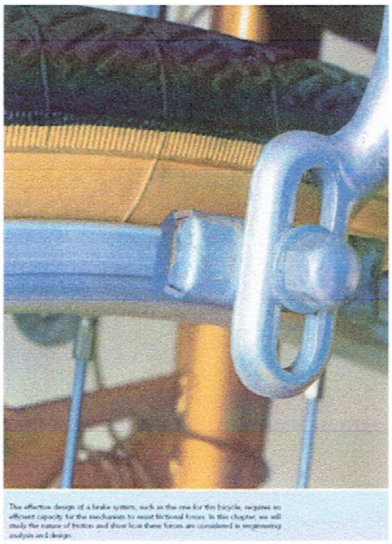
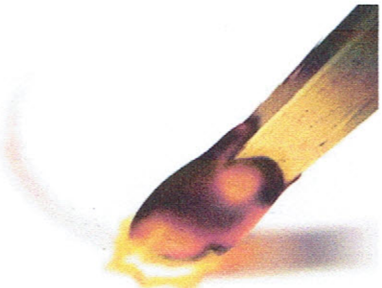
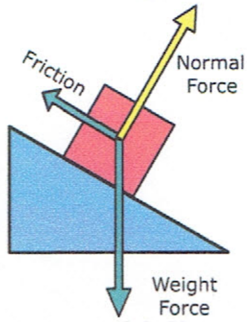
"Friction"







Introduction:

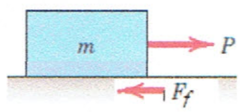
In engineering applications problems, there are no perfectly frictionless surface exists.

When two surfaces are in contact, tangential forces, called friction forces, will always develop if one attempt to move with respect to the other.

Friction Definition:

The Friction is the force that resist the movement of two contacting surfaces that slide relative to one another. This force always acts tangent to the surface at the points of contact and is directed to oppose the possible or existing motion between the surfaces.

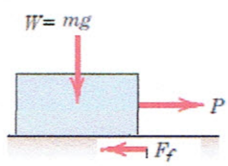
Or, ***it's the force which resist motion of contact surfaces.***



Depends on

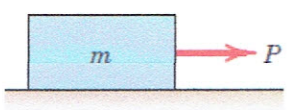
- Weight of object (normal force).
- Nature of the surfaces between the moving object and the supporting surface.

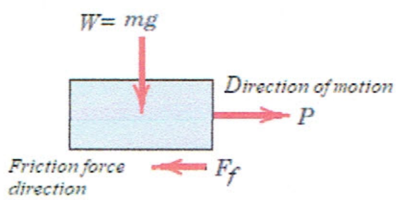
Frictional Forces



Tangential forces generated between contacting surfaces

- occur in the interaction between all real surfaces
- always act in a direction opposite to the direction of motion





Frictional forces are Not Desired in some cases:

- In some types of machines and processes, we want to minimize the retarding effect of friction forces, examples: Bearings, power screws, gears, flow of fluids in pipes, propulsion of aircraft and missiles through the atmosphere, etc
- Friction often results in a loss of energy, which is dissipated in the form of heat
- Friction causes Wear

Frictional forces are desired in some cases:

- In some situations, we wish to maximize the effect of friction, as ***in*** Brakes, clutches, belt drives, and wedges.
- walking depends on friction between the shoe and the ground

Types of Friction:
There are two types of friction can occur between surfaces:

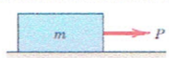
1. Dry Friction:
Dry friction occurs between the contacting surfaces of bodies in the absence of a lubricating fluid. This type of friction is also called "Coulomb friction", (C. A. Coulomb 1781).

2. Fluid Friction:

Fluid friction develops between layers of fluid (liquid or gas) moving at different velocities. Fluid friction is of great importance in problems involving the flow of fluids through pipes and orifices or dealing with bodies immersed in moving fluids. (*Fluid Mechanics*)
• We shall limits our present study to ***dry friction***, i.e., to problems involving rigid bodies which are in contact along non-lubricated surfaces.

Dry Friction:

Consider a solid block of mass "m" resting on a rough horizontal surface, as shown in Fig. below, and assume a horizontal force "*P*" to be applied to the block.



1- Block of weight W placed on horizontal surface. Forces acting on block are its weight and reaction of surface F_N. (Fig. b, below)

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

3- If P increases, static-friction force F_f increases as well until it reaches a maximum value F_{max}.

$$F_{max} = \mu_s F_N$$

4- Further increase in P causes the block to begin to move as F_f drops to a smaller *Kinetic-Friction force* F_k. (F_k remains approximately constant, and the block sliding with increasing velocity)

$$F_k = \mu_k F_N$$

1- Static friction:

The region in Fig. (1, C) up to the point of slippage or impending motion is called the range of "static friction", and in this range the value of the friction force is determined by the equations of equilibrium. This friction force may have any value from zero up to and including the maximum value. For a given pair of mating surfaces the experiment shows that this maximum value of static friction "F_{max}." Is proportional to the normal force "F_N". Thus, we may write

$$F_{max} = \mu_s F_N \quad \ldots\ldots\ldots\ldots (1)$$

Where:

F_{max} : The maximum friction force (F_{static}). *(Newton, N)*

μ_s: The coefficient of static friction.

F_N: The normal force (normal reaction). *(Newton, N)*

Note (1): Eqn. (1) used only when the body is just to move or motion is impending.

Note (2): when motion is not impending, the static friction is $F < F_{max}$.

2- Kinetic friction

After slippage occurs, a condition of kinetic friction accompanies the ensuing motion. ***Kinetic friction force*** it usually somewhat less than ***the maximum static friction force***. The kinetic friction force "F_k" is also proportional to the normal force. Thus,

$$F_k = \mu_k F_N \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where:

F_k : The kinetic friction force ($F_{kinetic}$). *(Newton, N)*

μ_k : The Coefficient of Kinetic Friction

F_N: The normal force (normal reaction). *(Newton, N)*

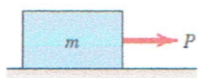
Note(3): always $\mu_k < \mu_s$, *then* $F_k < F_{max}$.

Table 8.1. Approximate Values of Coefficient of Static Friction for Dry Surfaces

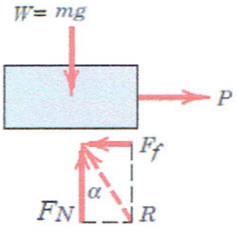
Metal on metal	0.15–0.60
Metal on wood	0.20–0.60
Metal on stone	0.30–0.70
Metal on leather	0.30–0.60
Wood on wood	0.25–0.50
Wood on leather	0.25–0.50
Stone on stone	0.40–0.70
Earth on earth	0.20–1.00
Rubber on concrete	0.60–0.90

Surfaces	Static	Sliding
Hardwood on hardwood	0.5	0.25
Rubber on dry concrete	1.0	0.75
Rubber on wet concrete	0.75	0.5
Steel on steel	0.74	0.6
Steel on steel (lub'd)	0.15	0.06
Human joints	0.01	0.003

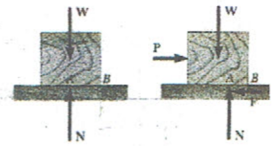
(من الشكل (b) ادناه، عندما تزداد القوة **P** تزداد قوة الاحتكاك (F_f) تبعا لها، بدرجة تكفي لمنع الانزلاق (*الحركة*) ويبقى هذا الاتزان قائما الى ان تصل القوة (F_f) الى الحد الأقصى (F_{max}) وتصبح الحركة على وشك الحدوث، وتنشأ حالة الاتزان الغير مستقر، بعد ذلك أي زيادة طفيفة بالقوة **P** تؤدي الى احداث الحركة، وبعد ذلك تقل قوة الاحتكاك(F_f). كما مبين في الشكل (1, Cادناه).



(a)



(b)



consider a block of weight W subjected to a horizontal force P, if P is small, the block will not move, the static friction force F will exist to balance P

if P increased, F also increased, until its magnitude reaches a certain maximum value F_m, if P is further increased, the friction force cannot balance it, the block starts sliding, and the magnitude of F drops from F_m to a lower value F_k, [where F_k is called kinetic friction force, F_k remains approximately constant, and the block sliding with increasing velocity]

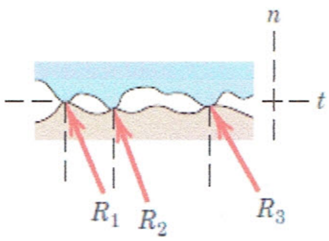


Fig (1, b)

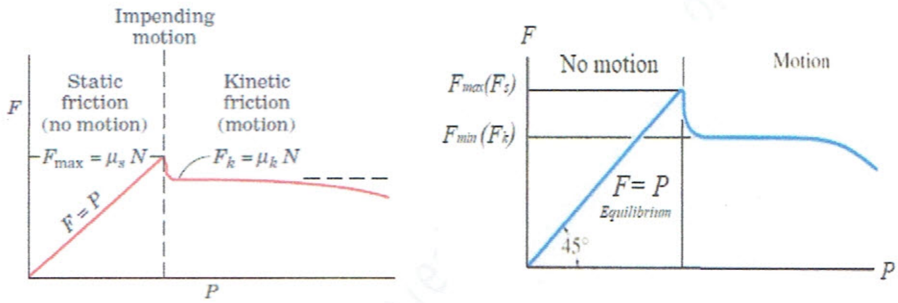


Fig (1, C)

Angle of friction:

From fig (b)

$$\tan\alpha = \frac{Ff}{FN}$$

$$F_f = \tan\alpha * F_N$$

$$F_f = \mu * F_N$$

$$\mu = \frac{Ff}{FN}$$

$$\tan\alpha = \mu$$

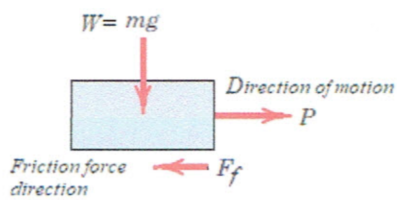
<u>Notes:</u>

From the figure beside

P < Ff ➡ Rest

P = Ff ➡ Impending motion

P > Ff ➡ Motion



$$F_f = \mu .\, F_N$$

Of plane surfaces

Where:

F_f = The friction force. (*Newton, N*)

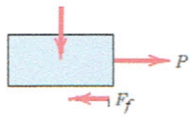
μ = The coefficient of friction. (*without units*)

(μ_s= *Static*, μ_k = *Kinetic*)

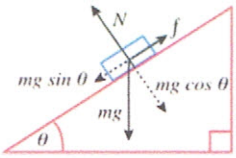
F_N = The normal force (normal reaction). (*Newton, N*)

أنواع الحركة المتوقعة في موضوع الاحتكاك هي:

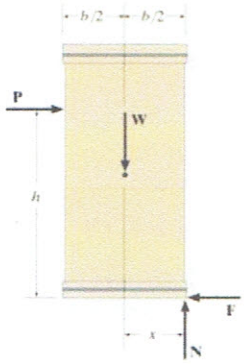
١- الانزلاق (Slipping) ويكون اما الى اليمين او اليسار

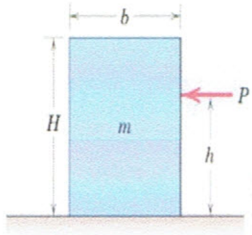


او، للأعلى او للأسفل

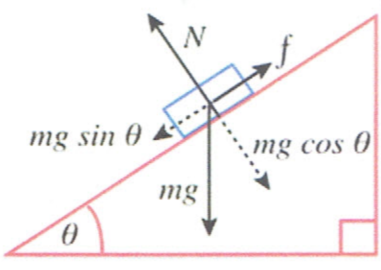


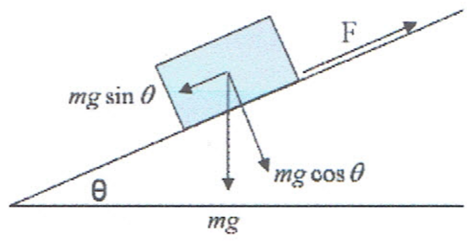
٢- الانقلاب (Tipping): يدقق الانقلاب عندما يكون للجسم ابعاد، دائما في الانقلاب نأخذ العزم في النقطة التي ينقلب عليها الجسم.



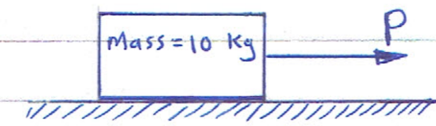


Friction on inclined plane:





Example 1: A crate with mass of 10 kg on horizontal rough surface, $\mu = 0.4$. Find the force (P) needed for start motion.



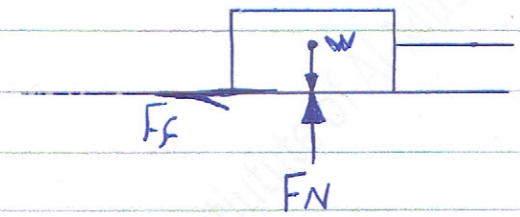
given: $\mu = 0.4$, mass = 10 kg

$P = ?$

Solution:

$W = m * g$

$= 10 * 9.81 = 98.1\ N$



(F.B.D)

$\Sigma F_y = 0$

$F_N - W = 0$

$F_N = W = 98.1$

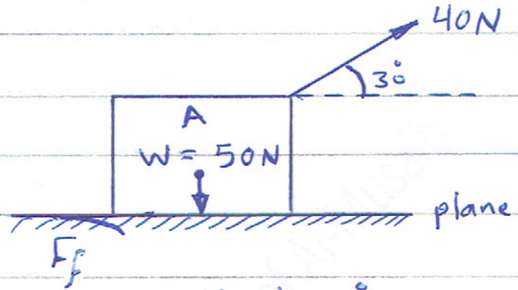
$F_f = \mu * F_N$

$= 0.4 * 98.1 = 39.24\ N$

For star motion $P = F_f$

$\therefore P = 39.24\ N$

Example 2: The Coefficient of friction (μ) between a body A with weight of 50 N and the plane is (0.4). Determine the forces acting on body A and (is it in motion or rest)?

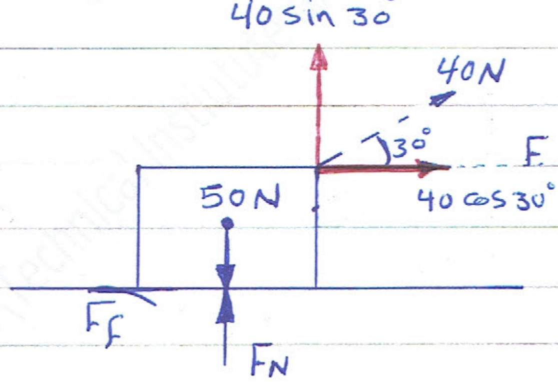


Solution:

① $\sum F_x = 0$

$40 \cos 30 - F = 0$

$\therefore F = \underline{\underline{34.7\ N}}$



② $\sum F_y = 0$

$40 \sin 30 + F_N - 50 = 0$

$20 + F_N - 50 = 0$

$\therefore F_N = \underline{\underline{30\ N}}$

③ $F_f = \mu * F_N$

$0.4 * 30 = \underline{\underline{12\ N}}$

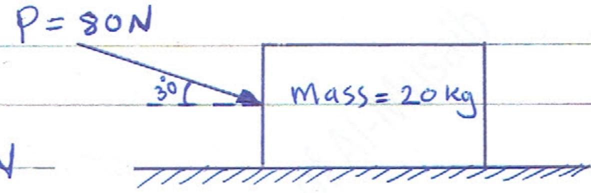
→ أكبر

$\therefore F_f < F$

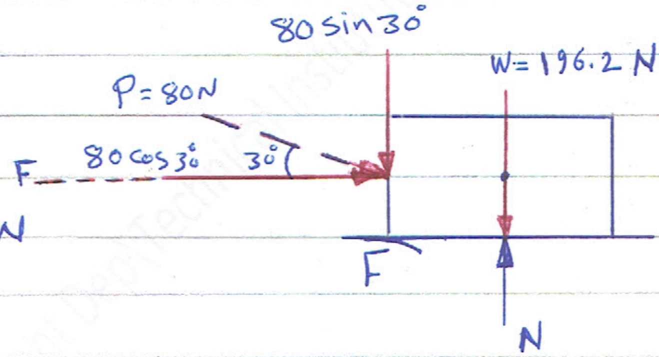
$\therefore$ The body in motion state ∴الجسم في حالة حركه

Example 3: The uniform crate shown in the Figure below has a mass of 20 kg, if a force P = 80 N is applied to the crate, determine if its remains in equilibrium. (The coefficient of Friction is $\mu = 0.3$).

Solution:



$W = m * g = 20 * 9.81 = 196.2\ N$



$\Sigma Fx = 0$

$80 \cos 30 - F = 0$

$\therefore F = 80 \cos 30 = 69.3\ N$

$\Sigma Fy = 0$

$N - 196.2 - 80 \sin 30 = 0$

$\therefore N = 196.2 + 80 \sin 30 = 236.2\ N$

The maximum friction force which can be developed at the contact surface is :-

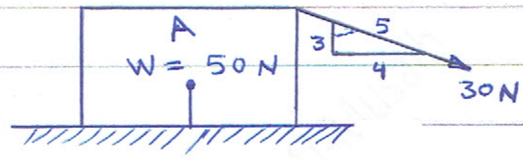
$Ff_{max} = \mu * F_N$

$= 0.3 * 236.2 = 70.86\ N$

Since $F = 69.3\ N < 70.8\ N$, so the crate will not slip, although it is very close to doing so.

Example 4: The coefficient of friction (μ) between the 50N body A and the plane is 0.5. Determine the forces acting on body A. (Is it in motion or rest).

Solution:

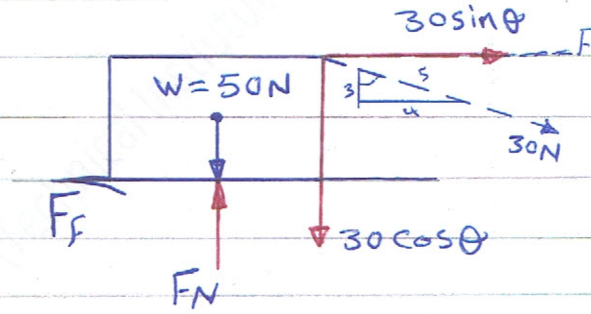


$\Sigma F_x = 0$

$30 \sin\theta - F = 0$ $\quad$ ($\sin\theta = \frac{4 \text{ مقابل}}{5 \text{ وتر}}$)

$30 * \frac{4}{5} - F = 0$ (مقابل / وتر)

$\therefore F = 24 \text{ N}$



$\Sigma F_y = 0$

$F_N - 50 - 30 \cos\theta = 0$ $\quad$ ($\cos\theta = \frac{3 \text{ مجاور}}{5 \text{ وتر}}$)

$F_N - 50 - 30 * \frac{3}{5} = 0$ (مجاور / وتر)

$\therefore F_N = 68 \text{ N}$

$F_f = \mu * F_N$

$= 0.5 * 68 = 34 \text{ N}$

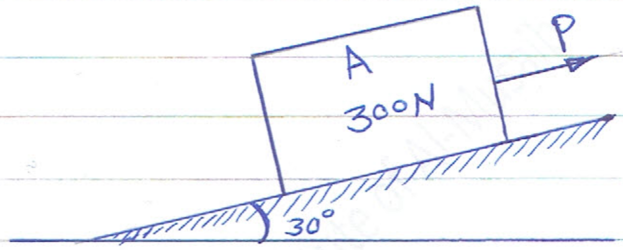
since

$\therefore F_f > F$ (اكبر)

So the body in rest state. إذاً الجسم في حالة سكون (اتزان).

Example 5: The homogenous block (A) shown in figure below weights 300N, the coefficient of friction (μ) between block (A) and the inclined plane is (0.3). Determine the force (P) when $F_f = F$.

Solution:



① $\sum F_y = 0$

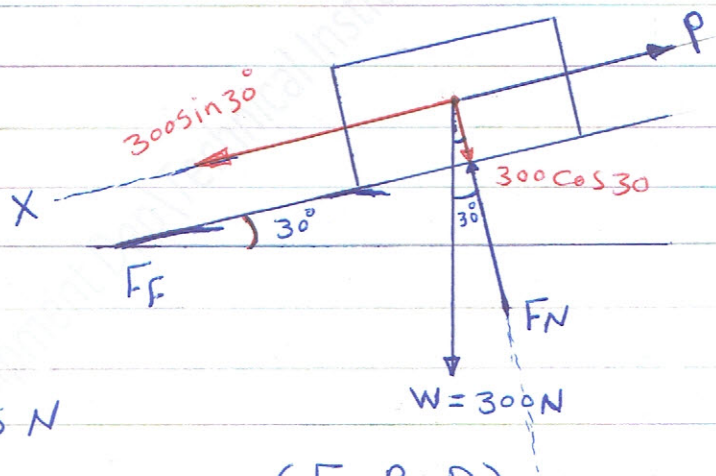
$F_N - 300 \cos 30 = 0$

$F_N - 259.8 = 0$

$\therefore F_N = 259.8\ N$

$F_f = \mu * F_N$

$= 0.3 * 259.8 = 77.95\ N$



(F.B.D)

② $\sum F_x = 0$

$P - 300 \sin 30 - F_f = 0$

$P - 150 - 77.95 = 0$

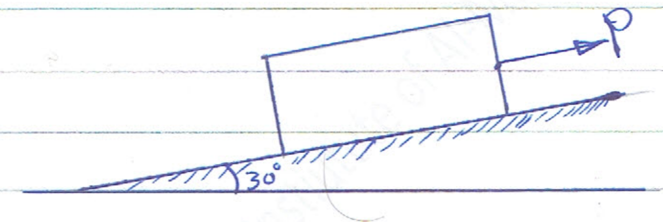
$\therefore P = 150 + 77.95$

$= 227.95\ N$

Example 6: A Force (P) act on block 200 N as shown in figure below, the coefficient of friction $\mu = 0.2$ for the inclined plane. Determine

a) Minimum force (P) enough to impending motion.

b) Minimum force (P) enough to prevent motion downward.



solution:

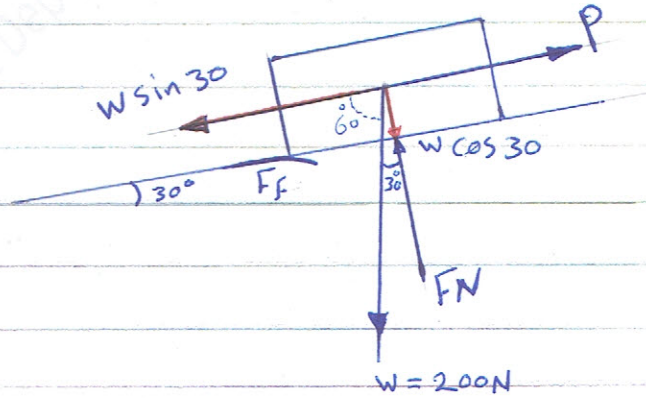
$\Sigma F_y = 0$

$F_N - W\cos 30 = 0$

$\therefore F_N = 200\cos 30 = 173.2\ N$

$F_f = \mu * F_N$

$= 0.2 * 173.2 = 34.7\ N$



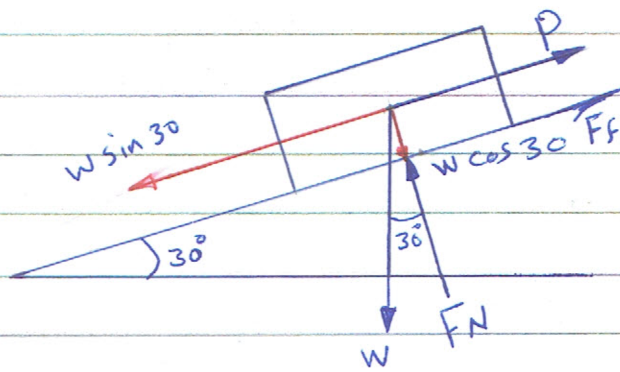
(a) $\Sigma F_x = 0$

$P - F_f - W\sin 30 = 0$

$P - 34.7 - (200\sin 30) = 0$

$\therefore P = 34.7 + 100 = 134.7\ N$

(F.B.D)(a)



(b) $\Sigma F_x = 0$

$P + F_f - W\sin 30 = 0$

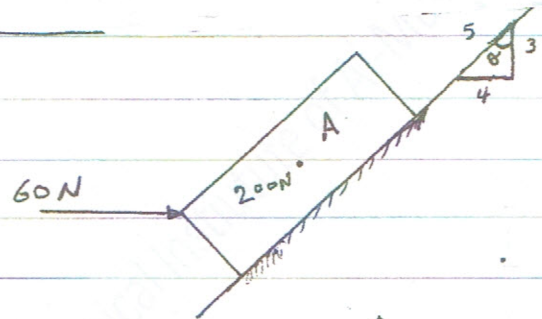
$P + 34.7 - 200\sin 30 = 0$

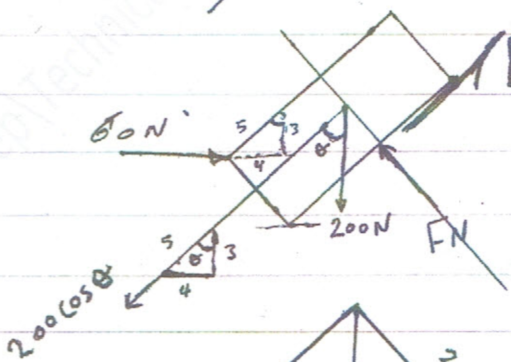
$P + 34.7 - 100 = 0$

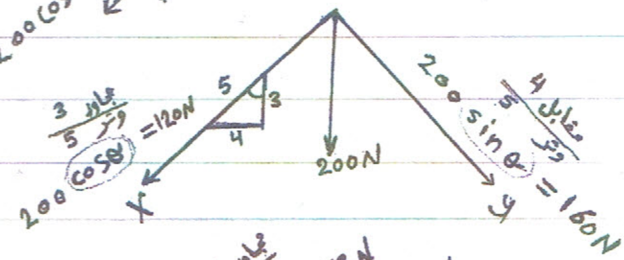
(F.B.D) (b)

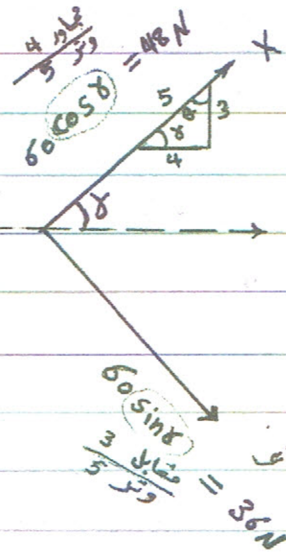
$\therefore P = -34 + 100 = 65.3\ N$

Example 7 : A body A weights 200N and the Coefficient of Friction between body A and the inclined plane is 0.4 . Determine the Frictional force on the block. Is the body A in equilibrium or not ?









__Solution :__

$\Sigma F_x = 0$

$-120 + F + 48 = 0$

$\therefore F = 120 - 48 = 72\ N$

$\Sigma F_y = 0$

$-160 - 36 + F_N = 0$

$\therefore F_N = 160 + 36 = 196\ N$

$\therefore F_f = \mu * F_N$

$= 0.4 * 196 = 78.4\ N$

since $F < F_f$

الجسم بحالة اتزان

$\therefore$ the body in equilibrium state (No motion)