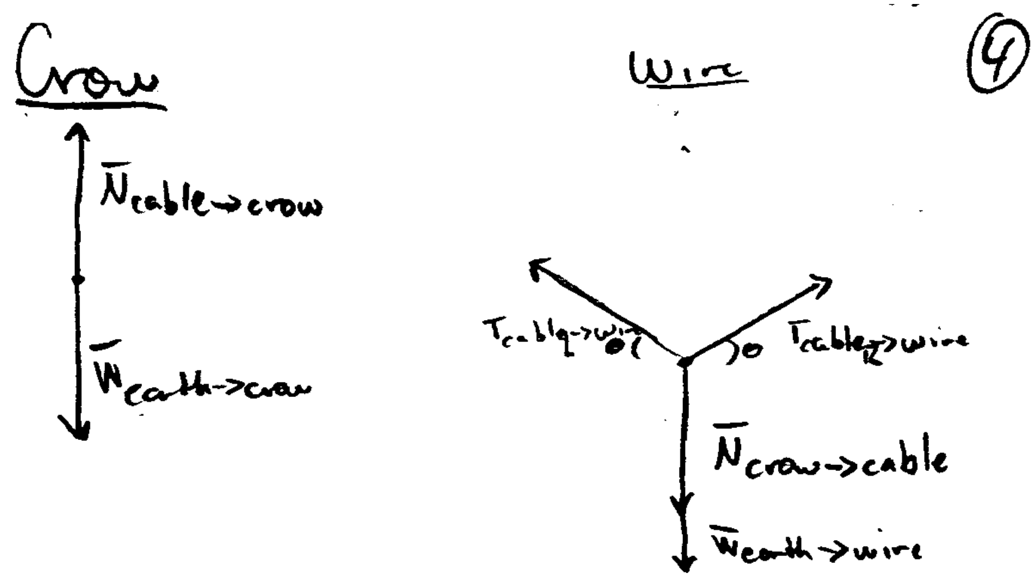
Spring 2001 Physics 2048 Test 2 solutions

Problem 5 (15 points)

A crow is sitting on a telephone wire near a field, waiting patiently for the farmer to leave so he can eat the farmer's corn. The crow is standing on a small piece of wire made straight by the force of his feet.

a. Identify all the forces acting on the crow and on the piece of wire under the crow's feet. Give any relationships between these forces that you can and explain where they come from



From Newton's second law, since neither the crow nor the wire is accelerating (they are both at rest) we know that the net force on both objects is zero and therefore the sum of the x-components and the y-components of the forces exerted on the two objects is also zero. Thus, using Newton's 2nd law of motion yields,

- $\vec{N}_{wire\to crow} = -\vec{W}_{earth\to wire}$
- The sum of the vertical forces acting on the wire = 0
- The sum of the horizontal forces acting on the wire = 0,
  $0 = T_{Left\,cable\to wire\ x} + T_{Right\,cable\to wire\ x} = T_{RHS\to wire}\cos\theta_{RHS} - T_{LHS\to wire}\cos\theta_{LHS}$
  $\left|\vec{T}_{RHS\to wire}\right| \cos\theta_{RHS} = \left|\vec{T}_{LHS\to wire}\right| \cos\theta_{LHS}$

From Newton's Third law, we know that $\vec{N}_{crow \to wire} = -\vec{N}_{wire \to crow}$

- Therefore, $\left|\vec{N}_{crow \to wire}\right| = \left|\vec{W}_{earth \to crow}\right| = m_{crow} g$

b. The angles that the left piece of wire and the right piece of wire make with the flat piece on the bottom are the same and equal to θ. If the crow has a mass of 0.4 kg, and θ = 40°, find the tension in the wire. *This is just like the problem on the practice test but with a lighter mass and a larger angle. From the test solution*

acceleration = 0

$\sin\theta = \frac{T_{1y}}{T_1}$

$T_{1y} = T_1 \sin\theta$

$\cos\theta = \frac{T_{1x}}{T_1}$

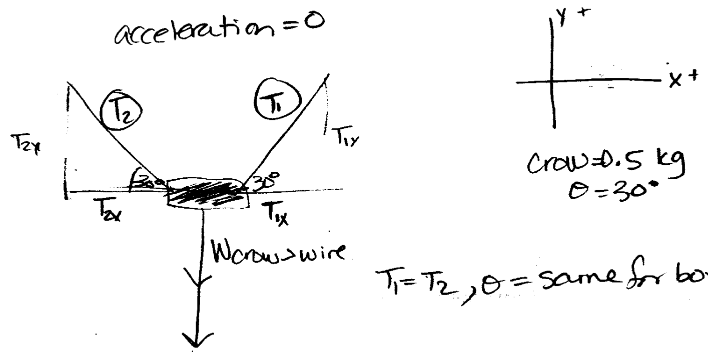
$T_{1x} = T_1 \cos\theta$

$\sin\theta = \frac{T_{2y}}{T_2}$

$T_{2y} = \sin\theta \cdot T_2$

$\cos\theta = \frac{T_{2x}}{T_2}$

$T_{2x} = T_2 \cos\theta$



Crow = 0.5 kg
θ = 30°

$T_1 = T_2$, θ = same for both wires.

$$a_x = \frac{\Sigma F_{net\,x}}{m} = T_{1x} - T_{2x} = T_1\cos\theta - T_2\cos\theta \equiv T_1\cos\theta = T_2\cos\theta,\ T_1 = T_2$$

$$a_y = \frac{\Sigma F_{net\,y}}{m} = \frac{T_{1y} + T_{2y} - W_{crow \to wire}}{m} = \frac{T_1 \sin\theta + T_2 \sin\theta - mg}{m} = 0$$

$$m a_y = T_1 \sin\theta + T_2 \sin\theta - mg$$

$$m a_y + mg = T_1 \sin\theta + T_1 \sin\theta$$

$$m(a_y + g) = 2T_1 \sin\theta$$

$$T_1 = \frac{m(a_y + g)}{2\sin\theta} = \frac{(0.5\,kg)(0 - 9.8\,m/s^2)}{2\sin(30^\circ)} = -4.9\,N$$

Comments: This is a pretty good solution starting from the component versions of Newton's 2nd Law and working toward the symbol solution before plugging in numbers and calculating the final answer. However, there are some minor errors.

- In the x-component equation, $T_1 \cos\theta - T_2 \cos\theta$ should have been set = 0 since $a = a_x = 0$.

- In the x-component equation shown above, it appears that the ≡ is saying that $T_1 \cos\theta - T_2 \cos\theta$ is defined to be $T_1 \cos\theta$.

- There is no weight force exerted by the crow on the wire (the gravitational force exerted by the crow on the wire is very small and can be neglected). However, there is a contact force exerted by the crow on the wire which by Newton's third law is equal in magnitude to the contact force that the wire exerts on the crow which in turn is equal in magnitude to the weight force the earth exerts on the crow since the crow is not accelerating and therefore the net force on the crow is zero. (There is a small weight force exerted on the wire by the earth but we will assume that it is small and can be neglected.)

- Also, if we take the component equations directly from the vector form of Newton's 2nd law $\vec{a} = \dfrac{\sum \vec{F}_{wire}}{m} = \dfrac{\vec{T}_1 + \vec{T}_2 + \vec{N}_{crow \to wire}}{m}$, then

  $$a_x = 0 = \frac{T_{1x} + T_{2x}}{m_{wire}} = \frac{T_1 \cos\theta - T_2 \cos\theta}{m_{wire}}$$ => $T_1 = T_2 = T$ and

  $$a_y = 0 = \frac{T_{1y} + T_{2y} + F_{y\ crow \to wire}}{m_{wire}} = \frac{T_1 \sin\theta + T_2 \sin\theta - m_{crow} g}{m_{wire}}$$

  $$0 = \frac{T \sin\theta + T \sin\theta - m_{crow} g}{m_{wire}} = \frac{2T \sin\theta - m_{crow} g}{m_{wire}}$$

  $$2T \sin\theta = m_{crow} g$$

  $T = m_{crow} g / 2 \sin\theta =$ (0.40 kg) (9.8 m/s^2) / 2 sin (40°) = 3.0 N