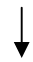
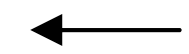
1. (a) A coordinate system attached to car A is a translating system, in which

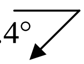
$$\mathbf{a}_B = \mathbf{a}_A + \mathbf{a}_{B/A}$$

Observe that

$$(a_B)_t = 3\,\text{m/s}^2$$ 

$$(a_B)_n = \frac{v_B^2}{\rho} = \frac{144}{100} = 1.44\ \text{m/s}^2$$ 

Thus

$$a_B = 3.33\,\text{m/s}^2$$ 64.4° 

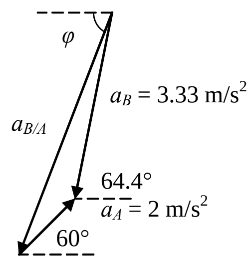
Either from a graphical or analytical solution,

$$a_{B/A} = 5.32\,\text{m/s}^2$$

$$\varphi = 62.72°$$

(b) A coordinate system attached to B is a rotating system. If $\mathbf{a}_{\text{rel}}$ is the acceleration of car A as observed from car B, $\mathbf{a}_{\text{rel}} \neq -\mathbf{a}_{B/A}$. It can be shown from rigid-body kinematics that $\mathbf{a}_{\text{rel}}$ satisfies

$$\mathbf{a}_A = \mathbf{a}_B + \dot{\boldsymbol{\omega}} \times \mathbf{r}_{A/B} + \boldsymbol{\omega} \times (\boldsymbol{\omega} \times \mathbf{r}_{A/B}) + 2\boldsymbol{\omega} \times \mathbf{v}_{\text{rel}} + \mathbf{a}_{\text{rel}}$$



2. Let T_1 be the tension in the upper string and T_2 tension in the lower string. Force balance on each mass gives

$$4mg - T_1 = 4m\ddot{q}_1 \qquad (1)$$

$$3mg - T_2 = 3m\ddot{q}_3 \qquad (2)$$

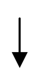
$$mg - T_2 = m\ddot{q}_4 \qquad (3)$$

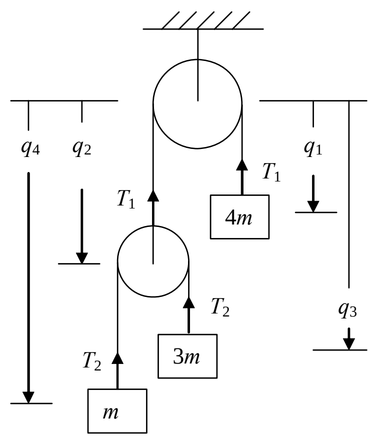
There are five unknowns $\ddot{q}_1$, $\ddot{q}_3$, $\ddot{q}_4$, T_1, and T_2 in three equations. However,

$$\ddot{q}_3 - \ddot{q}_2 + (\ddot{q}_4 - \ddot{q}_2) = 0 \qquad \Rightarrow \qquad \ddot{q}_3 + \ddot{q}_4 = 2\ddot{q}_2 = -2\ddot{q}_1$$

$$T_1 = 2T_2$$

Upon solution,

$$\ddot{q}_1 = \frac{1}{7}g = 1.40\,\text{m/s}^2$$ 



3. Let position 1 of the block be its initial position at 150 mm above the springs. Suppose position 2 corresponds to deflection x in the two springs. Between positions 1 and 2,

$$U = \Delta T + \Delta V_g + \Delta V_e$$

where the work done by forces other than gravitational and spring forces is

$$U = 0$$

$$\Delta T = T_2 - T_1 = 0$$

Define the reference level for measuring potential energy as the level associated with the precompressed springs before impact. Then

$$\Delta V_g = mgh_2 - mgh_1 = mg(-x) - mg(0.15) = -mg(x + 0.15)$$

$$\Delta V_e = 2\left(\frac{1}{2}kx_2^2\right) - 2\left(\frac{1}{2}kx_1^2\right)$$

$$= 2\left(\frac{1}{2}k(0.075 + x)^2\right) - 2\left(\frac{1}{2}k(0.075)^2\right) = k[(0.075 + x)^2 - 0.075^2]$$

Thus

$$U = \Delta T + \Delta V_g + \Delta V_e$$

$$\Rightarrow \quad -mg(x + 0.15) + k[(0.075 + x)^2 - 0.075^2] = 0$$

$$\Rightarrow \quad 5000x^2 + 651.9x - 14.715 = 0$$

$$\Rightarrow \quad x = 0.0196 \text{ or } -0.150$$

The additional deflection is $x = 19.6$ mm.