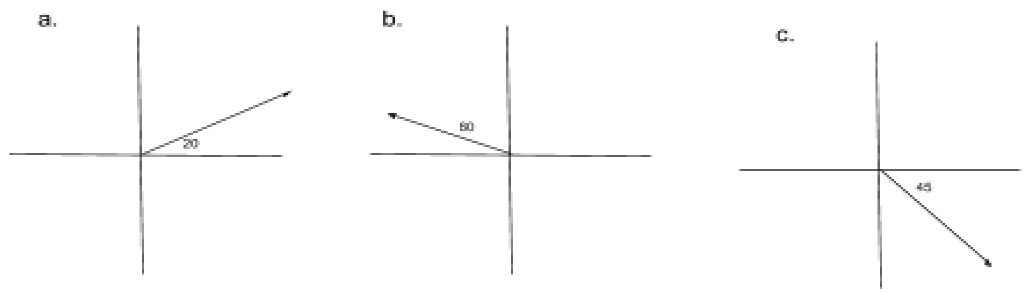
[30° nt of et]	[30° N of E]	[E30°N]
[60° et of nt]	[60° E of N]	[N60°E]

True Bearing - assigns a numeric value to each compass direction. North is [000], and other directions are determined according to degrees clockwise from North (et is [090], st is [180], wt is [270]). For this method, always use a minimum of 3 digits, but the maximum amount of digits is determined by the accuracy of the instrument used. In the example on the left, that arrow's direction is [060]

Vertical Orientation- Uses X-axis as 0 (horizon). In the previous example, the arrow would be considered 30° above the horizon.

Practice: Determine the direction of each arrow using all 3 of the above methods

sciencebowl



Answers:

a: 20° nt of et, [070], 20° above the horizon **b:** 80° wt of st, [280], 10° above the horizon **c:** 45° st of et, [135], 45° below the horizon

SIGNIFICANT DIGITS

It is crucial that Physicists are able to quantify their calculated values into accurate, and realistic values, instead of having a varying amount of digits and numbers. To accomplish this, they utilize a set of rules known as 'significant digits' (sig digs). *Note: The method for manipulating significant digits will be based on international standards, not Alberta Education's standards. It is expected that all given answers are in correct significant digit notation*

Basic Rules for Determining Sig Digs

- Any non-zero number is significant
  ex// 356.5 - all 4 numbers are significant
- Any zeros in between numbers are significant
  ex// 35.06 - all 4 numbers are significant
- Any zeroes following a number are significant
  ex// 35.30 - all 4 numbers are significant
- Any zeroes before (and not in between) a number is insignificant
  ex// 0.0035 - only two numbers are significant; the '3' and '5', the 0's are not

Practice: Determine the number of significant digits

A. 1.36
B. 2.00
C. 1.82
D. 0.0203
E. 6.03
F. 2.0020
J. 0.1230
K. 3200
L. 102
M. 3.1
N. 0.020202
O. 8.88

G. 0.31600
H. 0.01
I. 2.10
P. 1.2
Q. 3
R. 81.0016

Answers
A:3 B:3 C:3 D:3 E:3 F:5 G:5 H:1 I:3 J:4 K:4 L:3 M:2 N:5 O:3 P:2 Q:1 R:6

Manipulating Sig Digs
Sig digs are affected when multiplying & dividing as well as adding & subtracting. It is important that rounding rules are also followed when performing operations on numbers.

Multiplying and Dividing - multiply or divide both numbers, and use the number with less significant digits as the amount of significant digits in your answer.

ex//
3.5 x 7.72 = 27.02, 7.72 has 3 sig digs, and 3.5 has two, use the smaller amount of sig digs (two) in our final answer, giving us 27.

22.6 x 12.383=1.825082..., since 12.383 has five sig digs, and 22.6 has three, we use the smaller amount of sig digs (three) in our final answer, giving us 1.83. (1.825 rounds to 1.83)

Adding & Subtracting - add or subtract both numbers, and use the number with fewer decimal places as the amount of decimal places in your answer.
Note. When adding or subtracting, the total # of sig digs could decrease or increase

ex//
10.363+1.8=12.163, since 10.363 has three decimal places, while 1.8 only has one, our final answer will also only have one decimal place, making it 12.2. (12.16 rounds to 12.2)

101.3-12.215=89.085, since 12.215 has three decimal places, while 101.3 only has one, our final answer will also only have one decimal place, making it 89.1. (89.08 rounds to 89.1)

Combined calculations - questions that require numerous calculations, and will often require both addition/subtraction as well as multiplication/division. There are 2 methods, Albertan and International. Our competition will be utilizing the International method. Both systems follow order of operations

The Alberta method uses the number with the smallest amount of significant digits as the amount of significant digits for the answer.
ex//
$\frac{(2.5+12.833)}{3.735} = 4.1052208...$
Alberta: answer is 4.1, as the equation uses 2.5, which has two sig digs
International: answer is 4.11, calculate the significant digits after each individual calculation. Add 2.5 and 12.833 first, resulting in 15.3 (with proper sig digs), and then divide 15.3 by 3.735, resulting in an answer of 4.11.
Note: Make sure you don't round your answer while doing calculations, leave rounding to the end. You should only ever round during calculations to figure out how many sig digs your answer should have.
Practice:

A) 3.57658+4.00
B) 7.5767-5.6
C) 3.58 * 4.19
D) 4.69382.34
E) 10.934-1.1
F) 9.81 * 3.14159265
G) 69.667-21
H) 3.56 * 1.34 - 2.02230
I) 839.1723 * 2.345
J) 1.11111-0.0089
K) (3.76 + 34.294)/ 67
L) 5.100 + 2.34
M)45 + 903
N) (28.100 - 6.87)/ (5.00 + 2.3)
O) 8.98 * 1.2
P) (9.81+8.7837373)/5.87

Answers
A: 7.58 B: 2.0 C: 15.0 D: 2.01 E: 9.8 F: 30.8 G: 49 H: 2.75 I: 1968 J: 1.1022 K: 0.57 L: 7.44 M: 948 N: 2.9 O: 11 P: 3.12

SCIENTIFIC NOTATION

When working with larger or smaller numbers, long lines of trailing and leading zeroes are hindrances and are largely unnecessary. To fix this, physicists utilize a system called scientific notation to keep data simple and easy to use. Scientific notation uses powers of 10's to turn long numbers into shorter ones. It is similar to saying 350 is the same as 35×10 or 3.5×100.

To utilize scientific notation, you need to perform 3 simple steps.

1. Move the decimal place in the number so that it is behind the first significant digit (first significant number starting from the left)

ex// 7300.0 will become $7.3 \times n$, 0.003 will become $3 \times n$

2. Count how many spots the decimal place moves, if the decimal point moves left then the number is positive, and if the decimal moves right, then it is negative

   ex// 7300.0 moves left 3 places, so +3, 0.003 will move right 3 spaces, so -3
3. Turn your number into powers of ten, by putting x 10^n after your number (where n is the number from step 2)

   ex// 7300.0 will become 7.3×10^3 , 0.003 will become 3×10^{-3}

Note: Scientific Notation will also follow significant digit rules, so it is important to make sure your answers in scientific notation have the correct significant digits

KINEMATICS: SCALAR MOTION

A scalar quantity of motion one that has magnitude and appropriate units (most commonly used in this section are metres (m), seconds (s), and metres per second (m/s)).

Key Formula: v = d/t = Δx/t

ex// Soumav on a bike travels 400 m in 8.0 s at a constant speed. Determine:

a. His average speed
   d = 400m, t = 8.0 s, v = d/t = (400 m)/(8.0 s) = 50 m/s
b. How far he travelled in 3.0 s
   t = 3.0 s, v = 50 m/s, d = vt = (50 m/s) (3.0 s) = $1.5 \times 10^2\ m$
c. How long it took him to travel 200 m
   d = 200 m, v = 50 m/s, t = d/v = (200 m) / (50 m/s) = 4 s
d. What direction he was travelling
   Unable to determine, quantities are scalar, not vector.

Practice:

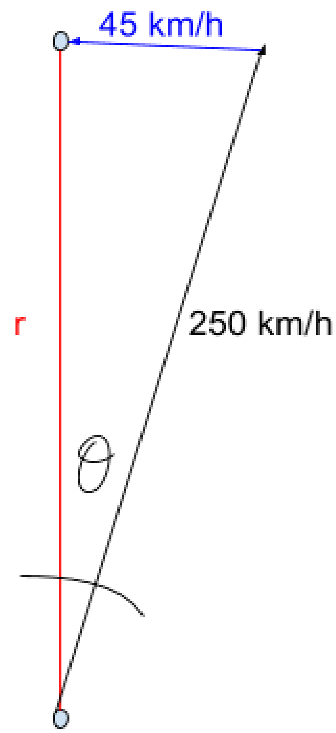
1. The distance from home plate to the pitcher's mound is 18.5 m. If Soumav can throw a baseball at 133 km/h, how much time does it take to reach home plate? (0.501 s)
2. Soumav ran for 30 min at 10 km/h and walked at 5 km/h for 3 hours. What's his average speed for the whole trip? (5.7 km/h)

VECTOR MOTION

Vectors quantities have magnitude, units, and directions. Vectors can be added to vectors of the same type to produce a resultant vector. The easiest way to do this is to use the

Pythagorean theorem and/or trigonometry to break them into their x and y components.

Key formula: $\vec{v} = \Delta \vec{d}/t$



ex// Soumav flies from Calgary due north to Edmonton, a distance of 350.0 km. The wind is blowing from the east at 45.0 km/h, and the plane cruises at 250 km/h. Determine

a. The bearing the pilot must use to travel north
   θ = $sin^{-1}(opp / hyp) = sin^{-1}((45.0\ km/h) / (250.0\ km/h)) = 10.369..°$ et of nt, or [010.4]
b. The relative velocity (r) of the plane as it travels due north
   r = $\sqrt{(250.0km/h)^2 - (45.0km/h)^2}$ = 245.916.. km/h [N],

   rounded to 246 km/h [N]
c. How many hours the flight will take
   t = d/v = (350 km [N] / 245.916… km/h [N]) = 1.423… h, rounded to 1.42 h

Practice:

1. On an airplane, Soumav travelled 50.0 km north and 30.0 km east. Determine
   a. Total distance travelled (80.0 km)
   b. Resultant displacement (58.3 km [31.0 ° et of nt]
2. Soumav walks 6.0 km from camp on a bearing of [160], then turns and walks 8.0 km with a bearing of [030]. Determine
   a. Resultant displacement of Soumav from camp (6.2 km [12 ° nt of et])
   b. Bearing that Soumav must follow to return to camp ([258])
3. Add the following: 110 m [60.0 ° wt of st] , 100 m [045.0], 80.0 m [et], 160 [wt 20.0 $°st$] (103 m [22.3°st of wt])

ACCELERATION

Acceleration is defined as the rate of change in velocity (an object slowing down or speeding up) , and is determined using the formula

$\vec{a} = \Delta \vec{v}/t$, and is given the units m/ s^2

Key formulas: $\vec{a} = \Delta \vec{v}/t$ d = $v_{initial}t + \frac{1}{2} \vec{a} t^2$ $v_{final}^2 = v_{initial}^2 + 2 \vec{a}$ d

ex//

1. What is the acceleration of Soumav if his speed is uniformly increased from 44 m/s [fd] to 66 m/s [fd] in 11 s?
   $v_i = 44 m/s\ [fd]$ $v_f = 66 m/s$ [fd] t = 11s a = ?
   $a = \frac{\Delta v}{t} = \frac{v_f - v_i}{t} = \frac{66 m/s\ [fd] - 44 m/s\ [fd]}{11 s} = 2.0 m/s^2 [fd]$
2. Soumav travelling at 88m/s [fd] is slowed down to 32m/s[fd] in 15s. What displacement does the rocket travel during this time?
   $v_i = 88 m/s\ [fd]$ $v_f = 32 m/s [fd]$ t = 15s d = ?
   d = $v_{initial} t + \frac{1}{2}$ a t^2 , find a
   a = $\frac{v_f - v_i}{t} = \frac{32 m/s [fd] - 88 m/s [fd]}{15 s}$ = -3.733... $m/s^2 [fd]$, substitute this into the formula for d
   d = $v_{initial} t + \frac{1}{2}$ a $t^2 = 88 m/s [fd] + \frac{1}{2}(-3.733... m/s^2 [fd])(15 s)^2$ = 9.0 $x\ 10^2 m$ [fd]

Note: notice how the direction of the acceleration vector changed the answer? Make sure that your directions are aligned prior to doing any calculations.

3. A traffic light turns green. Soumav's car starts from rest with a constant acceleration of 1.8 $m/s^2 [fd]$. at the same time, a truck travelling at a constant speed of 8.5 m/s [fd].
   a. How far from the traffic light will Soumav's car overtake the truck?

The best way to tackle this problem is to start with the truck and the car separate. Because the time that the car overtakes the truck will be the same for both vehicles, the formulas for time can be equated.

Car: $v_i = 0$ $v_f = ?$ a_c = 1.8 $m/s^2 [fd]$ d = same as truck t = same as truck

Use the formula d = $v_{initial} t + \frac{1}{2}$ a t^2 , $v_{initial} t$ drops out of the equation because $v_i = 0$. isolate t

$t^2 = \frac{2d}{a_c}$

Truck: $v_t = 8.5\ m/s\ [fd]$ d = same as truck t = same as truck

Use formula for constant velocity, v = d/t, isolate for t

t = d/ v_t , square in order to equate to formula for car

$t^2 = \frac{-d^2}{{v_t}^2}$

Now that the formulas are both solving for t^2 , we can equate them

$\frac{2d}{a_c} = \frac{-d^2}{{v_t}^2}$, simplify to solve for d

d = $\frac{2\,{v_t}^2}{a_c} = \frac{2\,(8.5\ m/s\ [fd])^2}{1.8 m/s^2 [fd]}$ = 80 m [fd]

   b. How fast will the car be travelling when it overtakes the truck?

Easiest way to solve this question is to use the formula $v_{final}^{\,2} = v_{initial}^{\,2} + 2$ ad, no need to solve for t, and v_i drops out of the equation. Use distance that we solved for in the first part of the question

$v_f^{\,2} = 2$ad , $v_f = \sqrt{2ad} = \sqrt{2(1.8m/s^2[fd])(80.27....m)}$ = 17 m/s [fd]

Practice:

1. A plane flown by Soumav starting from rest is accelerated uniformly to its takeoff speed of 72 m/s [fd] in 5.0 s. What is the plane's acceleration? (14 $m/s^2[fd]$)
2. A box falls out of a forklift driven by Soumav and slides along the ground for 62.5 m [fd]. Friction acts upon the box at 5.0 $m/s^2[bd]$. What was the initial velocity of the box? (25 m/s [fd])

3. While driving his car, Soumav sees Joseph on the road. His car is travelling at 25 m/s [fd], and it takes him 0.80 to react before he can apply the brakes.
    a. How far will the car travel before Soumav applies the breaks? (20 m [fd])
    b. When the brake is applied, the car decelerates at a rate of -9.4 $m/s^2[fd]$. If
    c. Joseph is 60 m ahead of the car, will he be hit? (no, car only travels 54 m [fd]

GRAVITY

Free fall is when a body undergoes a change in motion due to gravitational force. The accepted value for gravity at sea level is 9.81 $m/s^2[dn]$, and is represented by the symbol $\vec{g}$.

Falling Objects

Keys to solving questions involving dropping objects:

- Initial velocity is 0, unless specified by the question
- For the fall, acceleration = gravity = 9.81 $m/s^2[dn]$
- Final velocity is not 0, it's the speed of the object just before it hits the ground

- Directions are important

ex// Soumav drops a rock from a bridge and it hits the water after 3.5 s. How high above the water is the bridge?

$v_i = 0$ $a = 9.81\, m/s^2[dn]$ d = ? t = 3.5 s

Values suggest using the equation

d = $v_{initial}t + \frac{1}{2}$ a t^2 , $v_{initial}t$ drops out of the equation because $v_i = 0$

d = $\frac{1}{2}$ a t^2 = $\frac{1}{2}$ (9.81 $m/s^2[dn]$) $(3.5s)^2$ = 60 m [dn]

Height of bridge is 60 m

Throwing Stuff Upwards

Keys to solving problems involving vertical projectiles:

- Acceleration for both trips is constant
- Velocity at the top of the path is 0 m/s
- Initial and final velocities are not 0, v_i is the velocity just as the object is thrown, v_f is the velocity right before it hits the ground
- Trip up and trip down are symmetrical, meaning time going up = time falling down, and magnitudes of $v_{inst\ up} = v_{inst\ down}$
- Directions are important

ex// Soumav jumps up with a velocity of 25 m/s [up]. Determine

a. How high he'll jump

$v_i = 25\ m/s\ [up]$ $v_f = 0\ m/s$ $a = 9.81\, m/s^2[dn]$ d = ?

$v_f{}^2 = v_i{}^2 + 2$ ad, $v_f = 0\ m/s$ so $0 = v_i{}^2 + 2$ ad

d = $\frac{-v_i{}^2}{2a}$ = $\frac{-(25\ m/s\ [up])^2}{2\,(-9.81 m/s^2[up])}$ = 32 m [up]

b. How much time it will take for him to jump up and return to the ground

Method One: Time up = time down

$v_i = 25\ m/s\ [up]$ $v_f = 0\ m/s$ $a = 9.81\, m/s^2[dn]$ t = ?

a = $\frac{(v_f - v_i)}{t}$, v_f drops out of equation, rearrange to find t

$t_{up} = \frac{-v_i}{a} = \frac{-(25\ m/s\ [up]}{-9.81 m/s^2[up]}$ = 2.548… s, double the time to account for the entire trip time

t = 5.1 s

Method Two: Acceleration equation

$v_i = 25\ m/s\ [up]$ $a = 9.81\, m/s^2[dn]$ d = 0 m (total displacement is 0 because Soumav returns to the position that he started in, which is on the ground) t = ?

d = $v_i t$ + $\frac{1}{2}$ a t^2 , d drops out of the equation,
0 = $v_i t$ + $\frac{1}{2}$ a t^2 , - $\frac{1}{2}$ a t^2 = $v_i t$, rearrange for t
t = $\frac{2v_i}{-a}$ = $\frac{2(25\ m/s\ [up])}{-(-9.81 m/s^2[up])}$ = 5.1 s (time for the total trip)

Horizontal Projectiles

Keys to solving problems involving horizontal projectiles:

- Split the motion into its 2 components
  - X-component is the constant velocity
    - d_x = horizontal distance travelled
    - v_x = some value
    - t = time for the entire motion
  - y-component is the constant acceleration due to gravity
    - d_y = vertical distance, usually height
    - v_y = 0 if object is projected horizontally
    - a_y = 9.81 $m/s^2[dn]$
    - t = time for the entire motion
- Time for both components is the SAME

ex// Soumav is on top of a 30.0 m tall building and kicks a soccer ball horizontally off the roof with a velocity of 8.0 m/s. Determine how far from the base of the building the ball will land

$v_x = 8.0\ m/s$ [fd] d_x =? a_y = 9.81 $m/s^2[dn]$ $d_y = 30.0\ m$ $v_y = 0\ m/s$ t = ?

Equation suggested from values is

d_y = $v_y t$ + $\frac{1}{2}$ a_y t^2 , $v_y = 0$, so it drops out of the equation, rearrange for t

t = $\sqrt{\frac{2d_y}{a_y}}$ = $\sqrt{\frac{2(30.0m)}{9.81m/s^2[dn]}}$ = 2.47...s

Note: drop the direction, because time is not a vector quantity

Because time applies to both planes, we can use it to find distance in the x plane

$v_x = 8.0\ m/s$ [fd] d_x =? t = 2.47...s

Equation suggested from values is

v_x = $\frac{d_x}{t}$, rearrange for d_x

d_x = v_x t = ($8.0\ m/s$ [fd])(2.47...s) = 20 m [fd]

The ball lands 20 m [fd] from the base of the building

Practice Questions:

1. Soumav is lying on a bridge and throws a stone straight up at 5.0 m/s. 4.5 s later, the stone hits the water below. Determine the height of the bridge above the water. (77m)
2. While running forward at 8.00 m/s, Soumav throws a baseball straight up at 6.25 m/s. How far will Soumav run before the ball lands back in his hand? (10.2 m [fd])
3. In a hot air balloon far above the Earth, Soumav drops a bolt. He's so upset that 3.00 s later he throws a screw after it with an initial velocity of 45.0 m/s [dn]. When and where will the screw catch up to the bolt? (2.84 s, 167 m [dn])

4. Soumav lays at the edge of a riverbank 49.0 m above the water. He throws a stone upward and sees it splash below 6.50 s later. What was the initial velocity of the stone? (24.3 m/s [up])
5. While hammering nails on a high rise construction project, Soumav's hammer goes flying and breaks a window in the adjacent building 45 m below where he is working. The distance between the two buildings is 30.0 m.
   a. How long is the hammer in the air? (3.0 s)
   b. What was the initial horizontal velocity of the hammer? (9.9 m/s [fd])