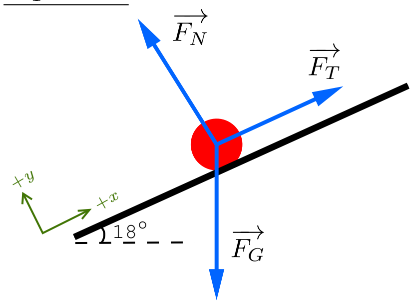
SPH4U: Dynamics Assignment

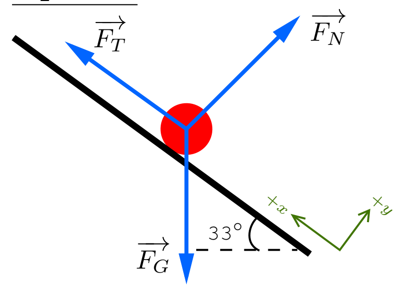
Q01. Two heavy boxes, m_1 and m_2, lie stationary on different inclines, as shown. A rope runs over a pulley and connects the boxes. Mass 1, m_1 is 380kg. Assuming that each incline is frictionless and the system is in equilibrium, answer the following:

(a) **Draw FBD(s).**

m_1 FBD:



m_2 FBD:



(b) **Find the magnitude of the tension in the cable.**

$$\begin{aligned}
\vec{F_{net_{1x}}} &= 0 \\
0 &= \vec{F_g}\sin 18^\circ + |F_T| \\
0 &= m_1 g \sin 18^\circ + |F_T| \\
0 &= 380(-9.8)\sin 18^\circ + |F_T| \\
|F_T| &= 1150.78\text{N} \\
|F_T| &= 1200\text{N}
\end{aligned}$$

$\therefore$ The magnitude of tension in the string is 1200N.

(c) **Calculate the mass of m_2 needed to keep the system in equilibrium.**

$$\begin{aligned}
F_{net_{2x}} &= 0 \\
0 &= \vec{F_g}\sin 33^\circ + 1150.78 \\
m_2 &= \frac{-1150.78}{-9.8\sin 33^\circ} \\
m_2 &= 215.6\text{kg} \\
m_2 &= 220\text{kg}
\end{aligned}$$

$\therefore$ The mass of the second box (m_2) is 220kg.

Q02. A girl applies a 140N force to a 35.0kg bale of hay at an angle of 28° above the horizontal. The force of friction acting on the bale is 55N.

(a) **What will be the horizontal acceleration of the bale?**

$$\begin{aligned}
\vec{F_{net_x}} &= \vec{F_{a_x}} - \vec{F_f} \\
&= 140\cos 28^\circ - 55 \\
&= 66.81\text{N[right]}
\end{aligned}
\qquad
\begin{aligned}
\vec{F_{net_x}} &= m\vec{a} \\
66.81 &= 35\vec{a} \\
\vec{a} &= 1.96\text{m/s}^2\text{[right]} \\
\vec{a} &= 2.0\text{m/s}^2\text{[right]}
\end{aligned}$$

$\therefore$ The horizontal acceleration is 2.0m/s^2[right]

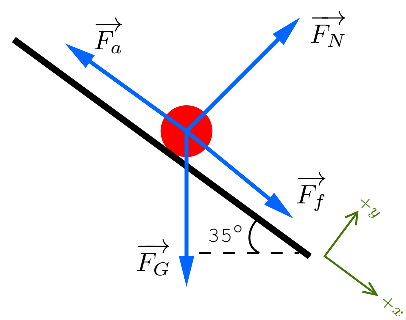
(b) **What is the coefficient of friction between the bale and the ground?**

$$
\begin{aligned}
\vec{F_f} &= \mu_f \vec{F_N} \\
55 &= \mu_f(\vec{F_g} - \vec{F_{a_y}}) \\
\mu_f &= \frac{55}{35 \times 9.8 - 140 \sin 35^\circ} \\
\mu_f &= 0.21
\end{aligned}
$$

$\therefore$ The coefficient of friction between the bale and ground is 0.21.

Q03. A 15kg box is pushed up a 35° ramp. A force of 110N exists between the box and the ramp.

(a) **Draw an FBD showing a tilted coordinate system (label positive x-direction)**



(b) **What minimum force, $\boldsymbol{F}$, would be necessary to move the box up the ramp at a constant speed?**

$$
\begin{aligned}
\vec{F_{net_x}} &= \vec{F_a} + \vec{F_{g_x}} + \vec{F_f} \\
0 &= \vec{F_a} + 15(-9.8)\sin 35^\circ - 110 \\
0 &= \vec{F_a} - 194.31 \\
\vec{F_a} &= 194.31\text{N}
\end{aligned}
$$

$\therefore$ Since constant speed implies no acceleration ($\vec{F_{net}} = 0$), the force required to move the box at constant speed must also result in 0 net force, meaning the minimum force required is 190N.

Q04. The apparatus shown in the diagram consists of a box of books connected by a string to a hanger plate loaded with masses. The mass, m_1, is for the box and books and the mass, m_2 is for the hanger with masses. The box is moving up the incline 35° to the horizontal with constant speed. What is the coefficient of friction between the box and the incline?

$\boldsymbol{m_1}$**:**

$$
\begin{aligned}
\vec{F_{net_x}} &= \vec{F_g}\sin 35^\circ + \vec{F_T} - \vec{F_f} \\
0 &= 0.45(-9.8)\sin 35^\circ + \vec{F_T} + \vec{F_f} \\
0 &= -2.53 + \vec{F_T} + \vec{F_f} \\
\vec{F_T} &= \vec{F_f} + 2.53\text{N[uphill]}
\end{aligned}
$$

$\boldsymbol{m_2}$**:**

$$
\begin{aligned}
\vec{F_{net_y}} &= \vec{F_g} - \vec{F_T} \\
0 &= 0.35 \times 9.8 - \vec{F_T} \\
\vec{F_T} &= 3.43\text{N[up]}
\end{aligned}
$$

Set Equations for $\boldsymbol{F_T}$ Equal:

$$
\begin{aligned}
3.43 &= \vec{F_f} + 2.53 \\
\vec{F_f} &= 0.9\text{N[downhill]}
\end{aligned}
$$

Solve for Friction Coefficient:

$\vec{F_f} = \mu_f \vec{F_N}$
$0.9 = \mu_f \times 0.45(9.8)\cos 35^\circ$
$\mu_f = 0.25$

$\therefore$ The coefficient of friction between the box and incline is 0.25.