

ave. = 7.0  
σ = 2.2

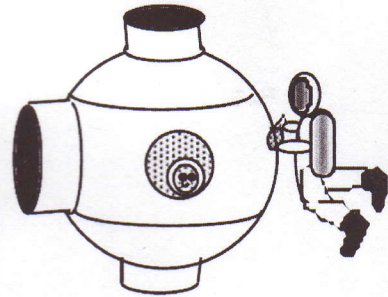
Name Answer Key

Lab: 8:00 am 11:15 am 2:30 pm

Quiz #5: Newton's 3<sup>rd</sup> Law

Problem 1 (2 points)

A 70.0-kg astronaut pushes to the left on a spacecraft with a force  $F$  in "gravity-free" space. The spacecraft has a total mass of  $1.0 \times 10^4$  kg. During the push, the astronaut accelerates to the right with an acceleration of  $0.36 \text{ m/s}^2$ . What is the magnitude of the acceleration of the spacecraft?



⇒ from Newton's 3<sup>rd</sup> Law, the magnitudes of the forces on astronaut and spacecraft are the same

- a)  $51.4 \text{ m/s}^2$
- b)  $0.36 \text{ m/s}^2$
- c)  $2.5 \times 10^{-3} \text{ m/s}^2$
- d)  $7.0 \times 10^{-3} \text{ m/s}^2$
- e)  $3.97 \times 10^{-4} \text{ m/s}^2$

C

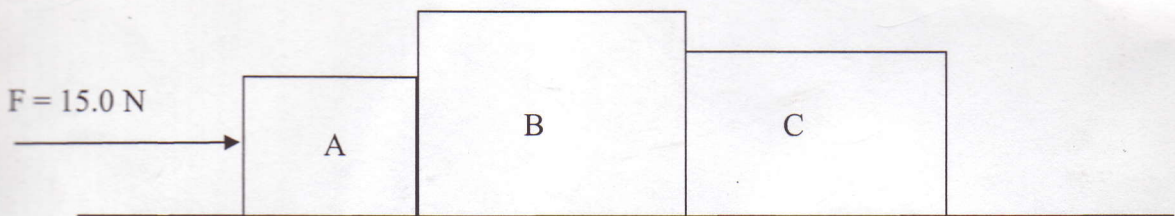
$$M_{\text{Astro}} a_{\text{astro}} = M_{\text{space}} a_{\text{space}}$$

$$\rightarrow a_{\text{space}} = \frac{M_{\text{Astro}}}{M_{\text{space}}} a_{\text{astro}} = \frac{70 \text{ kg}}{1.0 \times 10^4 \text{ kg}} (0.36 \text{ m/s}^2) = 2.5 \times 10^{-3} \text{ m/s}^2$$

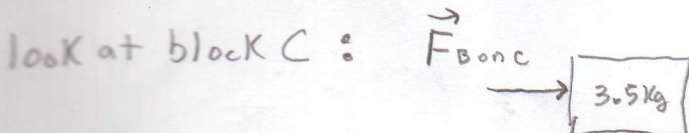
Problem 2 (3 points)

Three boxes are in contact with each other on a horizontal frictionless floor. The masses of the boxes are  $m_A = 2.5 \text{ kg}$ ,  $m_B = 4.0 \text{ kg}$ , and  $m_C = 3.5 \text{ kg}$ . A  $15.0 \text{ N}$  force is applied to box A as shown in the figure below. In unit vector notation, what is the magnitude and direction of (a) the force that box B exerts on box A and (b) the force that box C exerts on box B?

$$m_A + m_B + m_C = 10.0 \text{ kg}$$



acceleration of boxes  $a = \frac{\sum F}{m} = \frac{15.0 \text{ N}}{10.0 \text{ kg}} = 1.50 \text{ m/s}^2$

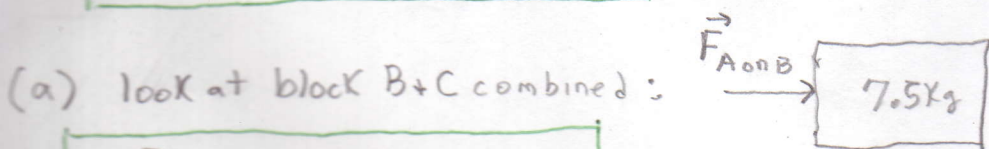


$$\sum F_x = m a_x$$

$$\vec{F}_{B \text{ on } C} = (3.50 \text{ kg}) (1.50 \text{ m/s}^2) = 5.25 \text{ N}$$

to the right

(b)  $\vec{F}_{C \text{ on } B} = -(5.25 \text{ N}) \hat{i}$



$$\sum F_x = m a_x$$

$$\vec{F}_{A \text{ on } B} = (7.5 \text{ kg}) (1.50 \text{ m/s}^2) = 11.25 \text{ N}$$

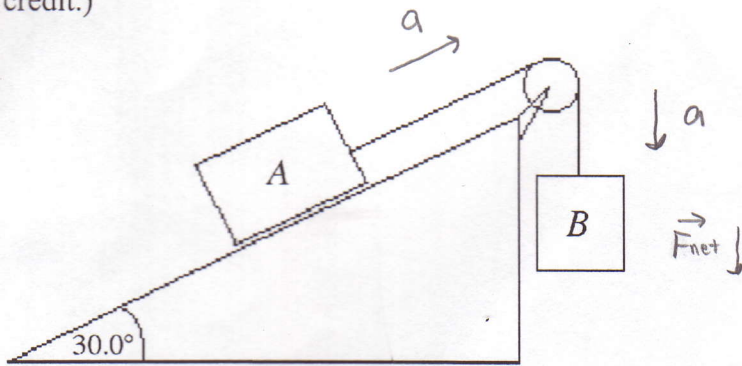
to the right

(a)  $\vec{F}_{B \text{ on } A} = -(11.25 \text{ N}) \hat{i}$

**Problem 3 (5 points)**

Two blocks are connected by a stretchless, massless string that passes over a massless, frictionless pulley as shown in the figure below. Block A has a mass of 3.00 kg and can slide over a rough plane inclined  $30.0^\circ$  to the horizontal. The coefficient of kinetic friction between block A and the plane is 0.400. Block B has a mass of 2.77 kg. What is the acceleration of the blocks **and** the tension in the string?

(Note: you must draw free-body diagrams and start with  $\sum \vec{F} = m\vec{a}$  for each mass to get full credit.)

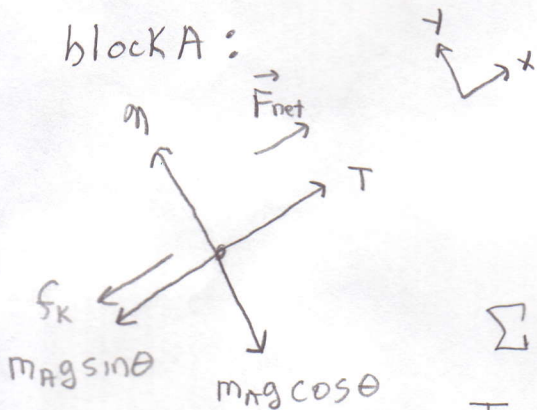


block B: define down as +

$$\sum F_y = ma_y$$

$$m_B g - T = m_B a$$

$$T = m_B g - m_B a \quad (1)$$



$$\sum F_y = ma_y = 0$$

$$n - m_A g \cos \theta = 0 \rightarrow n = m_A g \cos \theta$$

$$\sum F_x = ma_x$$

$$T - m_A g \sin \theta - f_k = m_A a_x \quad f_k = \mu_k n = \mu_k m_A g \cos \theta$$

$$T - m_A g \sin \theta - \mu_k m_A g \cos \theta = m_A a$$

put (1)  $\rightarrow$  (2)  $(m_B g - m_B a) - m_A g \sin \theta - \mu_k m_A g \cos \theta = m_A a$

$$a = \frac{m_B g - m_A g \sin \theta - \mu_k m_A g \cos \theta}{m_A + m_B}$$

$$a = \frac{(2.77 \text{ kg})(9.80 \text{ m/s}^2) - (3.00 \text{ kg})(9.80 \text{ m/s}^2) \sin 30^\circ - (0.400)(3.00 \text{ kg})(9.80 \text{ m/s}^2) \cos 30^\circ}{3.00 \text{ kg} + 2.77 \text{ kg}}$$

$$a = 0.392 \text{ m/s}^2$$

$$T = m_B g - m_B a = (2.77 \text{ kg})(9.80 \text{ m/s}^2 - 0.392 \text{ m/s}^2) \rightarrow T = 26.1 \text{ N}$$