Q1. \[ F = (m_1 + m_2) a \]
(a) \[ a = \frac{F}{m_1 + m_2} = \frac{3}{1 + 2} \text{ms}^{-2} = 1.0 \text{ms}^{-2} \]
Internal force: \[ F_{\text{int}} = m_2 a = ... = 1.0 \text{N} \]

Q2. In all cases, the force on the man is \[ N - mg = ma \].
(a) \[ N = mg = 980 \text{N} \]
(b) \[ N = mg = 980 \text{N} \]
(c) \[ N - mg = ma \Rightarrow N = m(a + g) = 100 \times 11.8 = 1180 \text{N} \]
(d) \[ mg - N = ma \Rightarrow N = m(g - a) = 680 \text{N} \]
(e) \[ mg - N = ma \Rightarrow N = 580 \text{N} \]
(f) \[ N - mg = ma \Rightarrow N = m(g + a) = 1480 \text{N} \]

Q3. (a)
Force on \( m_1 \) : \[ m_1 g \sin \theta - T = m_1 a \]
Force on \( m_2 \) : \[ T - m_2 g = m_2 a \]
Eliminate \( T \) : add
\[ m_1 g \sin \theta - m_2 g = (m_1 + m_2) a \]
\[ a = \frac{(m_1 g \sin \theta - m_2 g)/(m_1 + m_2)}{\text{-0.10g} \}
\[ m_1 g \sin \theta - T = m_1 a \]
\[ T = m_1 g \sin \theta + m_1 a = 18 \text{N} \]

Q4. \[ T \]
\[ \theta \]
\[ \bullet \]
\[ mg \]
(1) \[ T \cos \theta = mg \]
(2) \[ T \sin \theta = ma \]
\[ \tan \theta = a / g \]
\[ a = g \tan \theta \]
(N2 in vertical)
(N2 in horizontal)
divide (1) by (2)
Q5.

\[ L \cos \theta = mg \quad \text{(N2 in vertical)} \]
\[ L \sin \theta = \frac{mv^2}{r} \quad \text{(N2 in horizontal)} \]
\[ \therefore \tan \theta = \frac{v^2}{rg} \quad \text{(divide eqns)} \]
\[ r = \frac{v^2}{g \tan \theta} = \frac{(480/3.6)^2}{(9.8 \tan 40)} = 2.2 \text{ km} \]

Q6.

Maximum friction force = \( \mu N = \mu F = 36 \text{ N} \).

Weight = \( mg = 29 \text{ N} \).
The block will not move.

Actual friction force = 29.4 N.

\[ F = \sqrt{60^2 + 29.4^2} = 67 \text{ N} \]
\[ \theta = \tan^{-1}(60/29.4) = 63.9^0 \]
\[ \theta = 64^0 \]

Q7.

(a) If the string doesn’t stretch, the acceleration of both masses has the same magnitude, a, but opposite directions. Let’s suppose that the 5kg mass accelerates down with a, and that the 2 kg mass accelerates up with a. (If this supposition is incorrect, then a will turn out to be negative.)

\[ N2 \text{ on } 5 \text{ kg (} m_1 \text{)} \quad m_1 g - T = m_1 a \]
\[ N2 \text{ on } 2 \text{ kg} \quad T - m_2 g = m_2 a \]
\[ (m_1 + m_2) a = (m_1 - m_2) g \]
\[ \therefore a = (m_1 - m_2) g / (m_1 + m_2) = 20 / 7 \text{ g} \]

(b) 2 kg mass:

\[ v = at = 1.26m/s \]
\[ y = \frac{1}{2}at^2 = 0.19m \]
\[ v = -1.26m/s \]
\[ y = 1.29 - 0.19 = 1.1m \]

(c) \( a = -g \)

(d) Mass A:

\[ v_0 = 1.26, y_0 = 0.19 \]
\[ y = y_0 + v_0 t + \frac{1}{2}at^2 \]
\[ 0 = 0.19 + 1.26t - 4.9t^2 \]
\[ \therefore t = 0.36s \]
Mass B:

\[ v_0 = -1.26, y_0 = 1.1. \]
\[ y = 1.1 - 1.26t - 4.9t^2 \]
\[ y = 0 \implies t = 0.36s \]

Q8.

(a)

\[ F = ma = -\beta v^2 \]
\[ \frac{dv}{dt} = -\frac{\beta}{m} v^2 \]
\[ -\frac{dv}{v^2} = \frac{\beta}{m} \, dt \]
\[ \frac{1}{v} = \frac{1}{v_0} + \frac{\beta t}{m} \]
\[ \therefore v = \frac{mv_0}{\beta v_0 t + m} \]

(b)

\[ e^{\frac{\beta x}{m}} = \frac{m + \beta v_0 t}{m} \]
\[ \therefore v = v_0 \exp\left(-\frac{\beta x}{m}\right) \]
Newton 2 for \( m_2 \):
\[ F = m_2 g \]

Newton 2 for \( m_1 \) (vertical):
\[ 0 = m_2 a_{vert} = F \sin \theta - m_1 g = m_2 g \sin \theta - m_1 g \]
\[ \sin \theta = \frac{m_1}{m_2} \]

Newton 2 for \( m_1 \) (horizontal):
\[ m_1 a_{centrip} = m_1 r \omega^2 = F \cos \theta = m_2 g \cos \theta \]
substitute for \( r \) and \( \omega \):
\[ m_1 (R \cos \theta) \left( \frac{2\pi}{T} \right)^2 = m_2 g \cos \theta \]
\[ T = 2\pi \sqrt{\frac{m_1 R}{m_2 g}} \]

iii) The tension in both ends of the string is \( F \), so, from symmetry, the line of \( N \) bisects the angle between the segments of the string. So \( N \) is at an angle to the vertical
\[ \alpha = (90^\circ - \theta)/2 \]
\[ N = 2F \cos \alpha \]

iv) With finite friction, the tension in the string supporting \( m_1 \) may be greater than or less than \( m_2 g \) by the limit of the static friction. So a range of \( \theta \), both greater than and less than the value found above, is possible.

v & vi) \[ 0 < \theta < \pi/2, \text{ so } 0 < m_1/m_2 < 1 \]

If \( m_1 > m_2 \), then the weight of \( m_1 \), which equals the tension in the string, is not great enough both to support \( m_1 \) vertically and to provide centripetal acceleration. So \( m_2 \) rises until it hits the bottom of the tube.