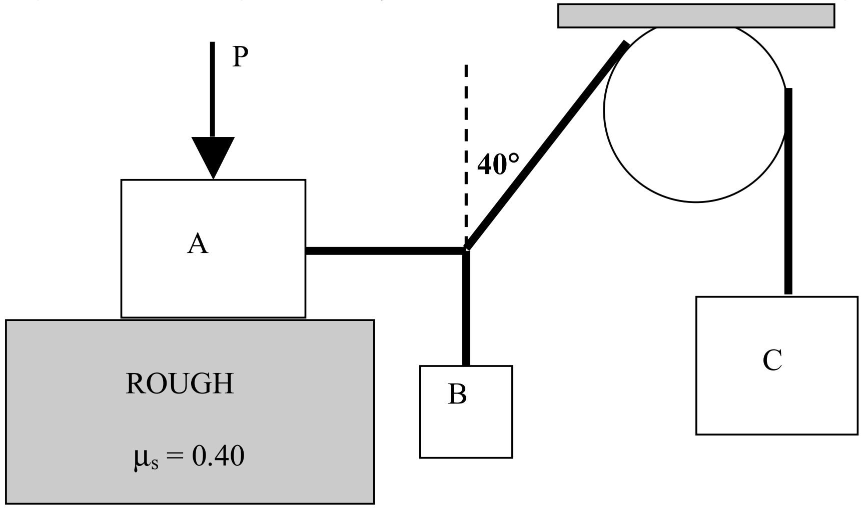
P1211 F2020
More Newton’s Law

Chapter 6

A Multiple Choice:

Shown below is a system of blocks and frictionless pulley. Block A has a mass of 5.0 kg and is on a rough surface (μs = 0.40). Block C has mass of 4.0 kg.

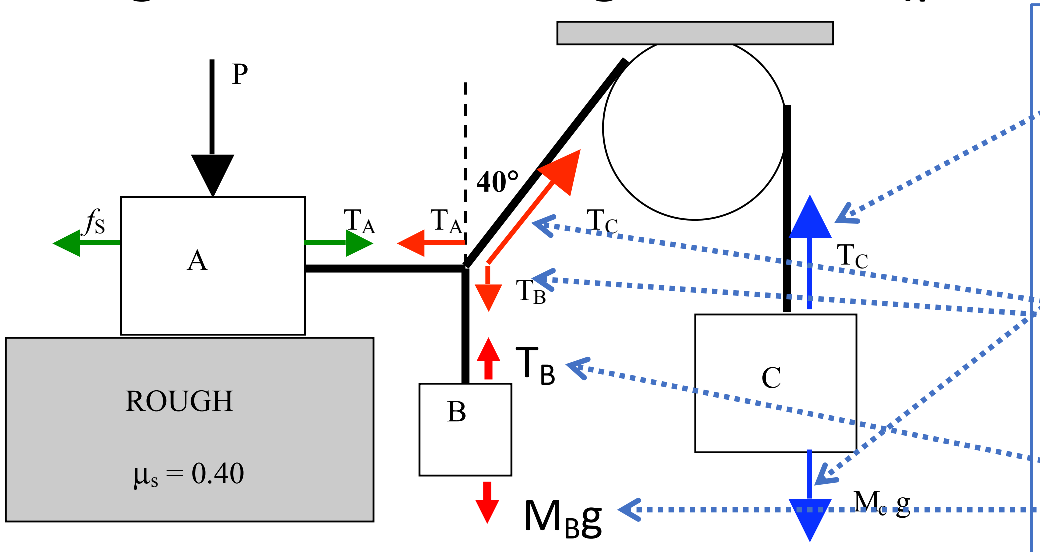


An external force P = 25.0 N is applied vertically on Block A to keep system in **equilibrium**. The mass on block B is closest to:

a) 2.3 kg b) 2.6 kg c) 2.1 kg d) 2.8 kg e) 3.1 kg

A Multiple Choice: Solution starts with drawing FBD

Shown below is a system of blocks and frictionless pulley. Block A has a mass of 5.0 kg and is on a rough surface (μs = 0.40). Block C has mass of 4.0 kg.



From the **blue force** diagram on block C:

$$T_C = M_C g = 4.9kg \times 9.8m \cdot s^{-2} = 39.2N$$

At the **red forces** where 3 ropes meet three tensions, T_A, T_B, and T_C must be balanced

Vertical Component:

$$F_{Net,y} = T_C \cos 40^{\circ} - T_B = 0$$

$$T_B = T_C \cos 40^{\circ} = 39.2N \times \cos 40^{\circ} = 30N$$

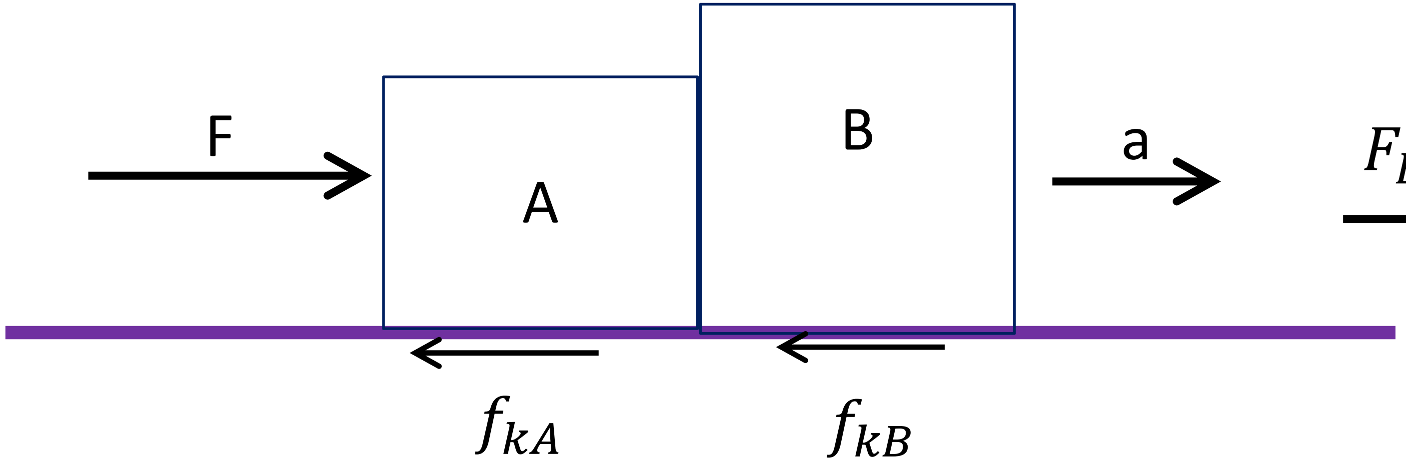
But $T_B = M_B g \rightarrow M_B = 3.1kg$

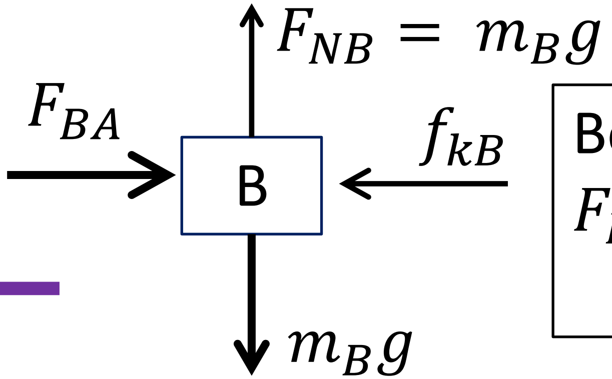
ANSWER: E

An external force P = 25.0 N is applied vertically on Block A to keep system in **equilibrium**. The mass on block B is closest to:
a) 2.3 kg b) 2.6 kg c) 2.1 kg d) 2.8 kg e) 3.1 kg

Pushing 2 boxes with friction, ch6 p20

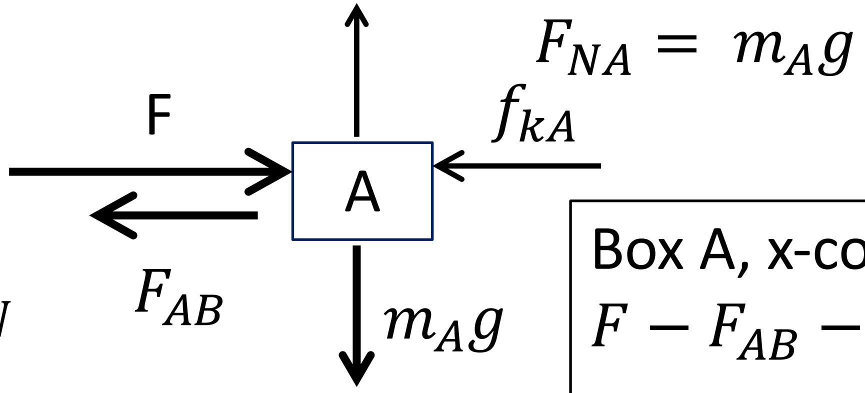
- A Box A ($m_A = 1.20kg$) and Box A ($m_B = 3.40kg$) is pushed by a horizontal force, F = 12.2 N. It accelerates to the right. If Box A feels a force of friction of $f_{kA} = 2.1N$, and on B, $f_{kB} = 5N$. Calculate the force between the boxes, F_{AB} and F_{BA}.





Box B, x-comp:

$F_{BA} - f_{kB} = m_B a$ [1]



Box A, x-comp:

$F - F_{AB} - f_{kA} = m_A a$ [2]

Solution: Add 1 and 2

$$F - F_{AB} - f_{kA} + F_{BA} - f_{kB} = (m_A + m_B)a$$

Use 3rd law: $F_{BA} = F_{AB}$

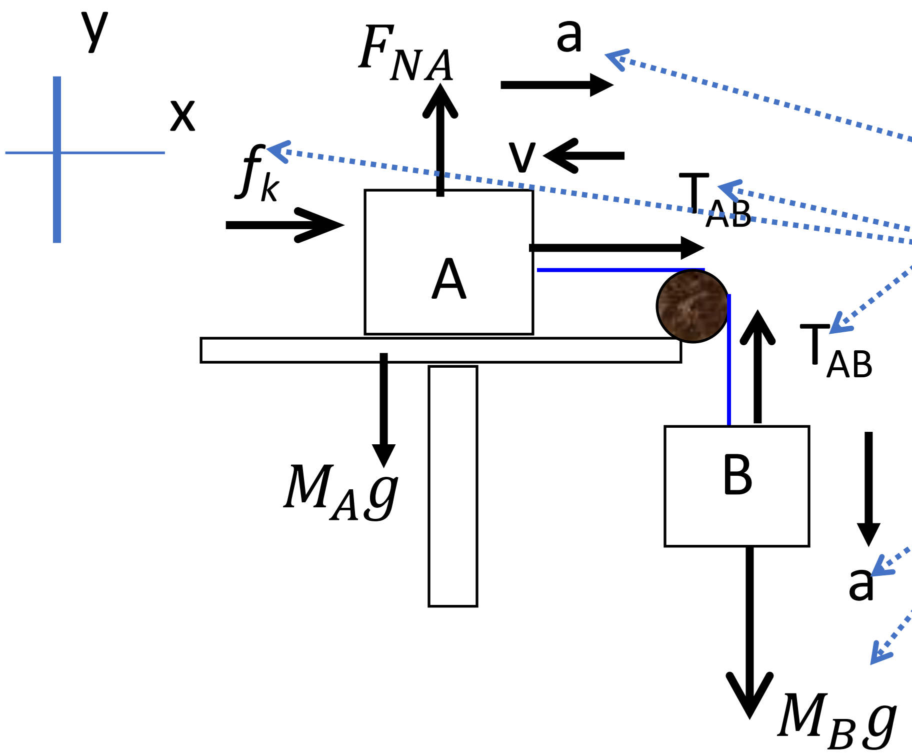
$$\mathrm{F} - f_{kA} - f_{kB} = (m_A + m_B)a \rightarrow a = 1.11 m \cdot s^{-2}$$

Using [1], $F_{BA} = f_{kB} + m_B a = 5N + 3.4kg \times a = 8.77N$

Verify with [2]!

2-Body with friction II

In the diagram below block A has a mass of 4.00 kg and block B has mass 8.00 kg. Block A is on a table with **frictionless coefficient**, $\mu_s = 0.3$, $\mu_k = 0.2$, and **moving left**. Calculate the Tensions T_{AB} and Acceleration a. The rope is massless, and there is **no friction** between the rope and pulley. Will the acceleration increase compare to the last problem?



<u>Draw FBD **B**</u>:

Y-comp: $T_{AB} - M_B g = -M_B a$ [1]

<u>Draw FBD **A**</u>:

Y-comp: $F_{NA} = 39.2N$

It already moving! Friction is kinetic, $f = f_k = F_{NA}\mu_k = 7.84N$

X-comp: $T_{AB} + f_k = M_A a$,

$$T_{AB} = -f_k + M_A a \quad [2]$$

<u>Solution</u>: Subs [2] into [1]

$$-f_k + M_A a - M_B g = -M_B a \rightarrow M_B g + f_k = (M_B + M_A)a$$

$$a = \frac{M_B g + f_k}{M_B + M_A} = \frac{8kg \times 9.8m \cdot s^{-2} + 7.84N}{8kg + 4kg} = 7.19m \cdot s^{-2}$$

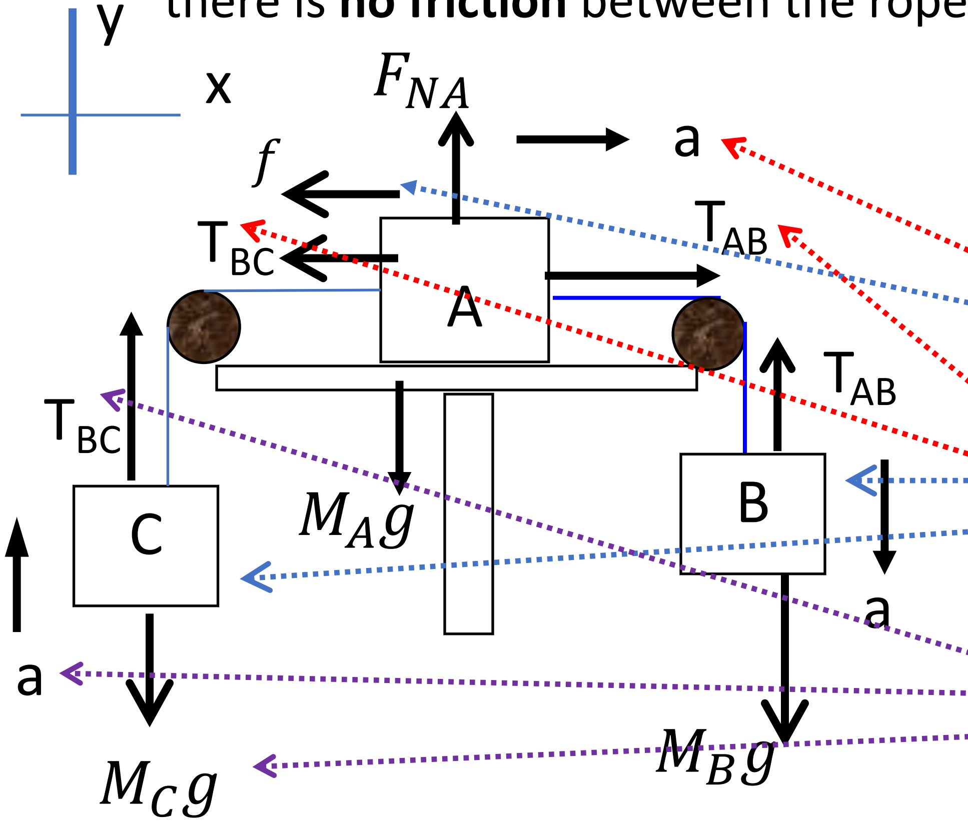
Use [2] $T_{AB} = -f_k + M_A a = -7.84N + 4kg \times 7.19m \cdot s^{-2} = 20.92N$

Verify with [1]

$$T_{AB} = 8kg(g - a) = 20.88N$$

Example 3: Another problem

In the diagram below block A has a mass of 4.00 kg, block B has mass 12.00 kg, block C has mass 8.00 kg. Block A is resting on a table with **frictionless coefficient**, $\mu_s = 0.2$, $\mu_k = 0.1$. Block A is released from rest, calculate the Tensions T_{AB} , T_{BC} and Acceleration a. The rope is massless, and there is **no friction** between the rope and pulley.



<u>Draw FBD **B**</u>:

Y-comp: $T_{AB} - M_B g = -M_B a$ [1]

<u>Draw FBD **A**:</u>

Y-comp: $F_{NA} = 39.2N$

Maximum static friction, $f_{s,max} = F_{NA}\mu_s = 7.84\ N$. Will it move?

$M_B g$ make A move **right**, $M_C g$ make A move **left**

$M_B g - M_C g - f_s = 31.36N > 0$

It will move! Friction is kinetic, $f = f_k = F_{NA}\mu_k = 3.92N$

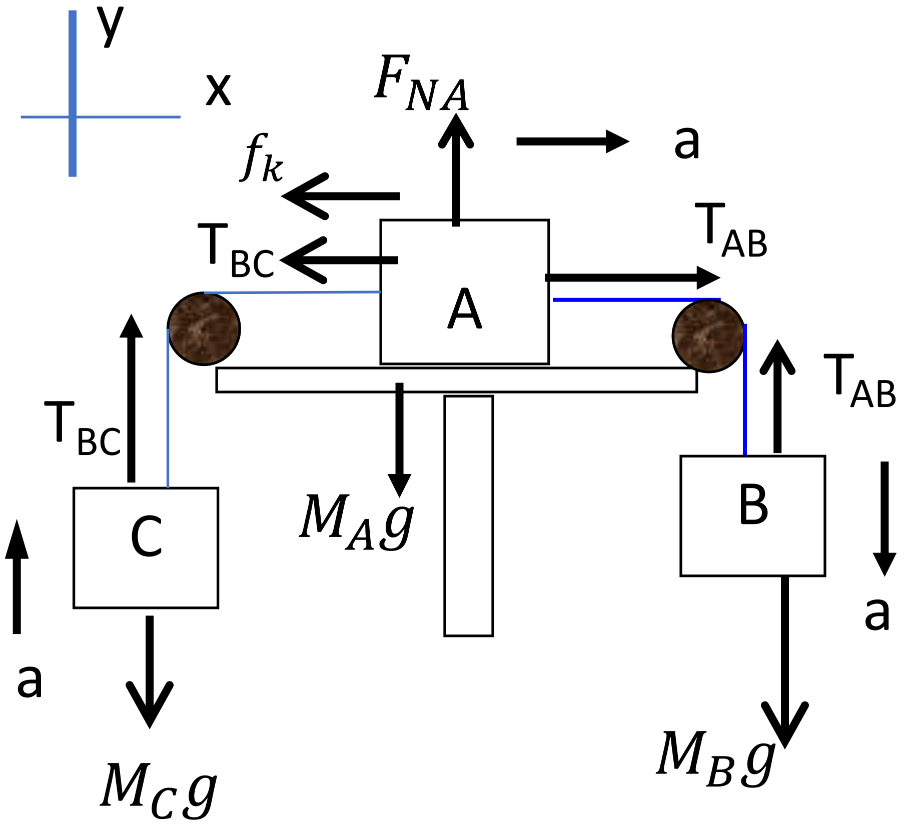
X-comp: $T_{AB} - T_{BC} - f_k = M_A a$, [2]

<u>Draw FBD **C**:</u>

Y-comp: $T_{BC} - M_C g = M_C a$ [3]

Example 3: Finding acceleration and Tensions, Part I

In the diagram below block A has a mass of 4.00 kg, block B has mass 12.00 kg, block C has mass 8.00 kg. Block A is resting on a table with **frictionless coefficient**, $\mu_s = 0.2$, $\mu_k = 0.1$. Block A is released from rest, calculate the Tensions T_{AB} , T_{BC} and Acceleration a. The rope is massless, and there is **no friction** between the rope and pulley.



$T_{AB} - M_B g = -M_B a$ [1]

X-comp: $T_{AB} - T_{BC} - f_k = M_A a$, [2]

Y-comp: $T_{BC} - M_C g = M_C a$ [3]

3 equations, 3 unknowns: a, T_{AB}, T_{BC}

Add [2] and [3]

$$\underbrace{T_{AB} - \cancel{T_{BC}} - f_k}_{\text{LHS of [2]}} + \underbrace{\cancel{T_{BC}} - M_C\, g}_{\text{LHS of [3]}} =.\ \underbrace{M_A\, a}_{\text{RHS of [2]}} \quad + \quad \underbrace{M_C a}_{\text{RHS of [3]}}$$

$$T_{AB} - f_k - M_C\, g = (M_A + M_C)a$$

$$T_{AB} = f_k + M_C\, g + (M_A + M_B)a \qquad [4]$$

Subs [4] into [1], $T_{AB} - M_B g = -M_B a$

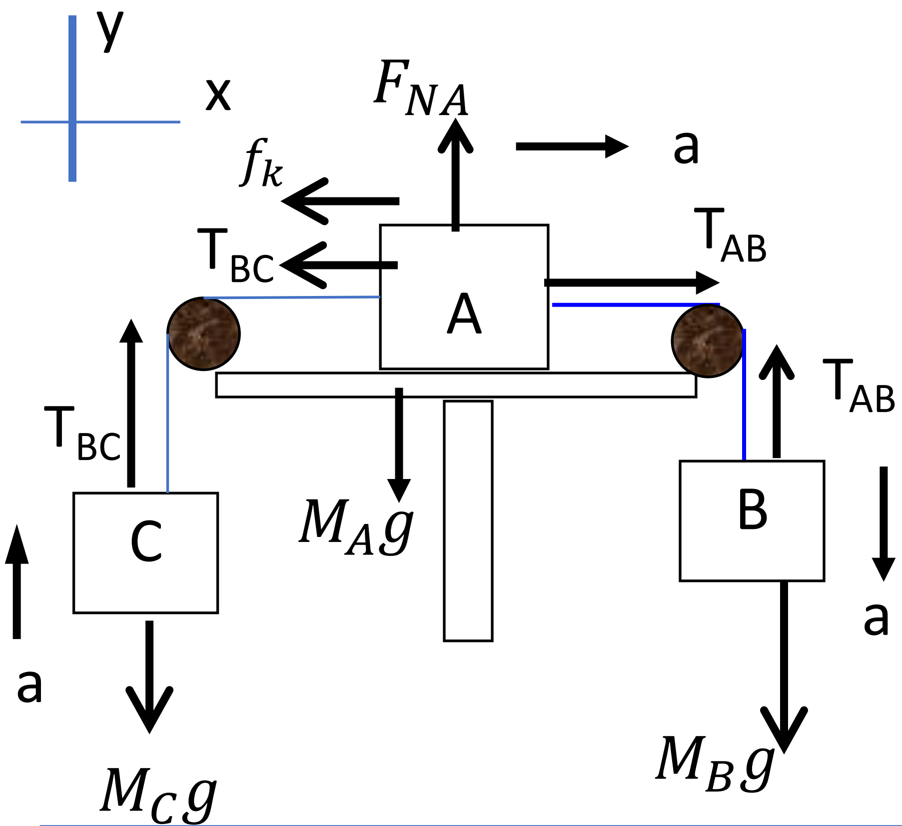
$$f_k + M_C\, g + (M_A + M_C)a - M_B g = -M_B a$$

$$(M_A + M_B + M_C)a = (M_B - M_C)g - f_k$$

$$a = \frac{(M_B - M_C)g - f_k}{(M_A + M_B + M_C)}$$

Example 3: Finding acceleration and Tensions, Part II

In the diagram below block A has a mass of 4.00 kg, block B has mass 12.00 kg, block C has mass 8.00 kg. Block A is resting on a table with **frictionless coefficient**, $\mu_s = 0.2$, $\mu_k = 0.1$. Block A is released from rest, calculate the Tensions T_{AB} , T_{BC} and Acceleration a. The rope is massless, and there is **no friction** between the rope and pulley.



$99.96N - 90.16N - 3.92N = 4kg \times 1.47m \cdot s^{-2}$

5.88N = 5.88N

$T_{AB} - M_B g = -M_B a$ [1]

X-comp: $T_{AB} - T_{BC} - f_k = M_A a$, [2]

Y-comp: $T_{BC} - M_C g = M_C a$ [3]

3 equations, 3 unknowns: a, T_{AB}, T_{BC}

$$a = \frac{(M_B - M_C)g - f_k}{(M_A + M_B + M_C)}$$

From earlier, $f_k = 3.92N$

$$a = \frac{(12kg - 8kg)g - 3.92N}{(4kg + 12kg + 8kg)} = 1.47\frac{m}{s^2}$$

Use [3] to find T_{BC}

$T_{BC} = M_C(g + a) = 8kg\left(9.8\frac{m}{s^2} + 1.47\frac{m}{s^2}\right)$ =90.16N

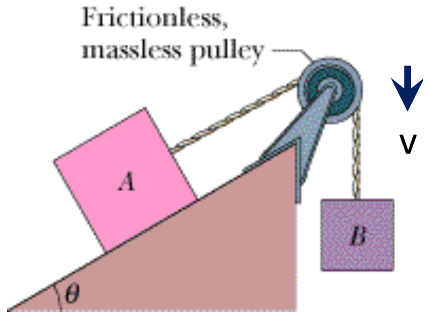
Use [1] to find T_{AB}

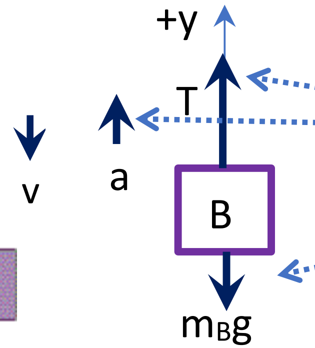
$T_{AB} = M_B(g - a) = 12kg\left(9.8\frac{m}{s^2} - 1.47\frac{m}{s^2}\right)$ =99.96N

Verify Using [2], $T_{AB} - T_{BC} - f_k = M_A a$

2-Body incline problem (10 Points)

In the diagram below, box A (mass m_A = 5 kg) is on a $\theta = 53.1°$ incline with friction coefficients: $\mu_s = 0.5$ and $\mu_k = 0.15$. It is connected to a hanging Box B by an ideal rope passed through a **frictionless pulley**. Box B has mass m_B = 4 kg. If Box B is falling find the **acceleration** of Box B and the **tension** in the rope.





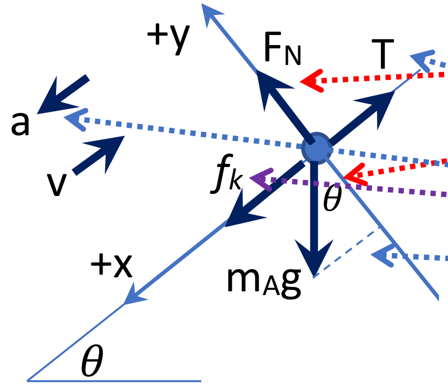
FBD of **Box B** that assumes **B accelerates up**, but B is **moving down** (**velocity** is **down**): FBD is **1 point**

Use 2nd law, $F_y^{net} = T - m_B g = m_B a$, or in numerical form

$$T - (4kg)g = (4kg)a$$

$$T - 39.2N = (4kg)a, \qquad [1]$$

Equation [1] has two unknowns tension T and acceleration a. (**2 points**)



FBD of **Box A** that assumes **A accelerates down incline**, but **A** is **moving up incline**: FBD is **2 points**

Y-com – $F_y^{net} = F_N - m_A g cos\theta = 0 \rightarrow$

$$F_N = (5kg)9.8\frac{m}{s^2}cos53.1 = 29.4N$$

Kinetic Friction: $f_k = F_N \mu_k = 29.4N \times 0.15 = 4.41N$, (**1 point**)

X-com 2nd law, $F_x^{net} = m_A g sin\theta + f_k - T = m_A a$,

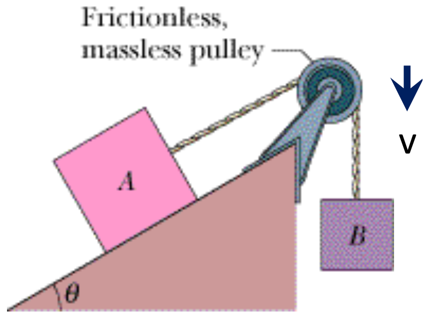
$$43.61N - T = (5kg)a. \qquad [2]$$

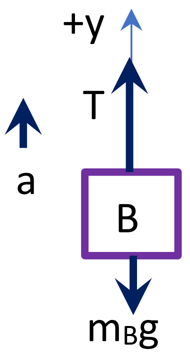
Equation [2] has two unknowns tension T and a. (**2 points**)

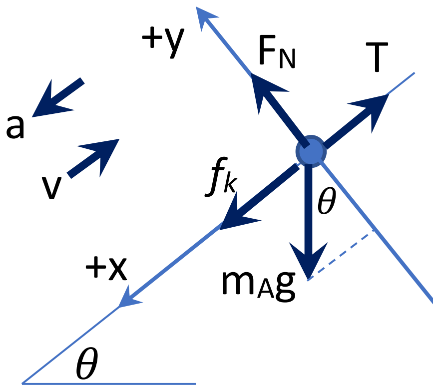
2-Body incline problem (10 Points), Part 2

In the diagram below, box A (mass m_A = 5 kg) is on a $\theta = 53.1°$ incline with friction coefficients: $\mu_s = 0.5$ and $\mu_k = 0.15$. It is connected to a hanging Box B by an ideal rope passed through a **frictionless pulley**.

Box B has mass m_B = 4 kg. If Box B is falling find the **acceleration** of Box B and the **tension** in the rope.







$$\boxed{T - 39.2N = (4kg)a, \qquad [1]}$$

$$\boxed{43.61N - T = (5kg)a. \qquad [2]}$$

The solution is found by adding equation [1] and [2] to obtain

$$T - 39.2N + 43.61 - T = (4kg)a + (5kg)a$$

$$4.41N = (9kg)a \rightarrow a = 0.49\frac{m}{s^2}, (\mathbf{1\ point})$$

Substituting $a = 0.49\frac{m}{s^2}$ into equation [1] gives $T - 39.2N = (4kg)\left(0.49\frac{m}{s^2}\right) = 41.16N$. (**1 point**)

Students should verify the value of the tension with equation [2]. Since a > 0, our assumption is correct A accelerates down, and B is accelerating up.