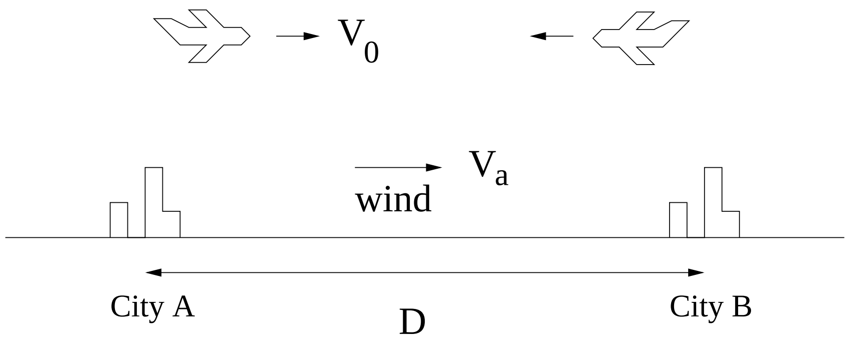
Problem 1 (15pts) A round trip flight:

An airplane flies between two cities separated by a distance D. Assume the wind blows directly from one city to the other at a speed V_a and the speed of the airplane is V_0 relative to the air.

(a) How long does it take for the airplane to make a round trip between the two cities?

(b) To an observer on the ground, what is the average speed of the airplane for such a round trip?

(c) To an observer on the ground, what is the average velocity for the round trip?



Solution:

(a) Total time $= \frac{D}{V_0+V_a} + \frac{D}{V_0-V_a} = \frac{2DV_0}{V_0^2-V_a^2}$.

(b) Average speed is $\frac{\text{Total distance traveled}}{\text{Total time}}$. We find the average speed $= \frac{2D}{2DV_0/(V_0^2-V_a^2)} = \frac{V_0^2-V_a^2}{V_0}$

(c) Average velocity is $\frac{\text{Net displacement}}{\text{Total time}} = 0$ since the net displacement is zero.

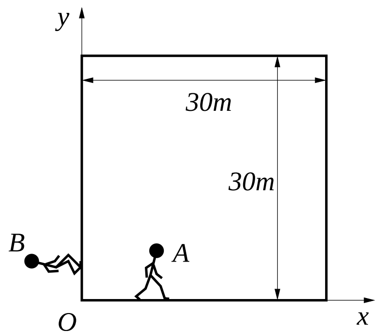
Problem 2 (15pts) Two walkers:

Two persons start from the same location O and walk around a square in opposite directions with constant speeds. The square is 30m by 30m. A's speed is 2m/s and B's speed is 1m/s.

(a) Find the coordinates of the point where A and B will meet for the first time.

(b) Find the distance between the meeting place and the origin O.

(c) Find the average velocity $\vec{V}_A$ of A and the average velocity $\vec{V}_B$ of B between the time when they first start and the time when they first meet.
(Either give the components of $\vec{V}_A$ and $\vec{V}_B$ or their magnitudes and directions.)



Solution:

(a) To meet A travels 80m and B travels 40m. They meet at $(10m, 30m)$.

(b) The distance is $\sqrt{10^2 + 30^2} = 10\sqrt{10}$m.

(c) The average velocities of A and B are the same since they have the same net displacement during the same time. A and B traveled for $\frac{40m}{1m/s} = 40s$. Thus $\vec{V}_A = \vec{V}_B = \frac{(10,30)m}{40s} = (0.25m/s, 0.75m/s)$.

Problem 3 (15pts) Targeting:

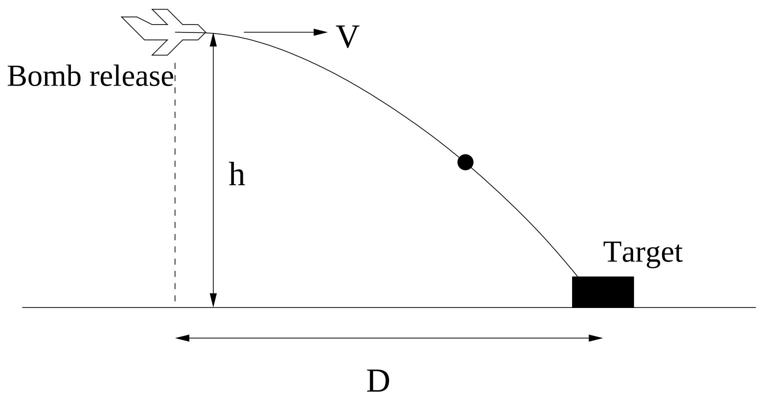
A bomber flies horizontally with a speed V and at a height h. Ignore the air friction and assume there is no wind. The acceleration of gravity is g. (Express your answer in terms of V, h, and g.)

(a) How long does it take for the bomb to reach the ground?

(b) To bomb a target, how far away from the target should the bomber release the bomb? (*ie* Find the distance D in the figure below.)

(c) What is the speed of the bomb just before it hits the target?

(d) What is the location of the airplane when the bomb strikes the target.



Solution:

(a) The bomb free fell for a distance h. From $h = \frac{1}{2}gt^2$, we find that it takes $t = \sqrt{\frac{2h}{g}}$ for the bomb to reach the target.

(b) The horizontal velocity of the bomb is always V. Thus $D = Vt = V\sqrt{\frac{2h}{g}}$.

(c) The vertical velocity of the bomb before striking the target is $V_{vert} = tg = \sqrt{2hg}$. The speed of the bomb before striking the target is $\sqrt{V_{vert}^2 + V^2} = \sqrt{2gh + V^2}$.

(d) Since the bomb and the airplane have the same horizontal velocity, when bomb striks target, the airplane is right above the target.

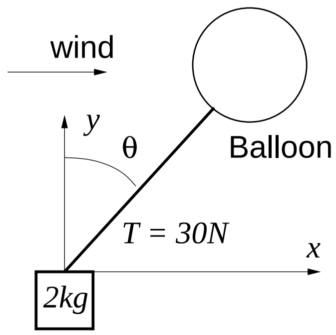
Problem 4 (15pts) A balloon and a block:

A balloon is tied to a block. The mass of the block is $2kg$. The tension of the string between the balloon and the block is $30N$. Due to the wind, the string has an angle θ relative to the vertical direction. $\cos\theta = 4/5$ and $\sin\theta = 3/5$. Assume the acceleration of gravity is $g = 10m/s^2$. Also assume the block is small so the force on the block from the wind can be ignored.

(a) Find the x-component and the y-component of the force $\vec{F}$ exerted on the block by the string.

(b) Find the x-component and the y-component of the acceleration $\vec{a}$ of the block.

(c) Assume the mass of the balloon is zero and the force of the wind on the balloon is in the x-direction. Find the magnitude of the force of the wind on the balloon.



Solution:

(a) The magnitude of the force (from the string) is $T = 30N$.
The x-component $= T\sin\theta = 30 \times \frac{3}{5} = 18N$.
The y-component $= T\cos\theta = 30 \times \frac{4}{5} = 24N$.

(b) The total force on the block is:
the x-component $= 18N$.
the y-component $= 24 - mg = 24 - 20 = 4N$.
The x-component of the acceleration $= 18N/2kg = 9m/s^2$.
The y-component of the acceleration $= 4N/2kg = 2m/s^2$.

(c) Since the mass of the balloon is zero, the net force on the balloon must be zero. The x-component of the force on the balloon by the string is $-18N$. The force from the wind on the balloon must balance that force and thus must be $18N$.