Statics SKMM1203

Friction

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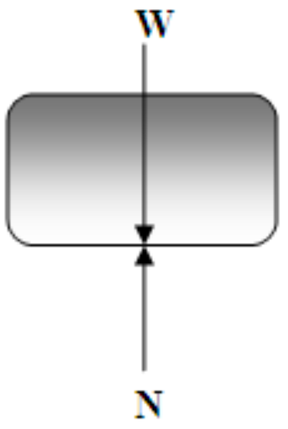
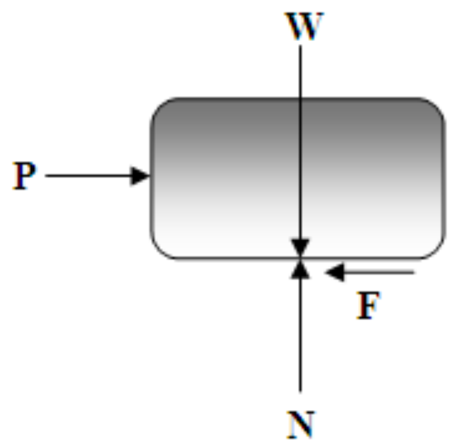
Brief concept:
FRICTION

Objectives

- To explain the law of dry friction
- To apply the law of dry friction

Principle of dry friction

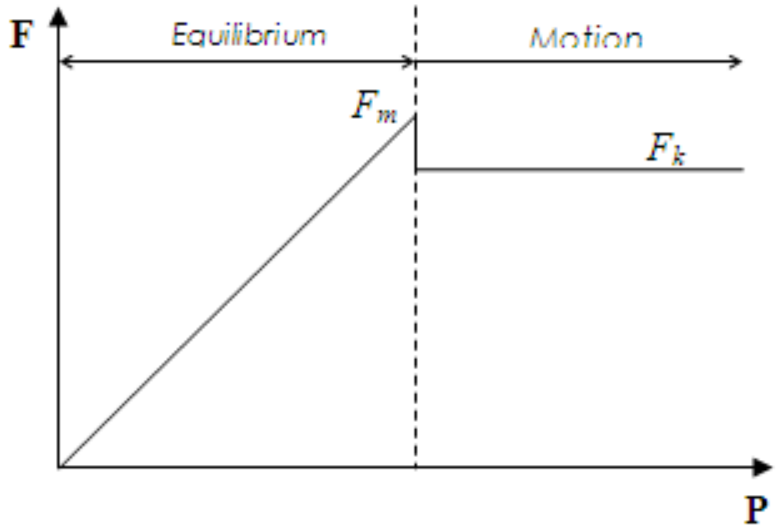




N = W
No Friction, F = 0

N = W
$F = \mu_s N$ if $F < F_m$ (body in equilibrium)
$F = \mu_s N$ if $F = F_m$ (motion impending)
$F = \mu_k N$ if $F > F_m$ (body in motion)

Brief concept:



Relationship between applied force P and friction force F

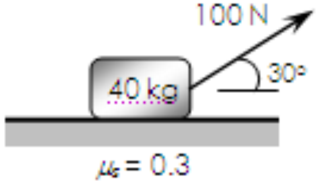
where, F_m = *maximum static friction force*
F_k = *kinetic friction force*
μ_s = *coefficient of static friction*
μ_k = *coefficient of kinetic friction*
N = *normal force*

- *Friction force is independent of surface area of contact but dependent on the roughness of surface area in contact*
- *Static friction, F is directly proportional to the normal force, N.*

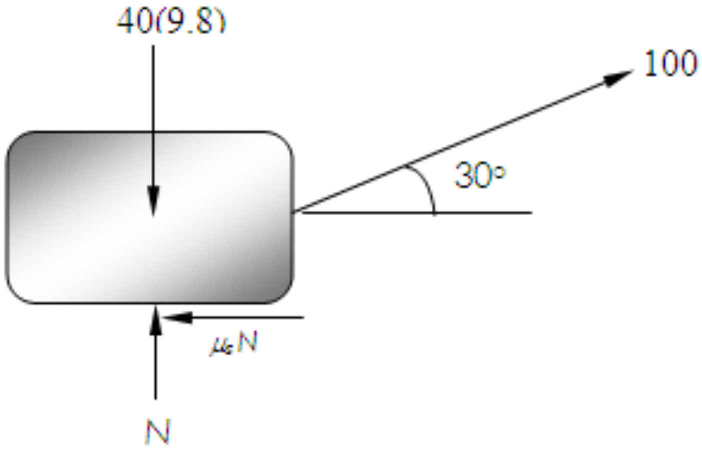
Examples:

QUESTION 1

Determine magnitude and direction of the friction force.



SOLUTION



$(+\rightarrow)\ \Sigma F_x = 0$

$\mu_s N + 100 \cos 30 = 0$ ....(1)

$(+\uparrow)\ \Sigma F_y = 0$

$N - 40(9.8) + 100 \sin 30 = 0$ ......(2)

$N = 342N$

Substitute into (1) for friction force $F = \mu_s N$

$F = (0.3)(342)$

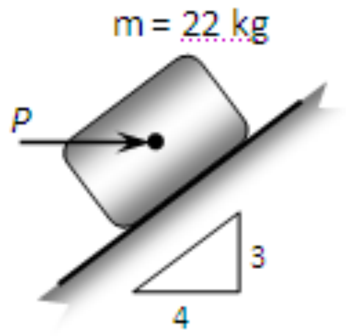
$= 102.6N$

Examples:

QUESTION 2

a. Determine the coefficient of statics friction μ_s if the minimum force required to stop the block from sliding down the inclined surface is $P = 40$ N.

b. If the coefficients of statics and kinetics friction between the block and the surface are $\mu_s = 0.5$ and $\mu_k = 0.4$ respectively, and $P = 200$ N, determine the magnitude and direction of the friction force.

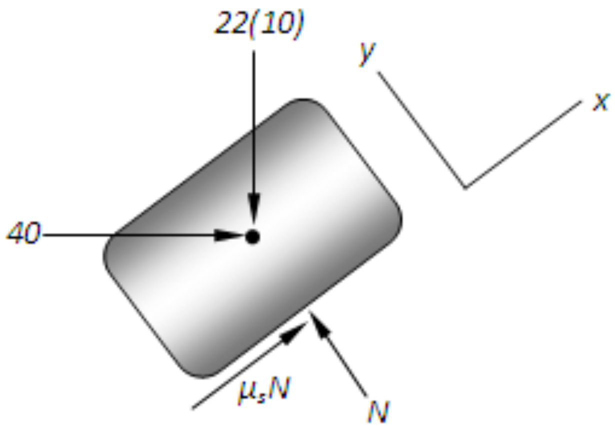


$g = 10\ \text{m/s}^2$

Examples:

SOLUTION

(a)



(+↗) $\Sigma F_x = 0$

$\mu_s N - 22(10)(3/5) + 40(4/5) = 0$ .....(1)

(+↖) $\Sigma F_y = 0$

$N - 22(10)(4/5) - 40(3/5) = 0$ ....(2)

$N = 200N$

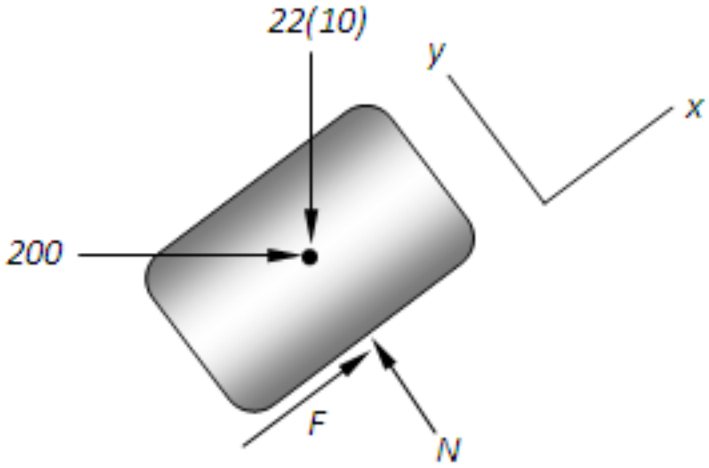
Substitute into (1)

$\mu_s(200) - 22(10)(3/5) + 40(4/5) = 0$

$\mu_s = 0.5$

Examples:

(b)



Assume the direction of friction force F is in + x –dir

(+↗) $\Sigma F_x = 0$

F – 22(10)(3/5) + 200(4/5) = 0 .....(1)

F = - 28N (Actual direction is opposite to the assumption)

(+↖) $\Sigma F_y = 0$

N -22(10)(4/5) – 200(3/5) = 0 ....(2)

N = 296N

Examples:

Maximum static friction $F_m = \mu_s N$

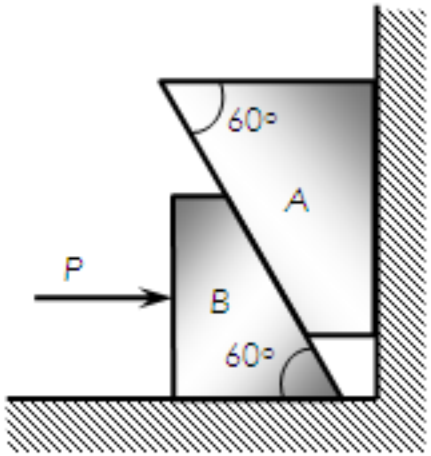
$F_m = (0.5)(296)$

$= 148N$

Since $F < F_m$*, the object is in equilibrium. Thus the magnitude and direction of friction force is 28N ↙ (-x direction)*

QUESTION 3

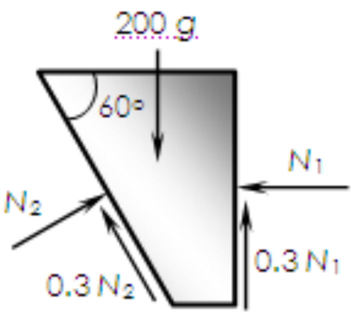
Two blocks A and B of mass 200 kg and 100 kg respectively are placed in contact with each other as shown. Determine the minimum force P required to maintain equilibrium if the coefficient of friction between all contacting surfaces is $\mu = 0.3$.



Examples:

SOLUTION

block A



$(+\rightarrow)\ \Sigma F_x = 0$

$N_2 \sin 60° - 0.3\ N_2 \cos 60° - N_1 = 0$

$= 0$

$0.866\ N_2 - 0.15\ N_2 - N_1 = 0$

$N_1 = 0.716\ N_2$

$(+\uparrow)\ \Sigma F_y = 0$

$N_2 \cos 60° + 0.3\ N_2 \sin 60° + 0.3\ N_1 - 100\ g = 0$

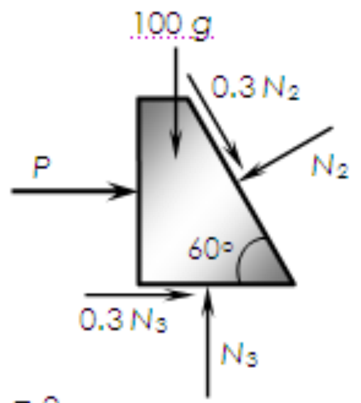
$= 0$

$0.5\ N_2 + 0.26\ N_2 + 0.3\ N_1 - 100\ g = 0$

$0.76\ N_2 + 0.3(0.716\ N_2) - 200\ g = 0$

$N_2 = 2012$ N

block B



$(+\uparrow)\ \Sigma F_y = 0$

$N_3 - N_2 \cos 60° - 0.3\ N_2 \sin 60° - 100\ g$

$N_3 - 1006 - 523 - 100\ g = 0$

$N_3 = 2510$ N

$(+\rightarrow)\ \Sigma F_x = 0$

$P + 0.3\ N_3 + 0.3\ N_2 \cos 60° - N_2 \sin 60°$

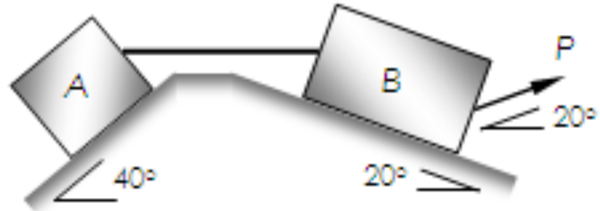
$P + 753 + 302 - 1742 = 0$

$P = 687$ N

Examples:

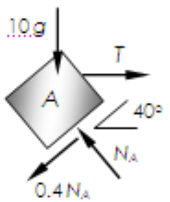
QUESTION 4

Determine the minimum force P required to start block B moving down the incline plane. m_A = 10 kg, m_B = 20 kg and the coefficient of statics friction between all contacting surfaces is $\mu_s = 0.4$.



SOLUTION

Block A



(+↖) $N_A - 10g \cos 40° - T \sin 40° = 0$

sin 40° = 0

$N_A - 0.643\,T = 75.1$ (1)

0.643 P = 0

(+↙) $10g \sin 40° + 0.4\,N_A - T \cos 40° = 0$

(3)

$0.4\,N_A - 0.766\,T = -63.1$ (2)

(1) $N_A - 0.643\,T = 75.1$ } −

$0.4\,N_B = 0$

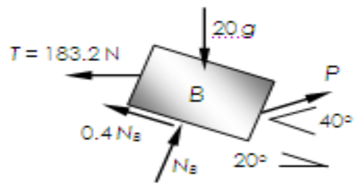
(2) ÷ 0.4 $N_A - 1.915\,T = -157.8$

(4)

$1.272\,T = 233$

∴ $T = 183.2$ N

Block B



(+↗) $N_B - 20g \cos 20° - T \sin 20° + P$

$N_B - 184.4 - 183.2 \sin 20° +$

$N_B + 0.643\,P = 247$

(+↘) $P \cos 40° + 20g \sin 20°$

$- T \cos 20° - 0.4\,N_B = 0$

$0.766\,P + 67.1 - 0.94(183.2) -$

$0.766\,P - 0.4\,N_B = 105.1$

(3) $N_B + 0.643\,P = 247$ } +

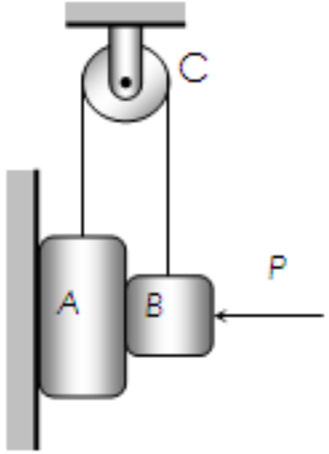
(4) ÷ 0.4 $1.915\,P - N_B = 262.8$

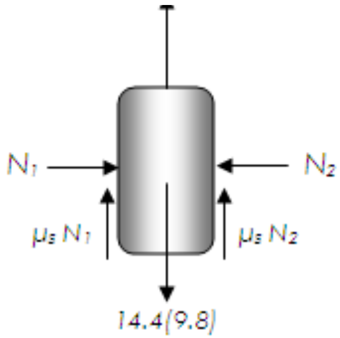
$2.56\,P = 509.8$

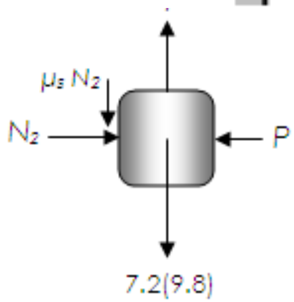
Examples:

QUESTION 5

Blocks *A* of mass 14.4 kg and *B* of mass 7.2 kg are connected by a cable that passes over smooth pulley *C*. If the coefficient of static friction at all surfaces of contact are μ_s= 0.12, determine the smallest value of *P* for which equilibrium is maintained. Determine also the tension in the cable, *T*.







$(+\rightarrow)\ \Sigma F_x = 0$

$N_1 - N_2 = 0$ ....(1)

$(+\uparrow)\ \Sigma F_y = 0$

$\mu_s N_1 + \mu_s N_2 + T - 14.4(9.8) = 0$ ......(2)

$(+\uparrow)\ \Sigma F_y = 0$

$T - \mu_s N_2 - 7.2(9.8) = 0$ ....(3)

$(+\rightarrow)\ \Sigma F_x = 0$

$N_2 - P = 0$ ....(4)

(3) – (2)

Examples:

$(3) - (2)$

$-\mu_s N_2 - 7.2(9.8) - \mu_s N_1 - \mu_s N_2 + 14.4(9.8) = 0$

From (1) $N_1 = N_2$, thus

$-\mu_s N_2 - 7.2(9.8) - \mu_s N_2 - \mu_s N_2 + 14.4(9.8) = 0$

$3\mu_s N_2 = 70.56$

$N_2 = 196\ N = N_2$

From (4), $P = N_2 = 196N$

From (3),

$T - \mu_s N_2 - 7.2(9.8) = 0$

$T = 0.12(196) + 7.2(9.8)$

$= 94.08N$