Problem 1.

A subway train is intially moving at 8 m/s. The conductor applies the brakes, producing a constant deceleration. After the train has moved 120 m, it has a speed of 4 m/s.

a) What is the magnitude of the acceleration?

b) How long did it take to travel that 120 m?

c) How far will it be from its initial location after an additional 10 s?

1D motion, constant acceleration

a) $v^2 = v_0^2 + 2a\Delta x \quad \therefore \quad a = \frac{v^2 - v_0^2}{2\Delta x} = \frac{(4\,m/s)^2 - (8\,m/s)^2}{2(120\,m)} = -0.2\,m/s^2$

magnitude of $a = \boxed{0.2\,m/s^2}$

b) $v = v_0 + at \quad \therefore \quad t = \frac{v - v_0}{a} = \frac{4\,m/s - 8\,m/s}{0.2\,m/s^2} = \boxed{20\,s}$

c) total time $= 20s + 10s = 30s$

$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

$$= 0 + \left(8\frac{m}{s}\right)(30s) + \frac{1}{2}\left(-0.2\,m/s^2\right)(30s)^2 = \boxed{150\,m}$$

or just consider last 10s ; "x_0" = 120m, "v_0" = 4m/s

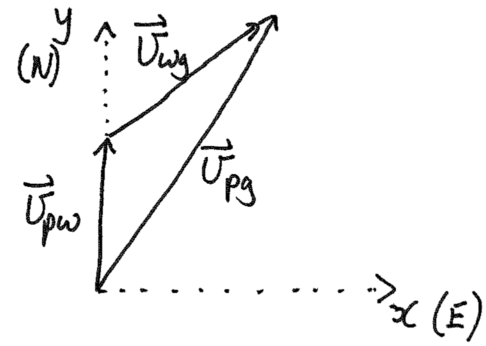
$$x = x_0 + v_0 t + \frac{1}{2}at^2$$

$$= 120m + \left(4\frac{m}{s}\right)(10s) + \frac{1}{2}\left(-0.2\frac{m}{s^2}\right)(10s)^2 = 150m$$

Problem 2.

A pilot heads her airplane due north at a speed, relative to still air, of 300 km/hr. There is a steady wind blowing. One hour later, she arrives at a location that is 330 km north and 40 km east of where she started.

What is the speed and direction of the wind?



Relative velocity problem.

Let: $\vec{v}_{pw}$: velocity of plane with respect to wind

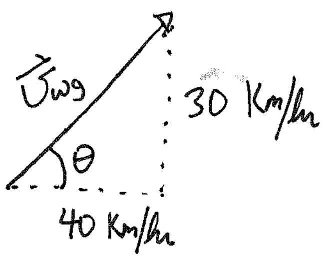
$\vec{v}_{pg}$: " " " " ground

$\vec{v}_{wg}$: " wind " " "

$$\vec{v}_{pg} = \vec{v}_{pw} + \vec{v}_{wg} \quad \therefore \quad \vec{v}_{wg} = \vec{v}_{pg} - \vec{v}_{pw}$$

$$\vec{v}_{pw} = \begin{cases} x: 0 \\ y: +300 \ \frac{Km}{hr} \end{cases} \qquad \vec{v}_{pg} = \begin{cases} x: +40 \ Km/hr \\ y: +330 \ Km/hr \end{cases}$$

$$\vec{v}_{wg} = \vec{v}_{pg} - \vec{v}_{pw} = \begin{cases} x: \ 40 \frac{Km}{hr} - 0 \frac{Km}{hr} = 40 \ Km/hr \\ y: \ 330 \frac{Km}{hr} - 300 \frac{Km}{hr} = 30 \ Km/hr \end{cases}$$



$$|\vec{v}_{wg}| = \sqrt{(40 \ Km/hr)^2 + (30 \ Km/hr)^2} = 50 \ Km/hr$$

$$\theta = \tan^{-1}\left(\frac{30}{40}\right) = 36.9^\circ$$

wind speed = 50 Km/hr direction = 36.9° north of east *

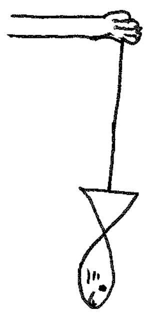
* which means it is a southwest wind ...

Problem 3.

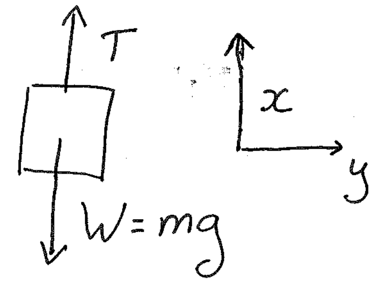
A 3 kg fish is suspended above the ground on a massless fishing line. The fish is a largemouth bass, not a red herring.

a) Assuming the fish is at rest, what is the tension in the fishing line?
b) Now assume that you are lowering the fish in such a way that it moves downward with a constant speed of 0.5 m/s. What is the tension in the line now?
c) Now assume that you are lowering the fish in such a way that it moves with a downward acceleration of 4.9 m/s^2. What is the tension in the line now?

a)



Free Body Diagram of fish:
$m = 3\,Kg$



$$F_{net} = ma$$
$$T - mg = ma = 0 \quad \text{(← @ rest)}$$
$$T = mg$$
$$= (3\,Kg)(9.8\,\tfrac{m}{s^2}) = \boxed{29.4\,N}$$

b) v = constant ∴ $a = 0$
∴ same answer $\boxed{29.4\,N}$
(the fish may not be a red herring, but the constant speed is...)

c) same FBD as above; now $a = -4.9\,m/s^2$

$$F_{net} = T - mg = ma$$
$$\therefore \quad T = m(g+a) = 3\,Kg\left(9.8\,\tfrac{m}{s^2} - 4.9\,\tfrac{m}{s^2}\right)$$
$$= \boxed{14.7\,N}$$

tension is reduced... if fish fell with $a = -g$ then the line would go completely slack (i.e. $T = 0$)

Problem 4.

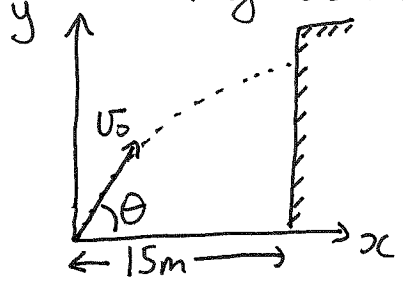
A student throws a raw egg at a fraternity house. The egg's initial speed is 30 m/s. The horizontal distance from the student to the house is 15 m. The egg hits the house 1 second after it is thrown. You can ignore air resistance.

a) At what initial angle θ was the egg thrown?

b) At what height is the egg when it hits the house?

c) How fast is the egg travelling when it hits the house?

Projectile motion ...



a) $x = x_0 + v_{0x} t \quad (x_0 = 0)$

$= v_{0x} t$

$= v_0 \cos\theta \, t$

$\therefore \cos\theta = \frac{x}{v_0 t} = \frac{15\text{m}}{(30\text{m/s})(1\text{s})} = 0.5 \quad \therefore \theta = \cos^{-1}(0.5)$

$\boxed{\theta = 60°}$

b) $y = y_0 + v_{0y} t - \frac{1}{2} g t^2$

$y_0 = 0 \quad v_{0y} = v_0 \sin\theta$

$y = 0 + v_0 \sin\theta t - \frac{1}{2} g t^2$

$= (30\frac{\text{m}}{\text{s}})(\sin 60°)(1\text{s}) - \frac{1}{2}(9.8\text{m/s}^2)(1\text{s})^2 = \boxed{21.1\text{m}}$

c) $v_x = v_{0x}$ (no x acceleration)

$v_y = v_{0y} - gt$

$v_x = v_{0x} = v_0 \cos\theta = (30\frac{\text{m}}{\text{s}})\cos 60° = 15\text{m/s}$

$v_y = v_0 \sin\theta - gt = (30\frac{\text{m}}{\text{s}})\sin 60° - (9.8\frac{\text{m}}{\text{s}^2})(1\text{s}) = 16.2\text{m/s}$

$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(15\text{m/s})^2 + (16.2\text{m/s})^2} = \boxed{22.1\text{m/s}}$

note: since we have the velocity components, it is easy to get the direction of the velocity, but we weren't asked for that ...