Force of Friction:

Theory of Friction:

A force acting in the opposite direction to the motion of the body .
قوة تعمل في الاتجاه المعاكس لحركة الجسم.

It is of the following two types:

1. Static friction ; and الاحتكاك الساكن
2. Dynamic friction. الاحتكاك الديناميكي

The friction, experienced by a body, when at **rest**, is known as **static friction**.

The friction experienced by a body, when in **motion**, is called **dynamic friction**. It is also called **kinetic friction**. It is of the following two types:

(a) Sliding friction ; and احتكاك انزلاقي
(b) Rolling friction. احتكاك دحرجة

- It is experimentally found that the magnitude of limiting friction bears a constant ratio to the normal reaction between two surfaces and this ratio is called **Coefficient of Friction**. (μ)

Laws of Static Friction:

Following are the laws of static friction:

1. The force of friction always acts in a direction opposite to that in which the body tends to move. **قوة الاحتكاك دائما تكون عكس اتجاه الحركة**
2. The magnitude of force of friction is exactly equal to the force which tends the body to move. **مقدار قوة الاحتكاك يساوي تماما القوة التي تحاول جعل الجسم يتحرك**
3. The magnitude of the limiting friction bears a constant ratio to the normal reaction between the two surfaces.

4. The force of friction is independent of the area of contact between the two surfaces. . قوة الاحتكاك لا تعتمد على مساحة السطوح المحتكه
5. The force of friction depends upon the roughness of the surfaces. قوة الاحتكاك تعتمد على مدى نعومة السطوح المحتكة

Laws of Dynamic or Kinetic Friction:

Following are the laws of dynamic or kinetic friction :

1. The force of friction always acts in a direction opposite to that in which the body tends to move.

2.The magnitude of the kinetic friction bears a constant ratio to the normal reaction between the two surfaces.

3.For moderate speeds, the force of friction remains constant. But it decreases slightly with the increase of speed.

بالنسبة للسرعات المعتدلة ، تظل قوة الاحتكاك ثابتة. لكنه يتناقص بشكل طفيف مع زيادة السرعة.

Coefficient of Friction:

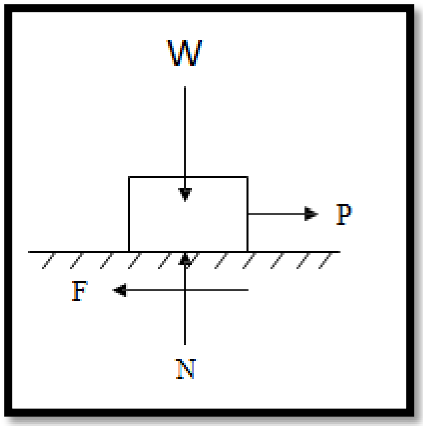
It is defined as the ratio of limiting friction (F) to the normal reaction (N) between the two bodies. It is generally denoted by μ. Mathematically,

$$\text{Coefficient of friction} = \frac{F}{N}$$

where F is limiting friction and N is normal reaction between the contact surfaces.

Coefficient of friction is denoted by μ.

$$Fm = \mu sN$$



- Block of weight W placed on horizontal surface. Forces acting on block are its weight and reaction of surface N.

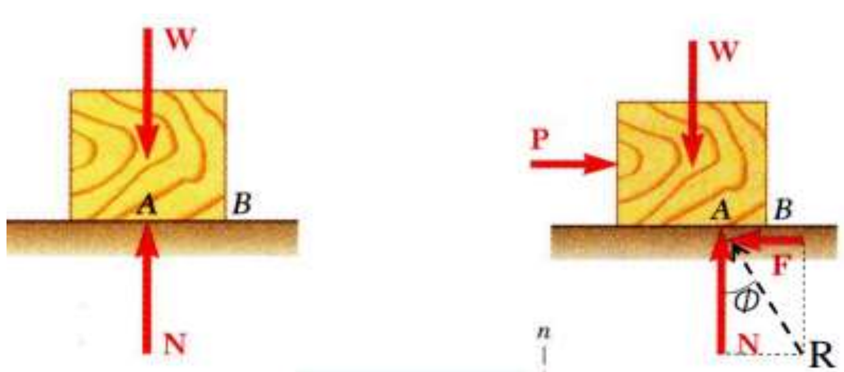
• Small horizontal force P applied to block. For block to remain stationary, in equilibrium, a horizontal component F of the surface reaction is required. F is a Static-Friction force.

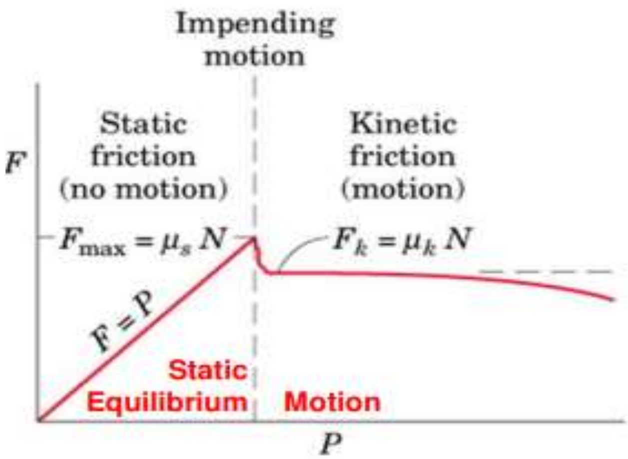
• As P increases, static-friction force F increases as well until it reaches a maximum value Fm. $F_m = \mu_s N$

• Further increase in P causes the block to begin to move as F drops to a smaller Kinetic-Friction force F_k. $F_k = \mu_k N$

μs is the Coefficient of Static Friction

μk is the Coefficient of Kinetic Friction.





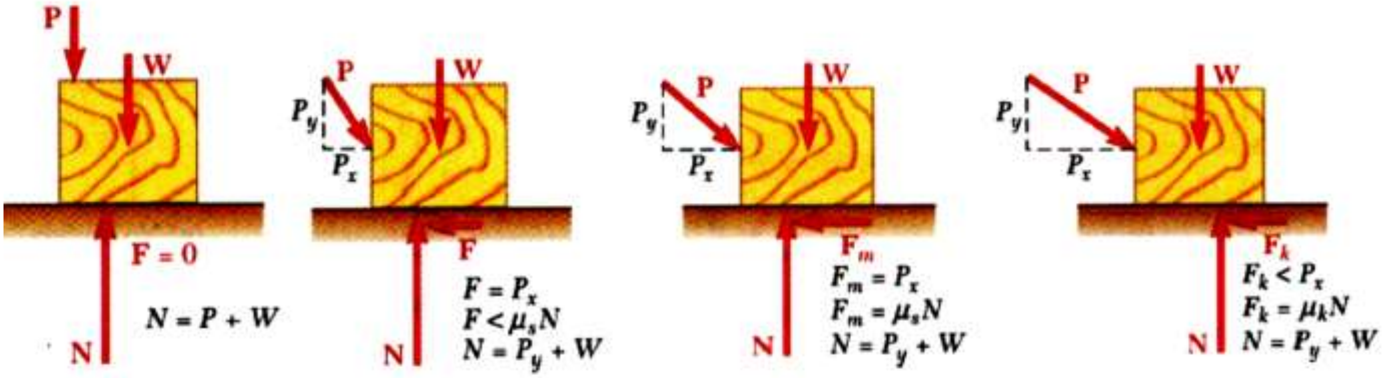
Mechanism of Dry Friction:

Dry Friction occurs between unlubricated surfaces of two solids.

يحدث الاحتكاك الجاف بين الأسطح غير(المشحمة)المزيتة لمادة صلبة.

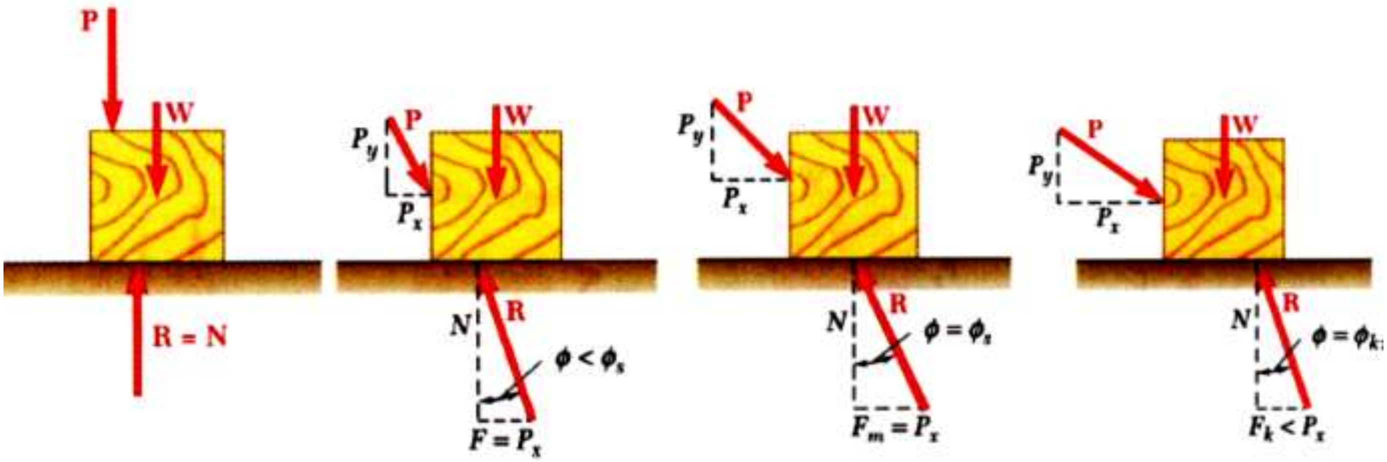
The laws of dry frictions:

- Four situations can occur when a rigid body is in contact with a horizontal surface:



- No friction, ($P_x = 0$)
- No motion, ($P_x < F$)
- Motion impending, ($P_x = F_m$)
- Motion, ($P_x > F_m$)

- It is sometimes convenient to replace normal force **N** and friction force **F** by their resultant **R**:



- No friction
- No motion
- Motion impending
- Motion

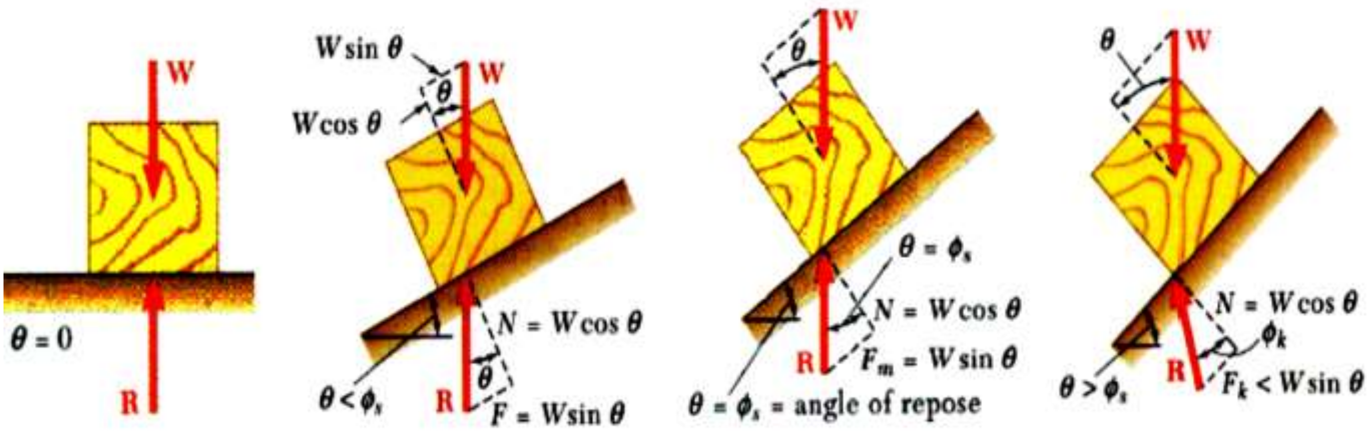
$$\tan\phi_s = \frac{F_m}{N} = \frac{\mu_s N}{N} \qquad \tan\phi_k = \frac{F_k}{N} = \frac{\mu_k N}{N}$$

$$\tan\phi_s = \mu_s \qquad \tan\phi_k = \mu_k$$

Friction on inclined plane :

Angle of frictions:

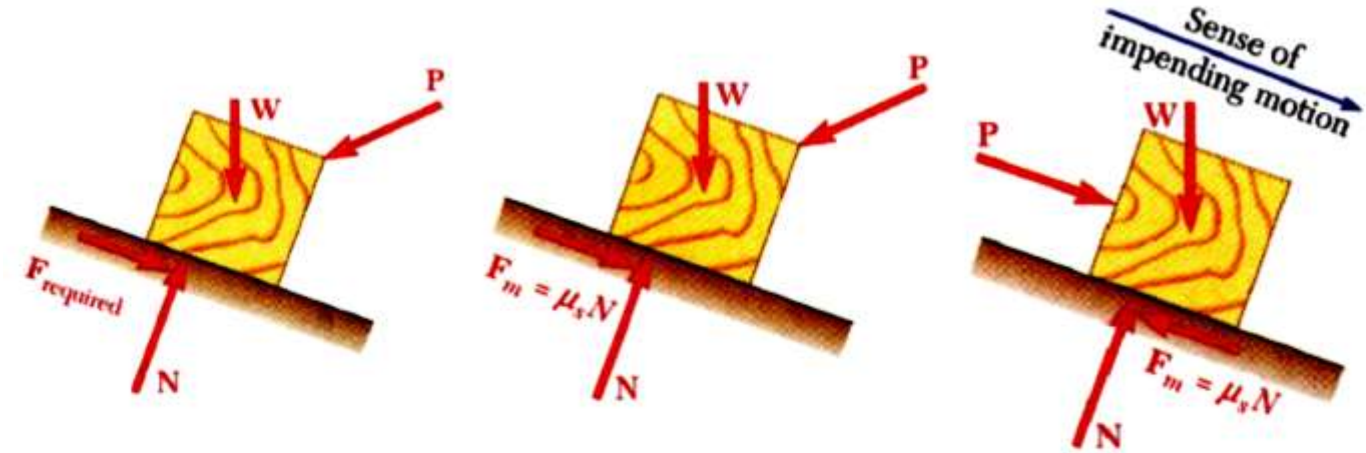
- Consider block of weight **W** resting on board with variable inclination angle θ.



- No friction
- No motion
- Motion impending
- Motion

Angle of Repose = Angle of Static Friction

Problem involved friction:

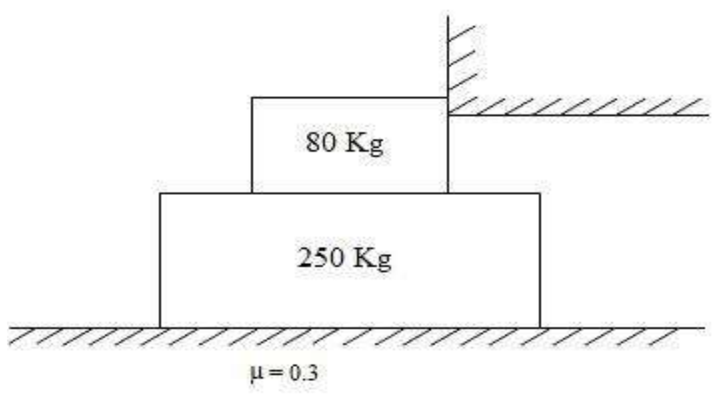


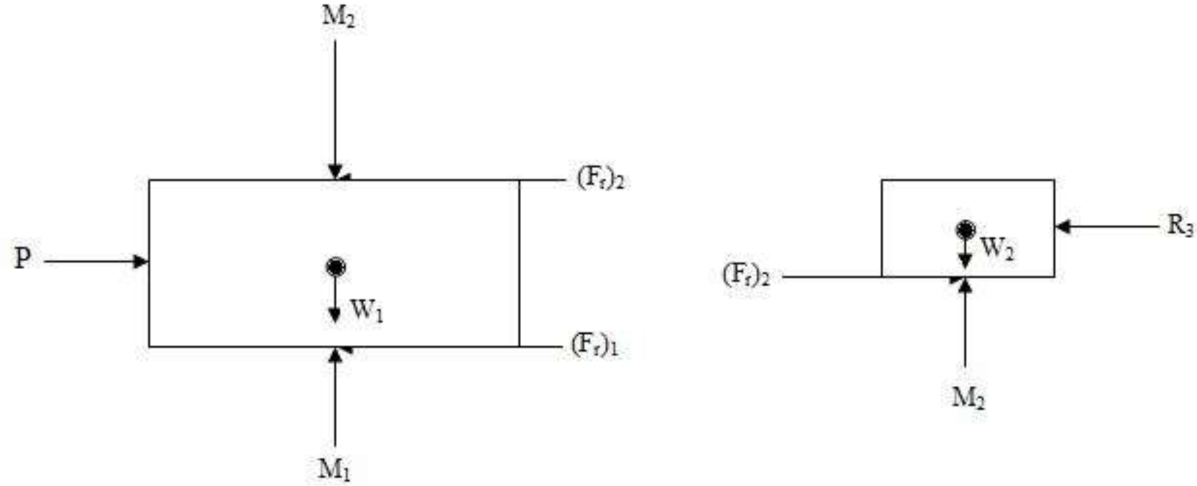
- All applied forces known
- Coefficient of static friction is known
- Determine whether body will remain at rest or slide

- All applied forces known
- Motion is impending
- Determine value of coefficient of static friction.

- Coefficient of static friction is known
- Motion is impending
- Determine magnitude or direction of one of the applied forces

Example: If coefficient of friction between all surfaces shown in Fig. is 0.30. What is the horizontal force required to get 250 kg block moving to the right?





(a) Lower block (b) Upper block

Note that $\sum F_y = 0$ for upper block give $M_2 - W_2 = 0$

$M_2 = W_2$, $M_2 = 80 \times 9.81 = 784.8$ N

For lower block, $\sum F_y = 0$, $M_1 - W_1 - M_2 = 0$

$M_1 = W_1 + M_2$ $M_1 = (250 \times 9.81) + 784.8 = 3237.3$ N

Also $(F_r)_1 = \mu M_1 = (0.3)(3237.3) = 971.19$ N

and $(F_r)_2 = \mu M_2 = (0.3)(784.8) = 235.44$ N

$\sum F_x = 0$ for lower block gives $P - (F_r)_1 - (F_r)_2 = 0$

$P = (F_r)_1 + (F_r)_2$, $P = 1206.63$ N

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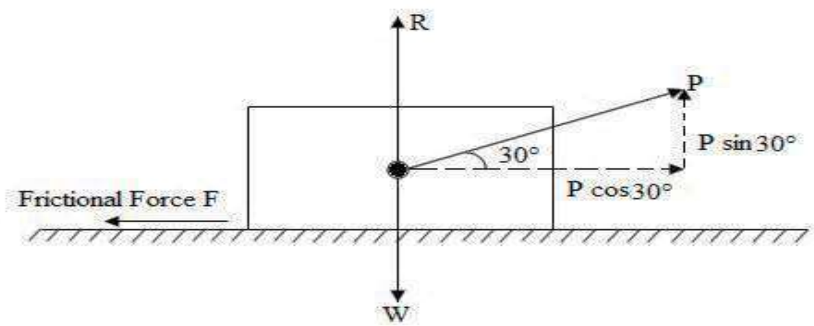
Example: A pull of 20 KN at 30° to the horizontal in necessary to move a block of wood on a horizontal table .If the coefficient of friction between the bodies in contact is 0.25, what is the weight of the block?



Solution: Pull (P) = 20 kN, inclination of the force θ = 30° to the horizontal

Coefficient of friction, μ = 0.25

Resolving the forces horizontally, $\sum F_x = 0$

P Cos30°-F = 0

F = P Cos30°

μR = P Cos30° ---(i)

$\sum F_y = 0$

R + P Sin30° - W = 0

R = W – P Sin30° --(ii)

Substituting the value of R in Eqn.(i), we get

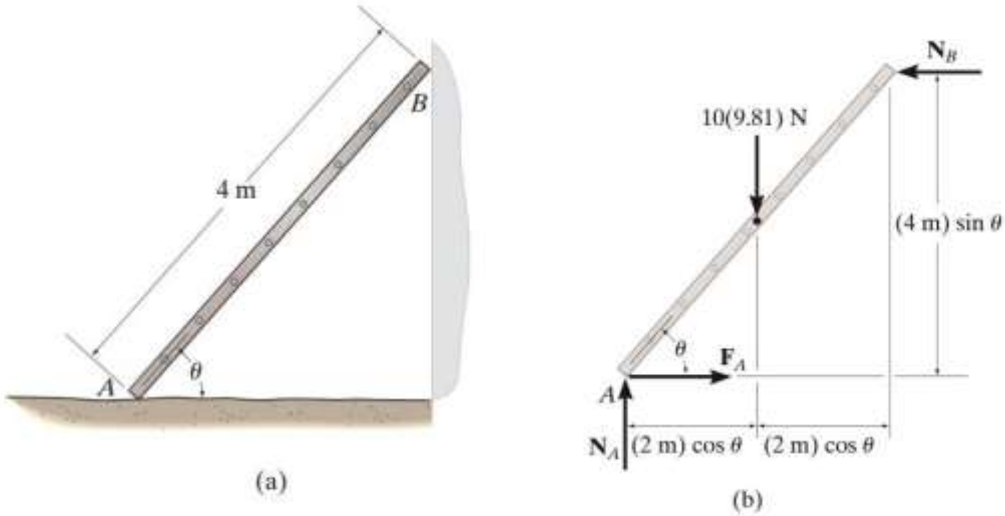
μ(W – P Sin30°) = P Cos30°

0.25(W – 20 Sin30°) = 20 Cos30°

0.25(W – 10) = 17.32

W = 79.28 kN

Example: The uniform 10-kg ladder in Fig. a rests against the smooth wall at B, and the end A rests on the rough horizontal plane for which the coefficient of static friction is μ_s = 0.3. Determine the angle of inclination θ of the ladder and the normal reaction at B if the ladder is on the verge of slipping.



Solution: As shown on the free-body diagram, Fig. b, the frictional force FA must act to the right since impending motion at A is to the left.

Equations of Equilibrium and Friction. Since the ladder is on the verge of slipping, then $F_A = \mu_s N_A = 0.3N_A$. By inspection, N_A can be obtained directly.

$$+\uparrow \Sigma F_y = 0; \qquad N_A - 10(9.81)\text{ N} = 0 \qquad N_A = 98.1\text{ N}$$

Using this result, $F_A = 0.3(98.1\text{ N}) = 29.43\text{ N}$. Now N_B can be found.

$$\overset{+}{\rightarrow} \Sigma F_x = 0; \qquad 29.43\text{ N} - N_B = 0$$

$$N_B = 29.43\text{ N} = 29.4\text{ N} \qquad \textit{Ans.}$$

Finally, the angle θ can be determined by summing moments about point A.

$$\Sigma M_A = 0; \qquad (29.43\text{ N})(4\text{ m})\sin\theta + [10(9.81)\text{ N}](2\text{ m})\cos\theta = 0$$

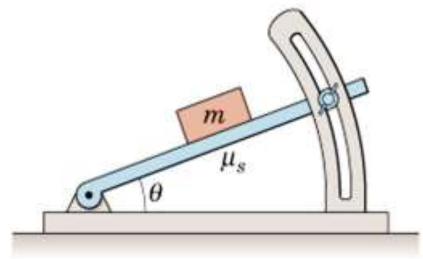
$$\frac{\sin\theta}{\cos\theta} = \tan\theta = 1.6667$$

$$\theta = 59.04^\circ = 59.0^\circ \qquad \textit{Ans.}$$

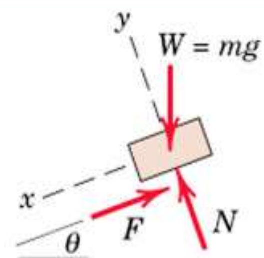
Example

Determine the maximum angle Θ before the block begins to slip.

μ_s = Coefficient of static friction between the block and the inclined surface



Solution: Draw the FBD of the block



$$[\Sigma F_x = 0] \qquad mg \sin\theta - F = 0 \qquad F = mg \sin\theta$$

$$[\Sigma F_y = 0] \qquad -mg \cos\theta + N = 0 \qquad N = mg \cos\theta$$

$$F/N = \tan\theta$$

Max angle occurs when $F = F_{max} = \mu_s N$

Therefore, for impending motion: $\mu_s = \tan\theta_{max}$ or $\theta_{max} = \tan^{-1}\mu_s$

The maximum value of Θ is known as *Angle of Repose*

EXAMPLE:

Determine the range of values which the mass m_0 may have so that the 100-kg block shown in the figure will neither start moving up the plane nor slip down the plane. The coefficient of static friction for the contact surfaces is 0.30.

CASE I

$[\Sigma F_y = 0]$ $\quad N - 981\cos 20^\circ = 0 \quad N = 922\text{ N}$

$[F_{max} = \mu_s N]$ $\quad F_{max} = 0.30(922) = 277\text{ N}$

$[\Sigma F_x = 0]$ $\quad m_0(9.81) - 277 - 981\sin 20^\circ = 0 \quad m_0 = 62.4\text{ kg}$

CASE II

$[\Sigma F_x = 0]$ $\quad m_0(9.81) + 277 - 981\sin 20^\circ = 0 \quad m_0 = 6.01\text{ kg}$