FORCE AND MOTION II

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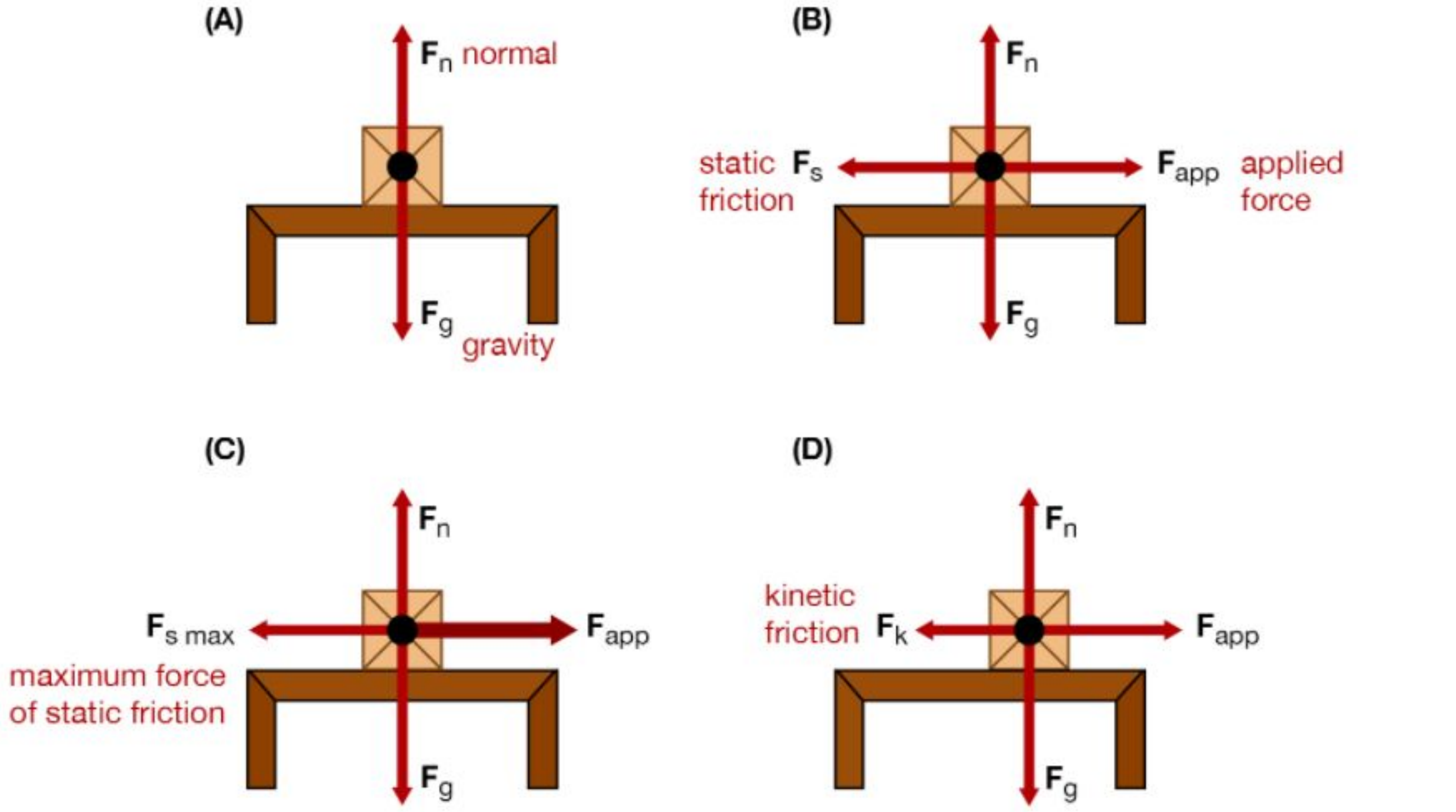
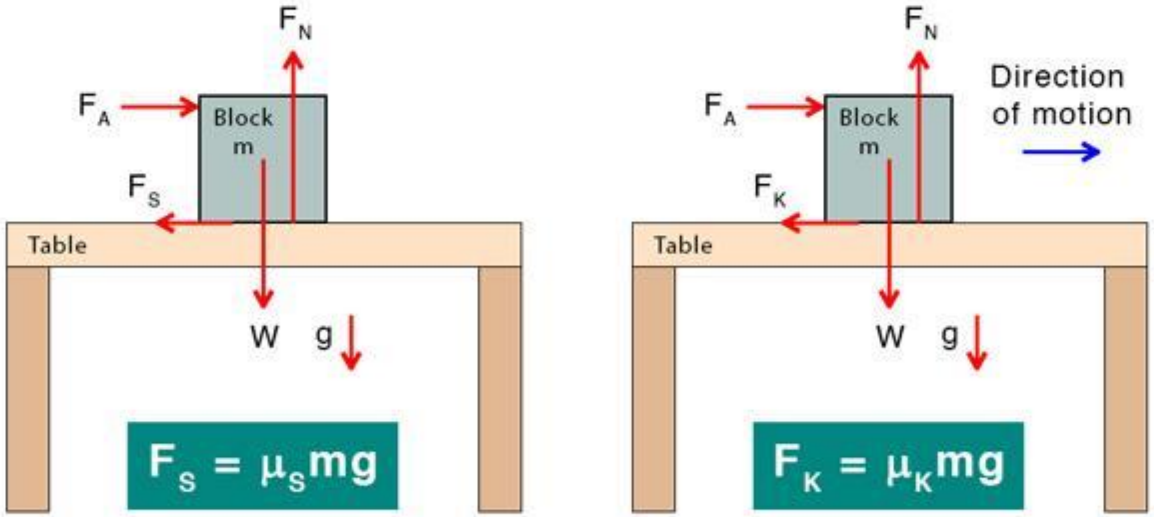
Friction forces



Static Friction vs. Kinetic Friction



F_N : Normal force

F_A : Aplied force

m : Mass of the block

F_S : Static friction

F_K : Kinetic friction

W : Weight of the block

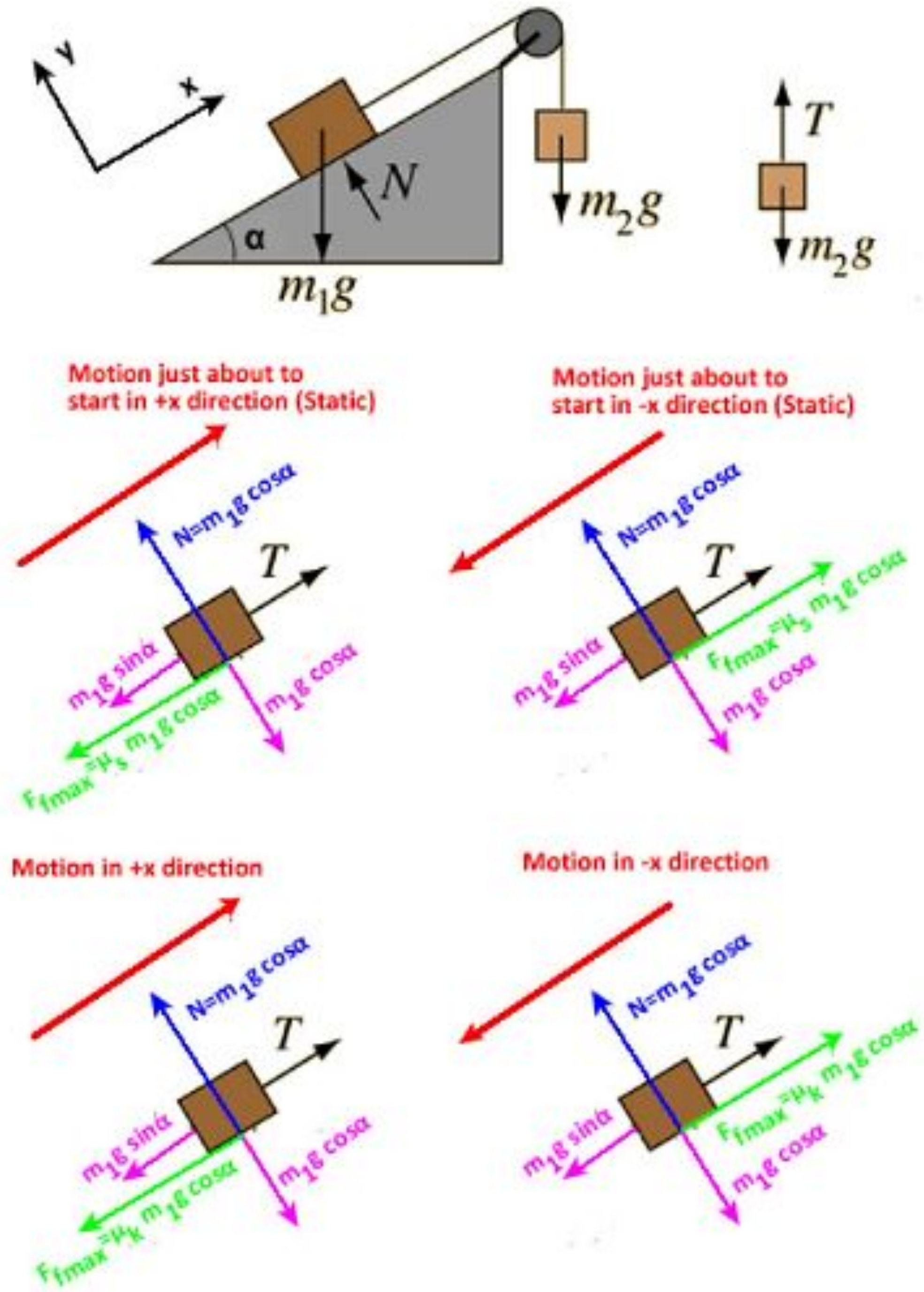
μ_S : Coefficient of static friction

μ_K : Coefficient of kinetic friction

g : Acceleration due to gravity

Static Friction vs. Kinetic Friction

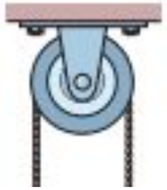
Property	Static Friction	Kinetic Friction
Object is	Stationary	Moving
Symbol for coefficient	μ_S	μ_K
Equation	$F_S = \mu_S F_N$	$F_K = \mu_K F_N$
Magnitude	Higher than kinetic friction	Lower than static friction

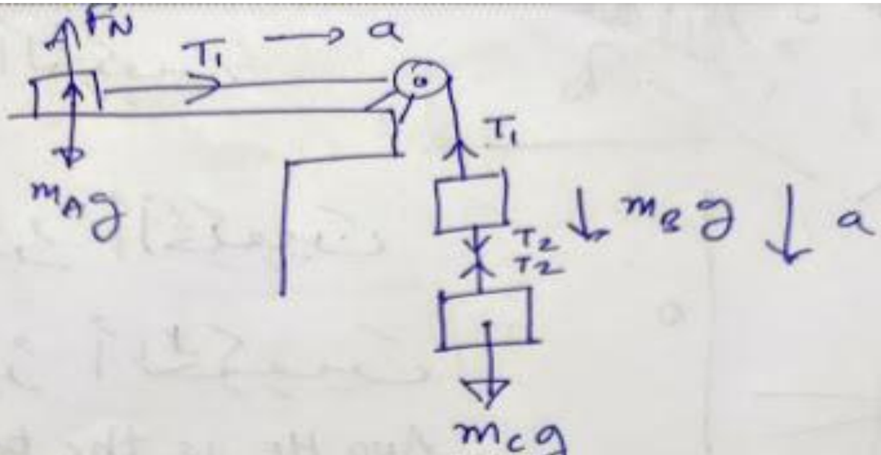


y
x
N
α
m_1g
m_2g
T
m_2g
Motion just about to start in +x direction (Static)
N=m_1g cosα
T
m_1g sinα
m_1g cosα
F_{fmax}=μ_s m_1g cosα
Motion just about to start in -x direction (Static)
N=m_1g cosα
T
m_1g sinα
F_{fmax}=μ_s m_1g cosα
m_1g cosα
Motion in +x direction
N=m_1g cosα
T
m_1g sinα
m_1g cosα
F_{fmax}=μ_k m_1g cosα
Motion in -x direction
N=m_1g cosα
T
m_1g sinα
F_{fmax}=μ_k m_1g cosα
m_1g cosα

••50 In Fig. 5-46, three ballot boxes are connected by cords, one of which wraps over a pulley having negligible friction on its axle and negligible mass. The three masses are $m_A = 30.0$ kg, $m_B = 40.0$ kg, and $m_C = 10.0$ kg. When the assembly is released from rest, (a) what is the tension in the cord connecting B and C, and (b) how far does A move in the first 0.250 s (assuming it does not reach the pulley)?

Fig. 5-46 Problem 50.





(a) At rest ~~a=0~~. $T_1 = m_A a$ — eq(1)

$T_1 - T_2 - m_B g = -m_B a$ — eq(2)

$T_2 - m_c g = -m_c a$ — eq(3)

Substituting equation (1) in eq(2) we get

$m_A a - T_2 - m_B g = -m_B a$ — eq(4)

$T_2 - m_c g = -m_c a$ — eq(3)

$m_A a - m_B g - m_c g = -m_B a - m_c a$

$\Rightarrow a = \frac{(m_B + m_c)g}{m_A + m_B + m_c} = \frac{30+10}{30+40+10} \times 9.8$

$= 4.9 \text{ m/s}^2$

$\therefore T_2 = m_c(g - a) = 10(9.8 - 4.9)$

$= 49\text{N}.$

•9 GO A 3.5 kg block is pushed along a horizontal floor by a force $\vec{F}$ of magnitude 15 N at an angle $\theta = 40°$ with the horizontal (Fig. 6-19). The coefficient of kinetic friction between the block and the floor is 0.25. Calculate the magnitudes of (a) the frictional force on the block from the floor and (b) the block's acceleration.

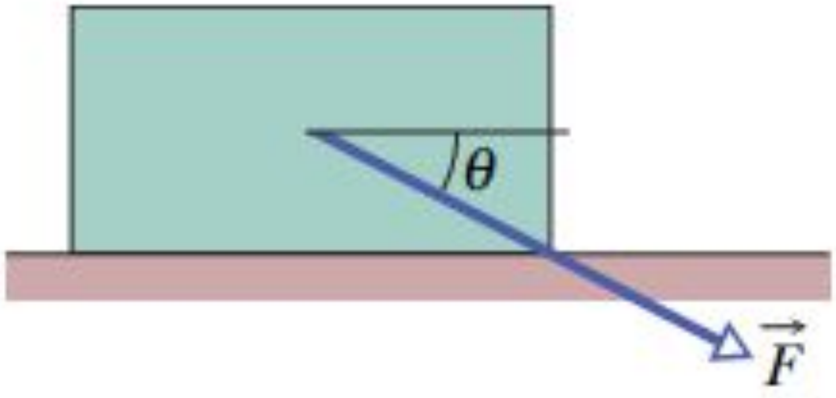


Fig. 6-19 Problems 9 and 32.

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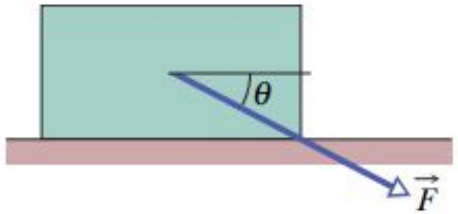
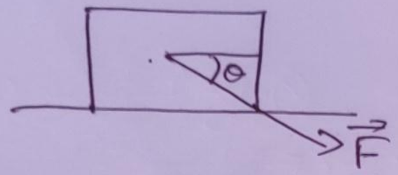


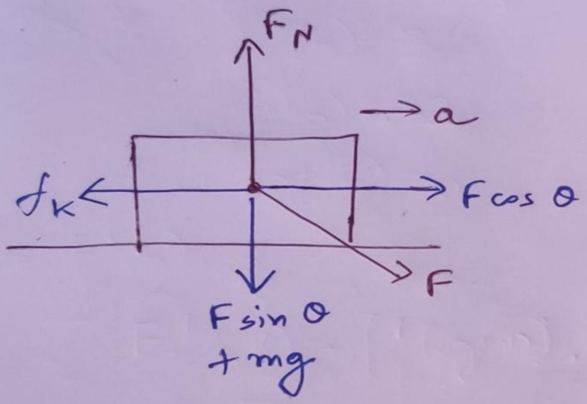
Fig. 6-19 Problems 9 and 32.

(9)



$F = 15N$, $\theta = 40°$
$\mu_K = 0.25$, $m = 3.5 kg$

a) Frictional force?
b) Block's acceleration



Vertical forces

$F_N - F\sin\theta - mg = 0$

$F_N = mg + F\sin\theta$

Horizontal forces

$F\cos\theta - f_K = ma$

$\Rightarrow F\cos\theta - \mu_K F_N = ma$

$\Rightarrow F\cos\theta - \mu_K(F\sin\theta + mg) = ma$

a) $f_K = \mu_K F_N = \mu_K(F\sin\theta + mg)$

$= 0.25(3.5 \times 9.8 + 15\sin 40)$

$= 10.99\ N$

b) $F\cos\theta - f_K = ma$

$\Rightarrow 15\cos 40 - 10.99 = 3.5 \times a$

$\Rightarrow a = 0.14\ m/s^2$

and (b) the block's acceleration.

•10 Figure 6-20 shows an initially stationary block of mass m on a floor. A force of magnitude $0.500mg$ is then applied at upward angle $\theta = 20°$. What is the magnitude of the acceleration of the block across the floor if the friction coefficients are (a) $\mu_s = 0.600$ and $\mu_k = 0.500$ and (b) $\mu_s = 0.400$ and $\mu_k = 0.300$?

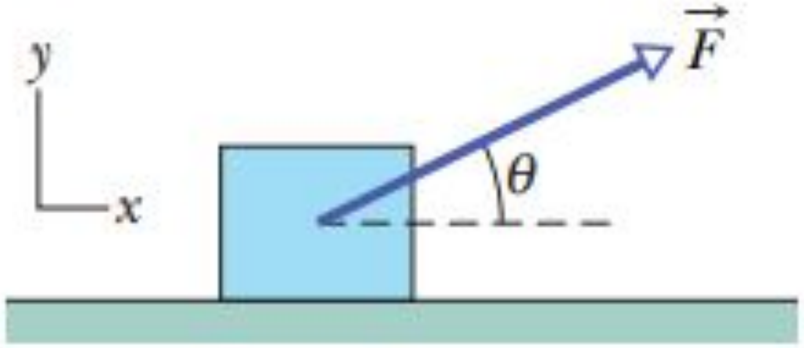


Fig. 6-20 Problem 10.

and (b) the block's acceleration.

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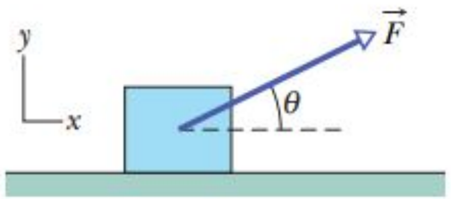

Fig. 6-20 Problem 10.

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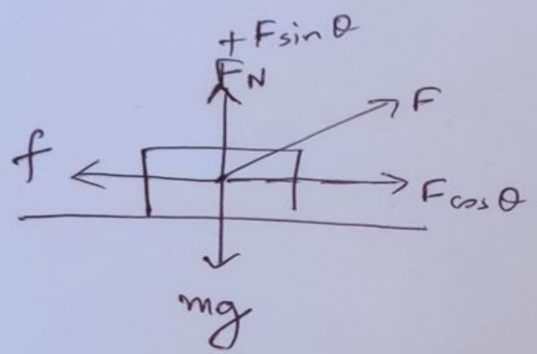


$F = 0.5\,mg$

$m = m$

$\theta = 20°$

a) $\mu_s = 0.6$ $\mu_K = 0.5$

Vertical Forces $F_N + F\sin\theta - mg = 0$

$\Rightarrow F_N = mg - F\sin\theta = mg - 0.5\,mg\sin 20$

$= 0.82\,mg$

$f_{s,max} = \mu_s F_N = 0.6 \times 0.82\,mg = 0.492\,mg$

$F\cos\theta = 0.5\,mg \times \cos 20 = 0.469\,mg$

Since $F\cos\theta < f_{s,max}$, $\therefore a = 0\ m/s^2$ (object is at rest/stationary)

b) $\mu_s = 0.4$, $\mu_K = 0.3$

$F\cos\theta = 0.469\,mg$, $F_N = 0.82\,mg$

$f_{s,max} = \mu_s F_N = 0.4 \times 0.82\,mg = 0.33\,mg$

$F\cos\theta > f_{s,max}$, so the object will accelerate.

$f_K = \mu_K F_N = 0.3 \times 0.82\,mg = 0.25\,mg$

Horizontal $F\cos\theta - f_K = ma$

$\Rightarrow 0.47\,mg - 0.25\,mg = ma$

$\Rightarrow a = 0.22g = 2.16\ m/s^2$

••29 In Fig. 6-34, blocks A and B have weights of 44 N and 22 N, respectively. (a) Determine the minimum weight of block C to keep A from sliding if μ_s between A and the table is 0.20. (b) Block C suddenly is lifted off A. What is the acceleration of block A if μ_k between A and the table is 0.15?

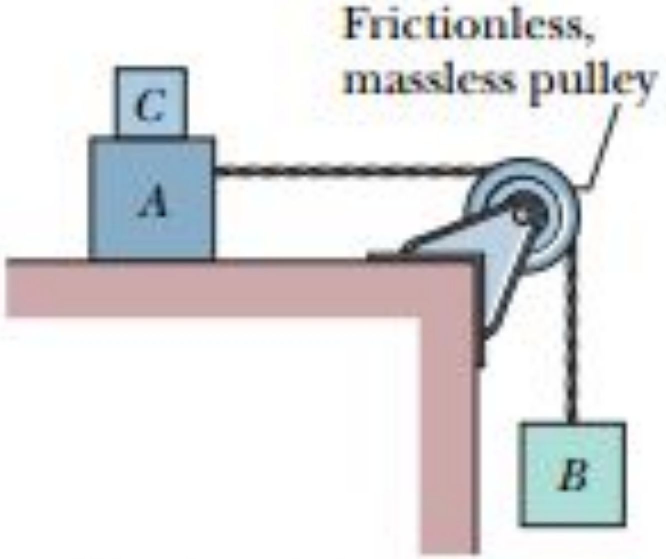


Fig. 6-34 Problem 29.

••29 In Fig. 6-34, blocks *A* and *B* have weights of 44 N and 22 N, respectively. (a) Determine the minimum weight of block *C* to keep *A* from sliding if μ_s between *A* and the table is 0.20. (b) Block *C* suddenly is lifted off *A*. What is the acceleration of block *A* if μ_k between *A* and the table is 0.15?

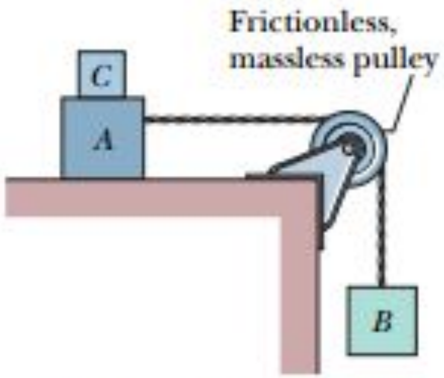
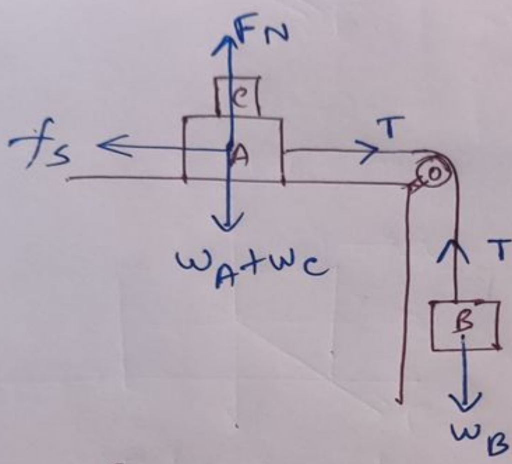


Fig. 6-34 Problem 29.

(29)



$W_A = 44N$, $W_B = 22N$

$F_N = W_A + W_C$

$f_s = \mu_s F_N$

$= \mu_s (W_A + W_C)$

$T - f_s = 0$ —— (1)

$T - W_B = 0$ —— (2)

(−)

$-f_s + W_B = 0$

$\Rightarrow -\mu_s (W_A + W_C) + W_B = 0$

$\Rightarrow -0.2(44 + W_C) + 22 = 0$

$\Rightarrow W_C = \frac{-22}{-0.2} - 44$

$= 66N$

friction is less than 0.700, is magnitude F_{32} more than, less than, or the same as it was when the coefficient was 0.700?

••27 Body A in Fig. 6-33 weighs 102 N, and body B weighs 32 N. The coefficients of friction between A and the incline are $\mu_s = 0.56$ and $\mu_k = 0.25$. Angle θ is 40°. Let the positive direction of an x axis be up the incline. In unit-vector notation, what is the acceleration of A if A is initially (a) at rest, (b) moving up the incline, and (c) moving down the incline?

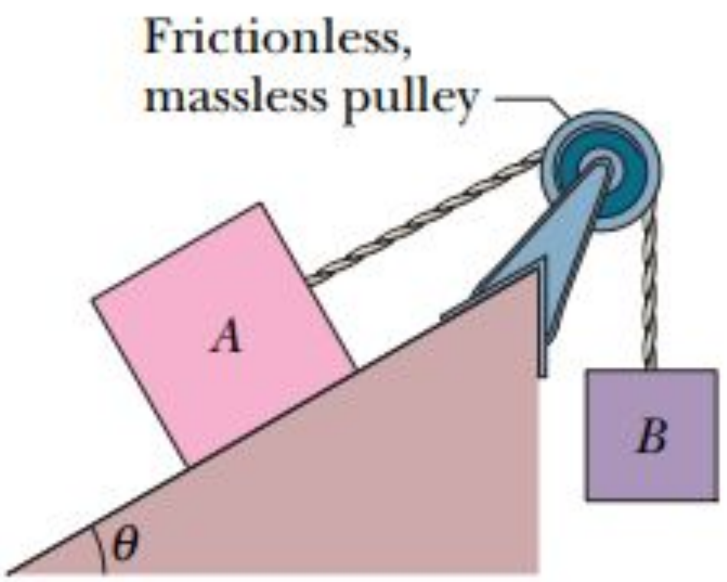
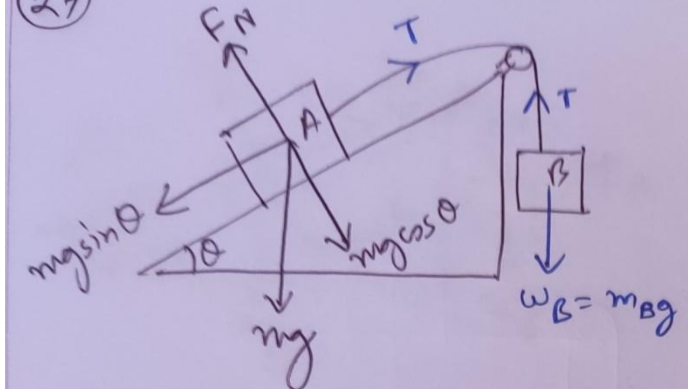


Fig. 6-33 Problems 27 and 28.

(27)

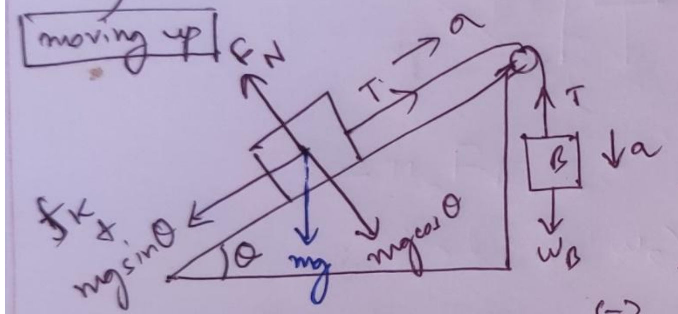


$W_A = 102\,N$
$W_B = 32\,N$
$\mu_s = 0.56$, $\mu_k = 0.25$
$\theta = 40°$

a) At rest, the acceleration of block A is zero

b)

moving up



$f_K = \mu_K F_N$
$= \mu_K W_A \cos\theta$

$T - W_A \sin\theta - f_K = m_A a$ —— (1)

$T - W_B = -m_B a$ —— (2)

(−)

$-W_A \sin\theta - f_K + W_B = m_A a + m_B a$

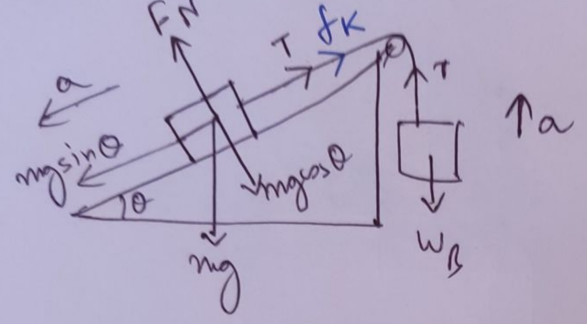
$\Rightarrow -102\sin 40 - (0.25 \times \cos 40 \times 102) + 32 = a(m_A + m_B)$

$\Rightarrow -102\sin 40 - 19.53 + 32 = a\left(\frac{102}{9.8} + \frac{32}{9.8}\right)$

$\Rightarrow a = -3.9\,m/s$

$\therefore a = -3.9\,m/s^2\ \hat{i}$ (the acceleration is down the plane)

(c)



$f_K = \mu_K F_N$
$= \mu_K (mg\cos\theta)$
$= \mu_K (W_A \cos\theta)$

$T + f_K - W_A \sin\theta = -m_A a$ —— (1)

$T - W_B = m_B a$ —— (2)