Bonnie and Clyde

(from Minnesota Cooperative Group Problems #12)
In your new job, you are the technical advisor for the writers of a gangster movie about Bonnie and Clyde. In one scene Bonnie and Clyde try to flee from one state to another. If they get across the state line, they could evade capture, at least for a while until they become Federal fugitives. In the script, Bonnie is driving down the highway at 108 km/hr and passes a concealed police car that is 1 km from the state line. The instant Bonnie and Clyde pass the patrol car, the cop pulls onto the highway and accelerates at a constant rate of 2 m/s^2. The writers want to know if they make it across the state line before the pursuing cop catches up with them.

This is a 1D kinematics problem.

There are several ways to check if they got away:

1. Find the time when Bonnie & Clyde pass the state line and use it to find where the cop is.

2. Find the time when Bonnie & Clyde pass the state line and compare it to when the cop does the same. If the cop crosses earlier, it means he caught them.

3. Find where the cop catches them and compare it to the state line distance.

We'll show you ② and ③

For either solution, you must first convert all distances and times so the units match:

$$V_{BC} = 108 \text{ km/hr} = 30 \text{ m/s}$$

$$\Delta x = 1 \text{ Km} = 1000 \text{ m}$$

② Finding time to cross the border:

Bonnie & Clyde	Cop
$x = \cancel{x_0}^{0} + V_0 t + \frac{1}{2}\cancel{a}^{0} t^2$	$x = \cancel{x_0}^{0} + \cancel{V_0}^{0} t + \frac{1}{2} a t^2$
$x = V_{BC}\, t$	$x = \frac{1}{2} a t^2$
$\boxed{t = 33.3\text{ s}}$	$\boxed{t = 31.6\text{ s}}$

③ When the cop catches Bonnie & Clyde,
it must be true that they have the same position.

$$x_{BC} = x_c$$

Based on the information in the problem,

$$x_{BC} = v_{BC} t \quad \text{and} \quad x_c = \frac{1}{2} a t^2$$

If the cop catches them, the positions must be the same at the same time t.

Solving the two equations for

$$x = x_{BC} = x_c$$

You should find

$$\boxed{x = 900 \text{ m}}$$

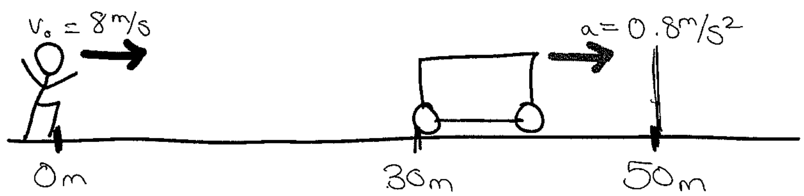
By any method, you will find that the cop catches Bonnie and Clyde.

Catching the Train

You are going to Chicago for the weekend and you decide to go first-class by taking the AmTrak train. Unfortunately, you are late finishing your mathematics exam, so you arrive late at the train station. You run as fast as you can, but just as you reach the platform your train departs, 30 meters ahead of you down the platform. You can run at a maximum speed of 8 m/s and the train is accelerating at 0.8 m/s^2. You can run along the platform for 50 meters before a barrier prevents you from going further. Will you catch your train?

No need to convert units this time, everything is in meters.

A picture might help keep track of the information:



For now, let's ignore the barrier and just find out where you will catch the train.

Your position: $x = \cancel{x_0}^{\,0} + v_0 t + \cancel{\tfrac{1}{2}a}^{\,0} t^2$ $\qquad x = v_0 t$

Train position: $x = \underbrace{x_0}_{30\,m} + \cancel{v_0}^{\,0} t + \frac{1}{2}at^2$ $\qquad x = x_0 + \frac{1}{2}at^2$

When you catch the train, x and t will be equal in both equations.

Using this information, solve for x.

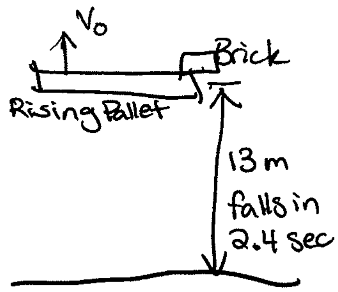
$$\boxed{x = 40\,m}$$

This is smaller than 50 m (the location of the barrier) so you catch your train.

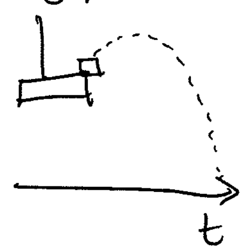
Falling Brick

As you are cycling to classes one day, you pass a construction site on Green Street for a new building and stop to watch for a few minutes. A crane is lifting a batch of bricks on a pallet to an upper floor of the building. Suddenly, a brick falls off while the pallet is rising. You clock the time it takes the brick to hit the ground at 2.4 seconds. The crane, fortunately, has height markings, and you see the brick fall off the pallet at a height of 13 meters above the ground. A falling brick, as we all know, can be dangerous, and you wonder how fast the brick was going when it hit the ground. Since you are taking physics, you quickly calculate the answer.

Let's draw the initial conditions



The brick is on the rising pallet, meaning $V_o > 0$.



Use the time and distance information to find V_o:

$$y = y_o + V_o t + \frac{1}{2} a_y t^2$$

$$0 = 13 + V_o(2.4) + \frac{1}{2}(-9.8)(2.4)^2$$

You should find $V_o = 6.34\ \text{m/s}$

Using this new information, you can find V_f:

$V_f = V_o + at$ or $V_f^2 = V_o^2 + 2a\Delta y$ ← Note: Δy is negative

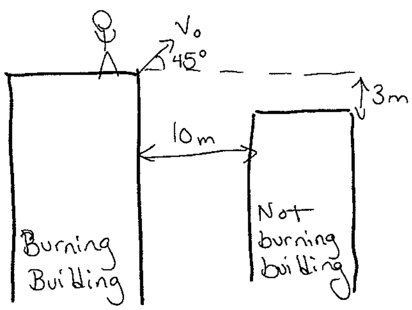
You should find

$$\boxed{V_f = -17.2\ \text{m/s}}$$

Escape from Burning Building

Your friend, a world-class long jumper, is trapped on the roof of a burning building. His only escape route is to jump to the roof of the next building. Fortunately for him, he is in telephone contact with you, a Physics 211 student, for advice on how to proceed. He has two options. He can jump to the next building by using the long-jump technique where he jumps at 45° to the horizontal. Or, he can take his chances by staying where he is in the hopes that the fire department will rescue him. You learn from the building engineers that the next building is 10 m away horizontally and the roof is 3 m below the roof of the burning building. You also know that his best long-jump distance is 7.9 m. What do you advise him to do?

Once again, a picture will help us keep track of the information:



This is a 2D kinematics problem so we now have to think about vector components.

You know how far your friend needs to jump, but you don't know his initial speed!

We can use his long jump information to determine V_0:

Long jump:

$y = y_0 + V_{oy} + \frac{1}{2}at^2$

$x = x_0 + V_{ox}t + \frac{1}{2}at^2$

V_{oy} and V_{ox} are the x- and y- components of $\vec{V}_0$

$V_{oy} = V_0 \sin\theta \qquad V_{ox} = V_0 \cos\theta$

From these, you can find

$\boxed{V_0 = 8.8\ m/s}$

We're not done yet!

To see if your friend should jump, we need to find out how far he goes with the v_0 we found:

- Find how much time he spends in the air

$$y = y_0 + V_{0y} t + \frac{1}{2} a_y t^2$$

$$-3 = 0 + v_0 \sin\theta t + \frac{1}{2}(-9.8) t^2$$

↑

other roof is 3m lower

- Find how far he travels in this time

$$x = x_0 + V_{0x} t + \frac{1}{2} a t^2$$

$$x = 0 + V_0 \cos\theta t$$

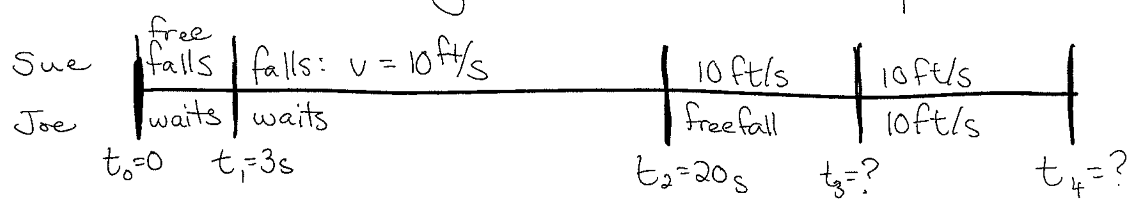
You should find $\boxed{x = 10.21 \text{ m}}$

It is safe for your friend to jump.

Skydivers

The U of I Skydiving Club has asked you to plan a stunt for an air show. In this stunt, two skydivers will step out of opposite sides of a stationary hot air balloon 5,000 feet above the ground. The second skydiver will leave the balloon 20 seconds after the first skydiver, but you want them both to land on the ground at the same time. The show is planned for a day with no wind so you may assume all motion is vertical. To get a rough idea of the situation, assume that a skydiver will fall with a constant acceleration of 32 ft/sec^2 before the parachute opens. As soon as the parachute is opened, the skydiver falls with a constant speed of 10 ft/sec. If the first skydiver, Sue, waits 3 seconds after stepping out of the balloon before opening her parachute, how long must the second skydiver, Joe, wait after leaving the balloon before opening his parachute?

1D kinematics again! A timeline will help:



We are looking for $t = t_3 - t_2$

Joe pulls his parachute so that he and Sue will land at the same time. From t_3 to t_4 both skydivers fall at the same speed, so they must share the same position from t_3 to t_4 (or else they cannot land together).

Thus we know $y_{Sue}(t_3) = y_{Joe}(t_3)$ ← functions $y(t)$, <u>not</u> $y \times t$

What is $y_{Sue}(t_3)$?

t_0 to t_1: 3 sec free fall: $y_1 = \underset{5000ft}{y_0} + \frac{1}{2}\underset{-32 ft/s^2}{a} t^2$

t_1 to t_3: Parachute fall for $(17+t)$: $y_{3S} = y_1 + \underset{-10 ft/s}{v}(17+t)$

How about $y_{Joe}(t_3)$?

t_0 to t_2: nothing happens

t_2 to t_3: freefall for t seconds: $y_{3J} = \underset{5000ft}{y_0} + \frac{1}{2}\underset{-32ft/s^2}{a} t^2$

Set $y_{3S} = y_{3J}$ to find $\boxed{t = 4.75 \text{ sec}}$