Chapter - 5

Laws of Motion

Q. 1) Define inertia, explain the types of inertia?
Q. 2) Write the Newton's first law of motion.
Q. 3) What is momentum. Write its SI unit and dimension.
Q. 4) Write the newton's second law of motion.
Q. 5) Write thes newton's third law of motion.

Ans. 1. Inertia - The property of the bodies by virtue of which they are not able to change their state of motion or of rest on their own is called their inertia

There are 3 types of inertia -

1) Inertia of rest
2) Inertia of motion
3) Inertia of direction

Q.6. Write the law of conservation of linear momentum and Proof it.

Ans. **Law of Conservation of linear Momentum :-**

According to the law of conservation of linear momentum, in the absence of external force the total linear momentum of the system remains conserved. (constant).

a) For one Particle system ⇒

$$\Rightarrow \quad F \propto \frac{\Delta P}{\Delta t}$$

$$\Rightarrow \quad F = K \frac{\Delta P}{\Delta t}$$

SI system $K = 1$

$$\Rightarrow \quad F = \frac{\Delta P}{\Delta t}$$

$(F = 0)$

$$\Rightarrow \quad 0 = \frac{\Delta P}{\Delta t}$$

$$\Rightarrow \quad \Delta P = 0$$

$$\boxed{P = \text{constant}}$$

B) For two Particle System $\Rightarrow$

$$\Rightarrow \quad F_{AB} = -F_{BA}$$

$$\Rightarrow \quad \frac{\Delta P_A}{\Delta t} = -\frac{\Delta P_B}{\Delta t}$$

$$\Rightarrow \quad \frac{\Delta P_A}{\Delta t} + \frac{\Delta P_B}{\Delta t} = 0$$

$$\Rightarrow \quad \frac{\Delta (P_A + P_B)}{\Delta t} = 0$$

$$\Rightarrow \quad \Delta (P_A + P_B) = 0$$

$$\boxed{P_A + P_B = \text{constant}}$$

Static Friction :- If we try to slide one body over the surface of the other body by applying an external force and the body remains at rest, the force of friction acting between surfaces of the two bodies is called static friction

Limiting Friction :- when we try to slide one body over the other by applying an external force and the first body is just about to commence it's motion and the force of friction between the two surfaces ~~is called~~ in the state of limiting equilibrium is called the limiting friction.

Kinetic friction :- when a body is sliding over the surface of the other, the force of friction acting between the surfaces of the bodies is called the kinetic friction.

Q.7 Write the law of limiting friction or static friction?

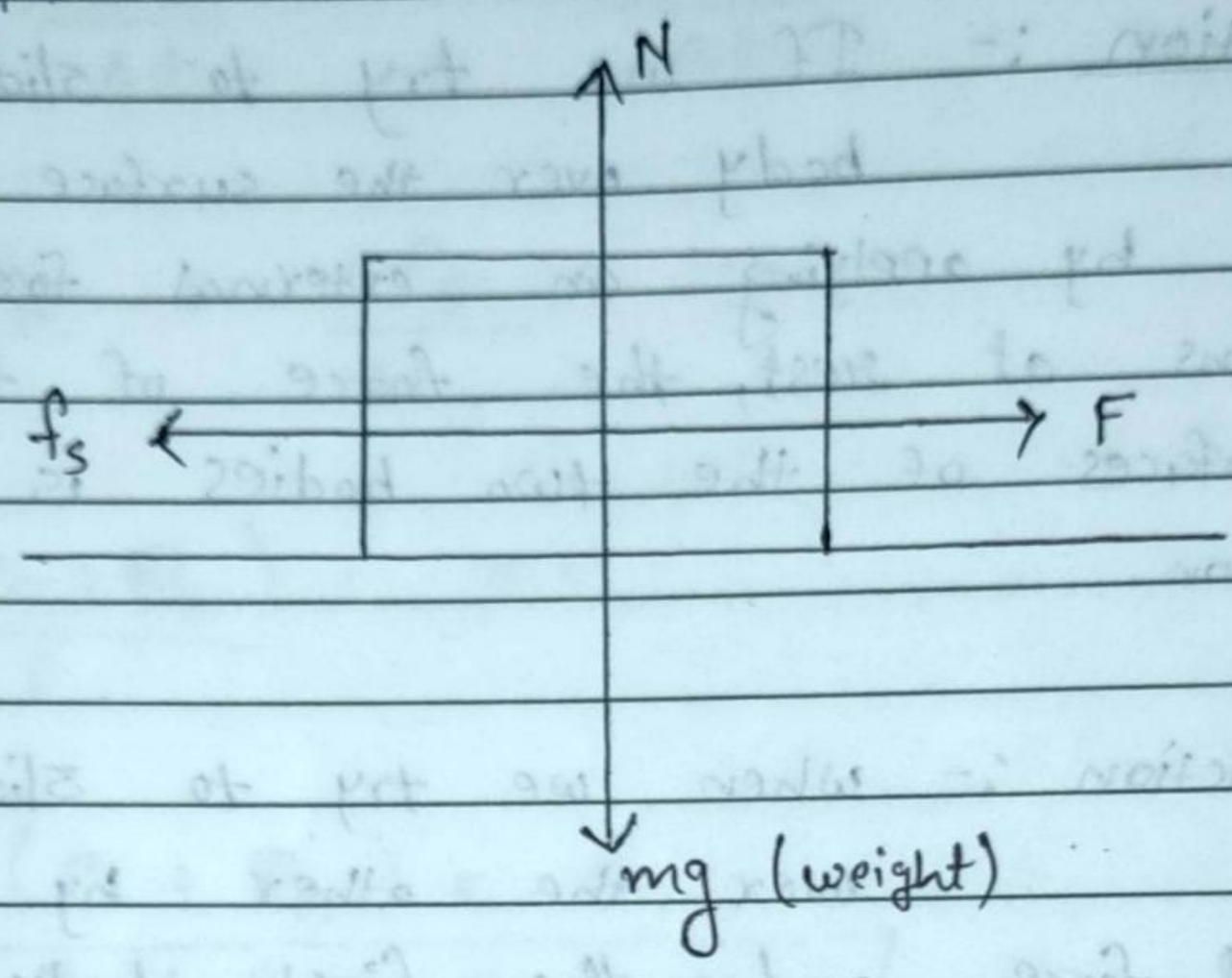
~~Q.8~~ Write the law of kinetic friction.

Ans. 7)

1) Law of limiting and Static friction :-

a) Static friction depends on the nature of surface.

b)



Here, N = normal reaction
f_s = static friction
mg = weight
F = external force.

$f_s \propto N$
$f_s = \mu N$

$\boxed{\mu = \frac{f_s}{N}}$ cofficient of static friction.

c) $0 \leq f_s \leq (f_s)_{limiting}$ → $(f_s)_{lim} = \mu_s N$
$0 \leq f_s \leq \mu_s N$

d) Static friction is also an example of self adjusting force.

e) Static friction (f_s) and Normal (N) must be of the same person.

2) laws of kinetic friction :-

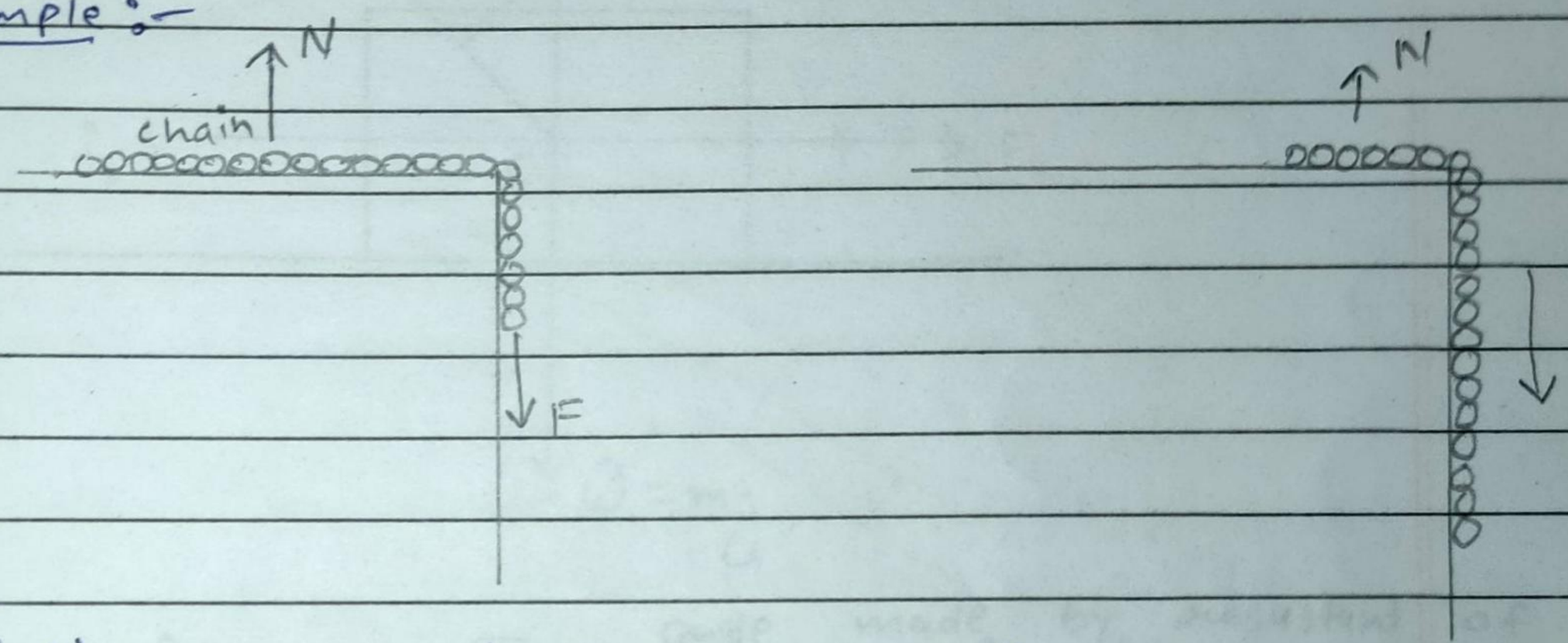
a) $f_k \propto N$

$$\boxed{f_k = \mu_k N}$$

Kinetic friction

coefficient of Kinetic friction

Example :-



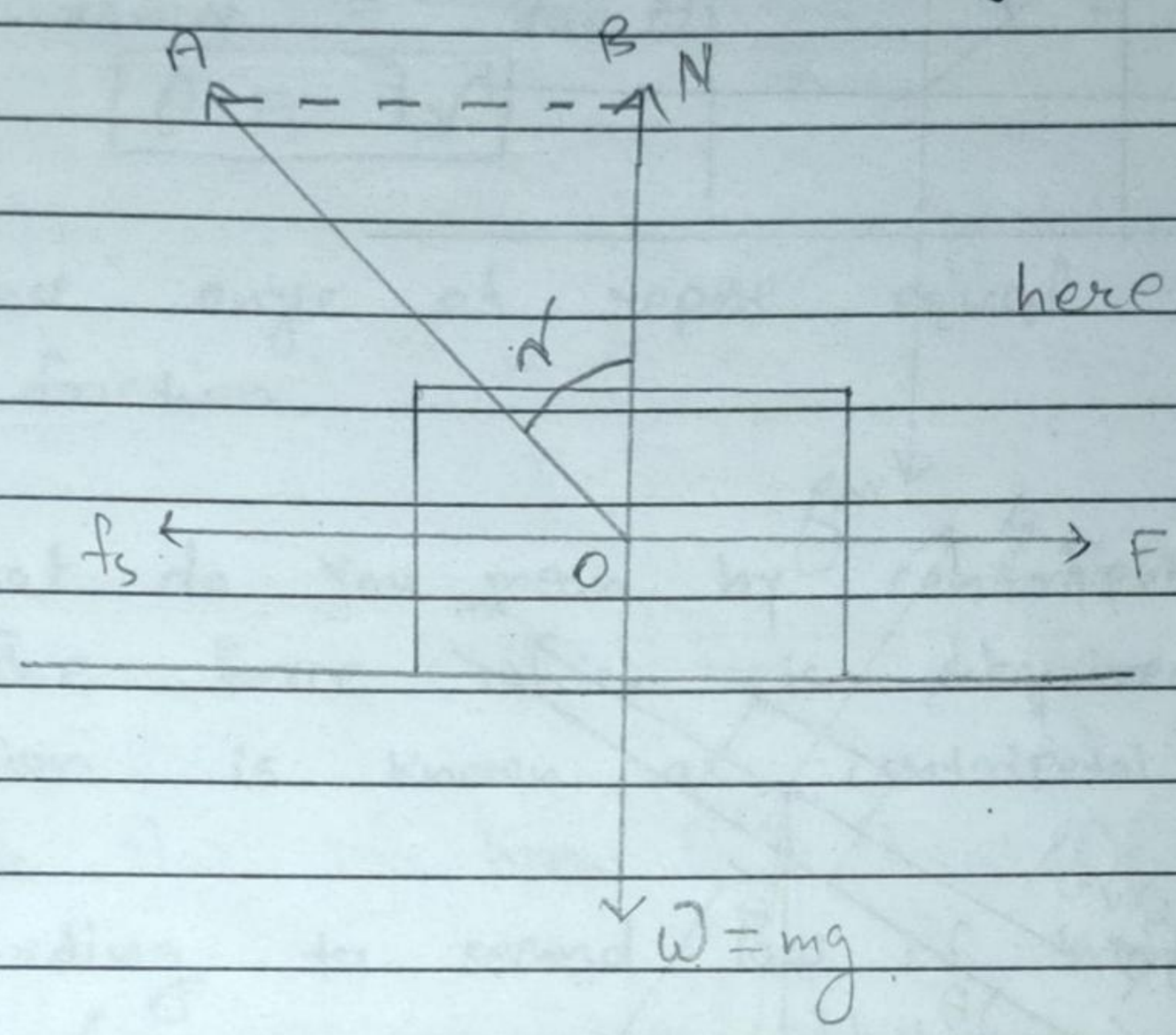
Relative motion is happening, then

$$\boxed{f_k = \mu_k N}$$

Q.8. What do you mean angle of friction. derive the formula for it

Q.9. What do you mean by angle of repose.

Ans. 8.)



here, γ = Gamma.

=> Angle of friction :- The ~~resultant of limiting~~ angle made by resultant of limiting reaction and Normal reaction in the direction of normal reaction is known as angle of friction.

By the diagram,
in ΔOAB,

$$\tan\gamma = \frac{BA}{OA}$$

$$\tan\gamma = \frac{f_s}{N}$$

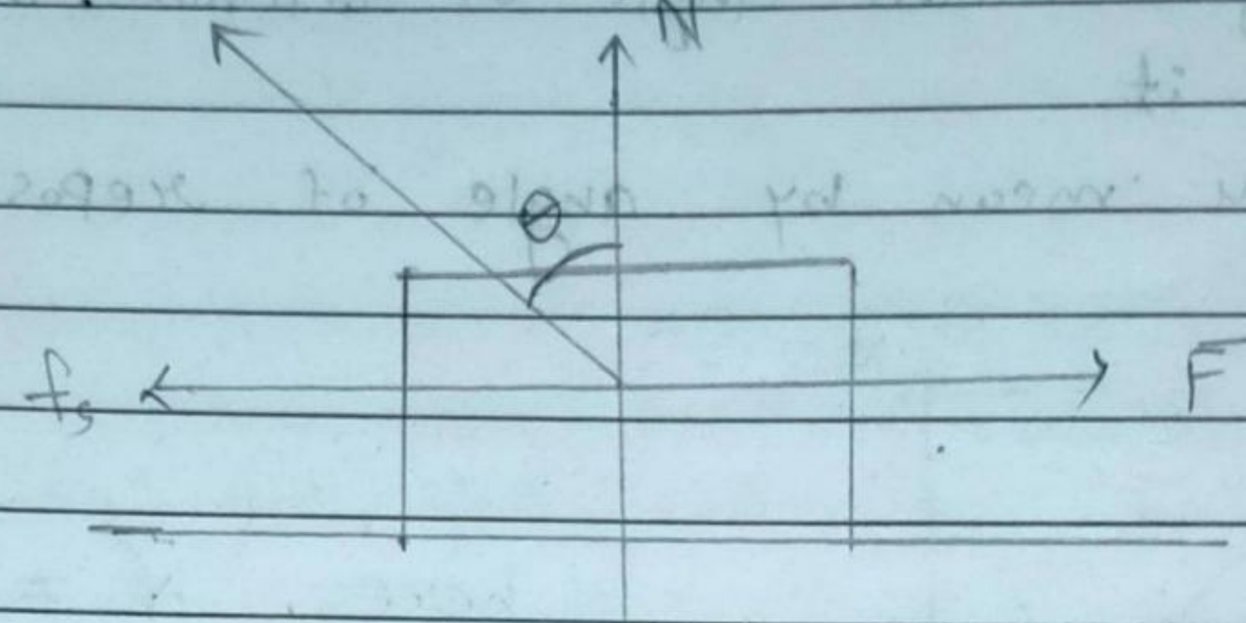
$$\mu_s = \frac{f_s}{N}$$

$$\boxed{\tan\gamma = \mu_s}$$

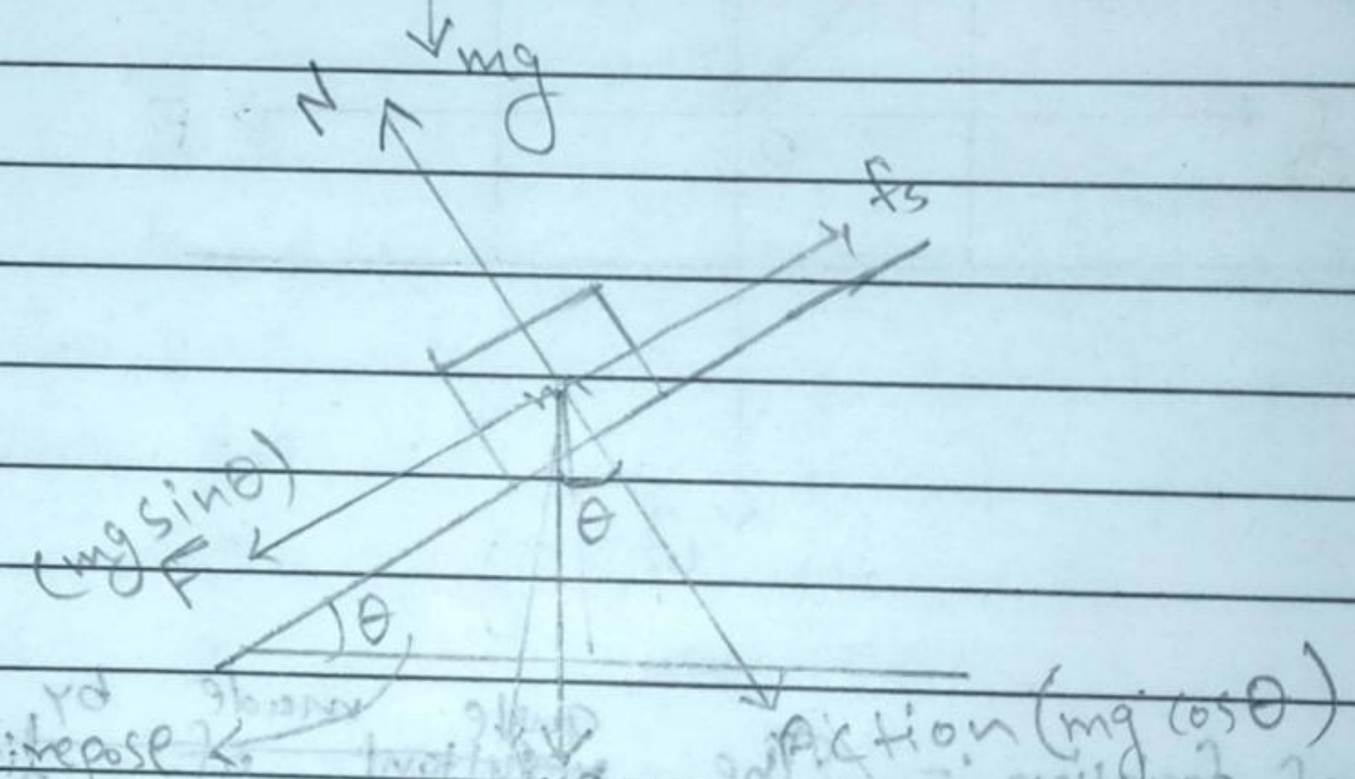
When a body is in limiting equilibrium on an inclined plane, then the Angle b/w inclination of the plane with the horizontal is called angle of repose.

Ans. 9)

(1)



(2)



Here,

$$f_s = mg\sin\theta \quad - i$$
$$N = mg\cos\theta \quad - ii$$

dividing $\left(\frac{i}{ii}\right)$

$$\frac{f_s}{N} = \frac{mg\sin\theta}{mg\cos\theta}$$

$$\tan\theta = \frac{f_s}{N}$$

$$\boxed{\tan\theta = \mu_s} \quad \left[\because \mu_s = \frac{f_s}{N}\right]$$

We know that,

$$\tan\alpha = \mu_s$$
$$\tan\alpha = \tan\theta$$
$$\boxed{\theta = \alpha}$$

Hence angle of repose equal to the angle of friction.

Q.10) What do you mean by centripetal force.

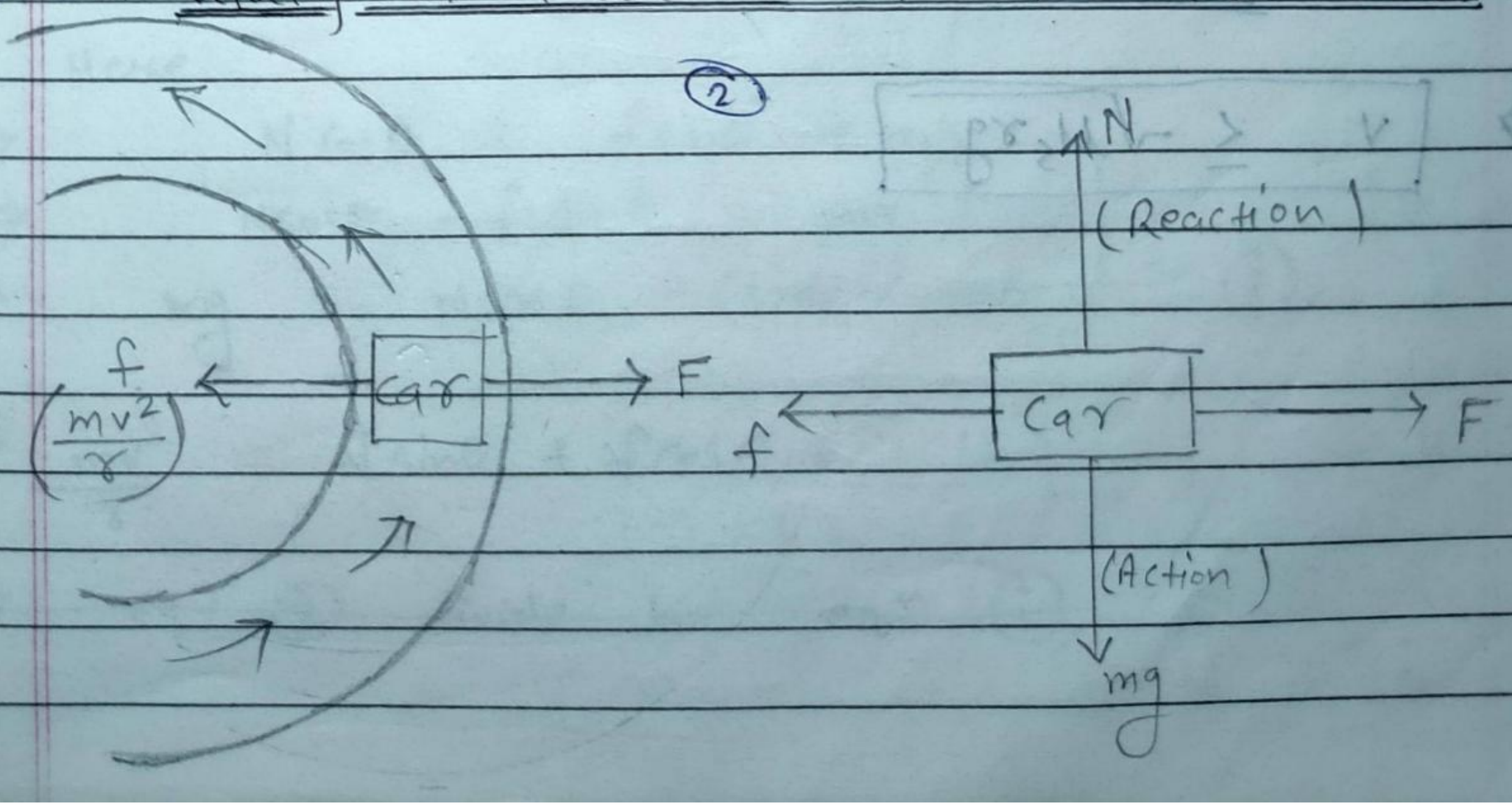
Ans:- The force which is required for the circular motion is known as centripetal force.

According to second law of motion,

$$F = ma$$
$$\boxed{F = \frac{mv^2}{r}} \quad \left[\because \text{we know that, } \because a = \frac{v^2}{r}\right]$$

Q.11) Derive the expression for velocity of a car in a level circular road.

Ans. → # Velocity of a car in a level circular road :-



Here, from diagram (i),

$\Rightarrow \quad N = mg$

$\Rightarrow$ and $f = \frac{mv^2}{r}$ —— (i)

$\because \frac{f}{N} = \mu_s$

$f = N\mu_s$

$f = mg\mu_s$ —— (ii)

from eq^n (i) and (ii) and for safe driving,

$\Rightarrow \quad \frac{mv^2}{r} \leq \cancel{mg\mu_s} \; mg\mu_s$

$\Rightarrow \quad v^2 \leq g\mu_s r$

$\Rightarrow \quad \boxed{v^2 \leq \mu_s r g}$

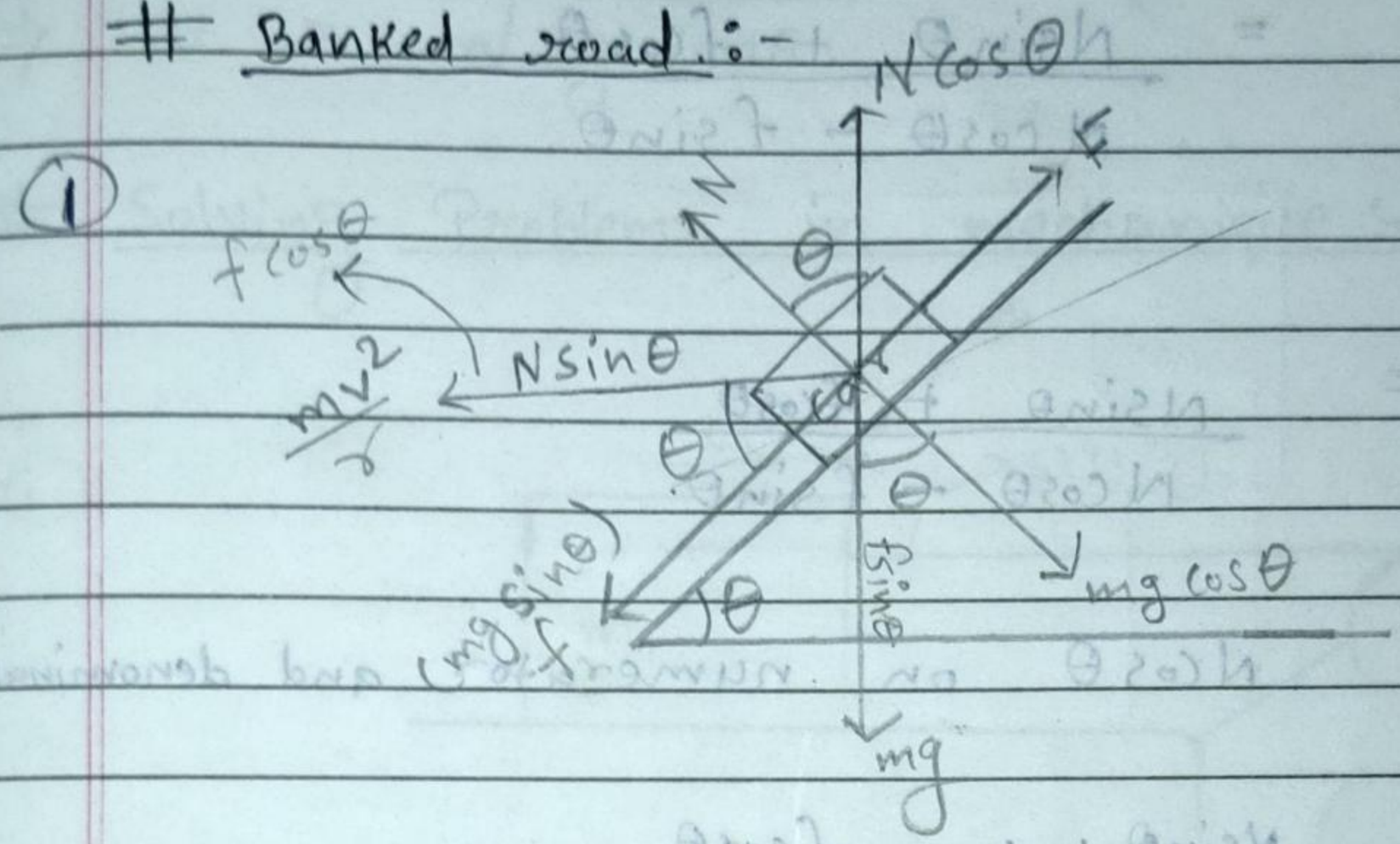
or.

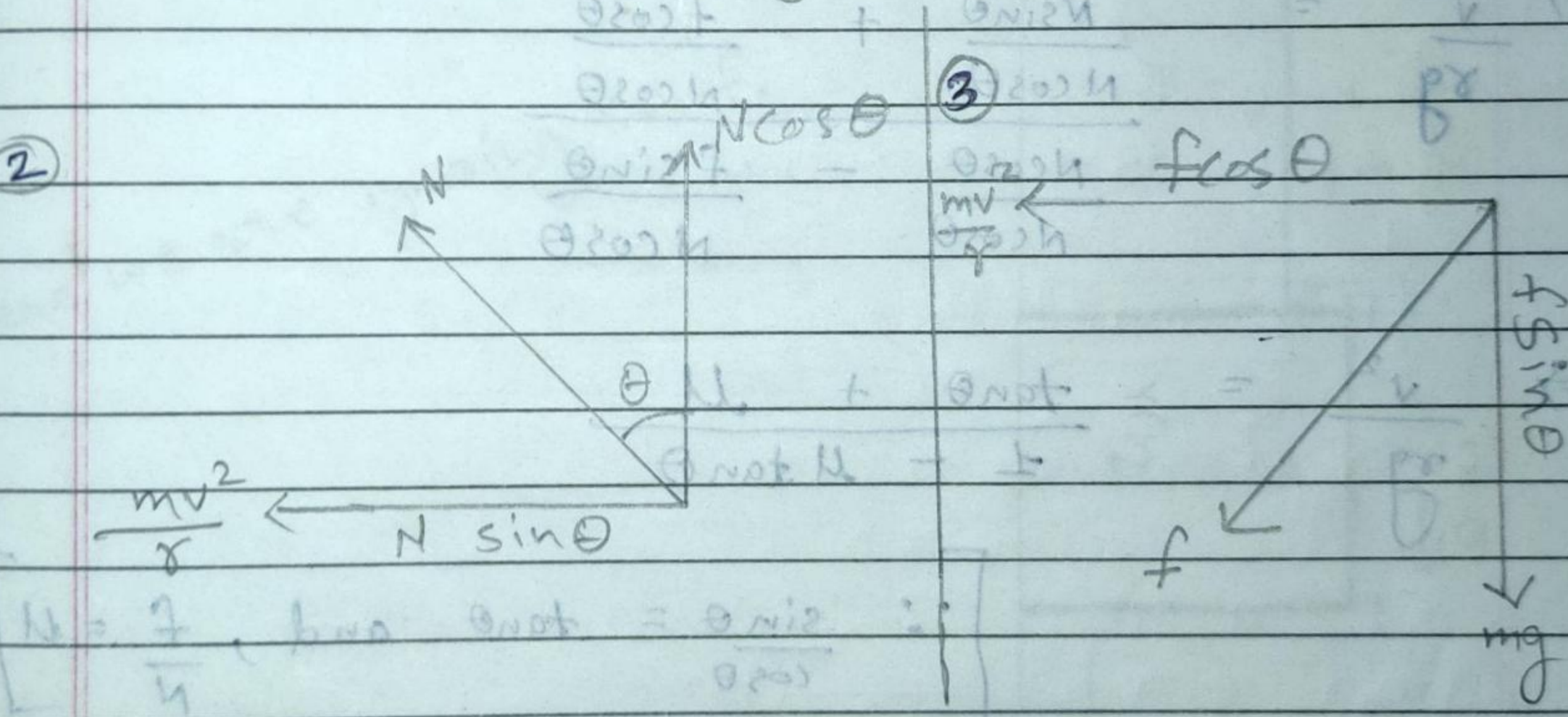
$\Rightarrow \quad \boxed{v \leq \sqrt{\mu_s r g}}$

Q. 12) Derive an expression for velocity of car in a Banked road.

Ans.

Banked road :-





Here,

$\Rightarrow \quad N\cos\theta = f\sin\theta + mg$

$\Rightarrow \quad N\cos\theta - f\sin\theta = mg$

$\Rightarrow \quad mg = N\cos\theta - f\sin\theta$ ——— (i)

$\Rightarrow \quad \frac{mv^2}{r} = N\sin\theta + f\cos\theta$

$\Rightarrow$ eqⁿ (2) divide by eqⁿ (i)

dividing eq^n $\frac{(ii)}{(i)}$,

$$\Rightarrow \frac{\frac{mv^2}{r}}{mg} = \frac{N\sin\theta + f\cos\theta}{N\cos\theta - f\sin\theta}$$

$$\Rightarrow \frac{v^2}{rg} = \frac{N\sin\theta + f\cos\theta}{N\cos\theta - f\sin\theta}$$

dividing $N\cos\theta$ on numerator and denominator,

$$\Rightarrow \frac{v^2}{rg} = \frac{\frac{N\sin\theta}{N\cos\theta} + \frac{f\cos\theta}{N\cos\theta}}{\frac{N\cos\theta}{N\cos\theta} - \frac{f\sin\theta}{N\cos\theta}}$$

$$\Rightarrow \frac{v^2}{rg} = \frac{\tan\theta + \mu}{1 - \mu\tan\theta}$$

$$\left[\because \frac{\sin\theta}{\cos\theta} = \tan\theta \text{ and, } \frac{f}{N} = \mu\right]$$

$$\Rightarrow v^2 = rg\left(\frac{\mu + \tan\theta}{1 - \mu\tan\theta}\right)$$

$$\Rightarrow v = \sqrt{rg\left(\frac{\mu + \tan\theta}{1 - \mu\tan\theta}\right)}$$

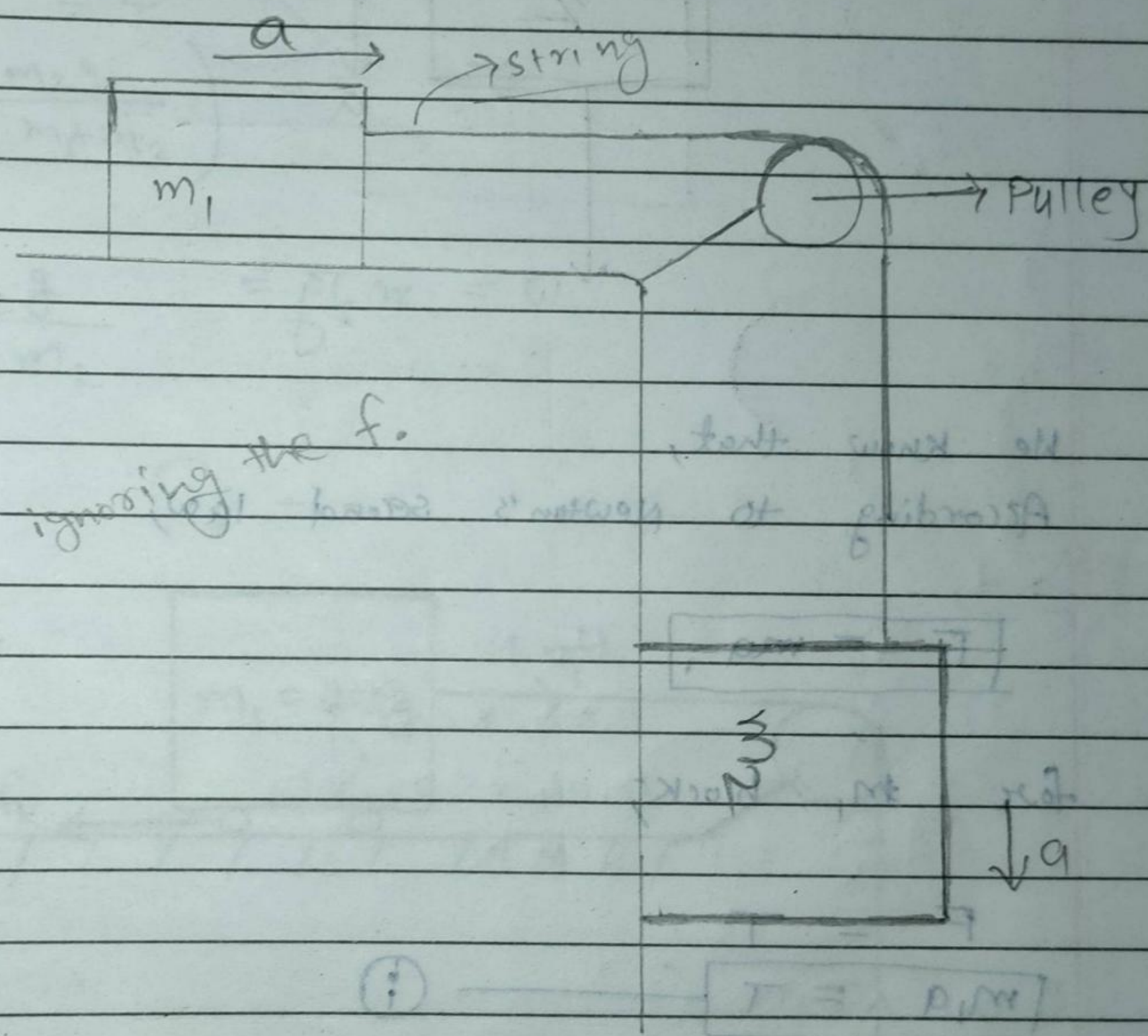
if $\mu = 0$,

$$\Rightarrow \quad v = \sqrt{rg\left(\frac{\tan\theta}{1}\right)}$$

$$\Rightarrow \quad v = \sqrt{rg\tan\theta}$$

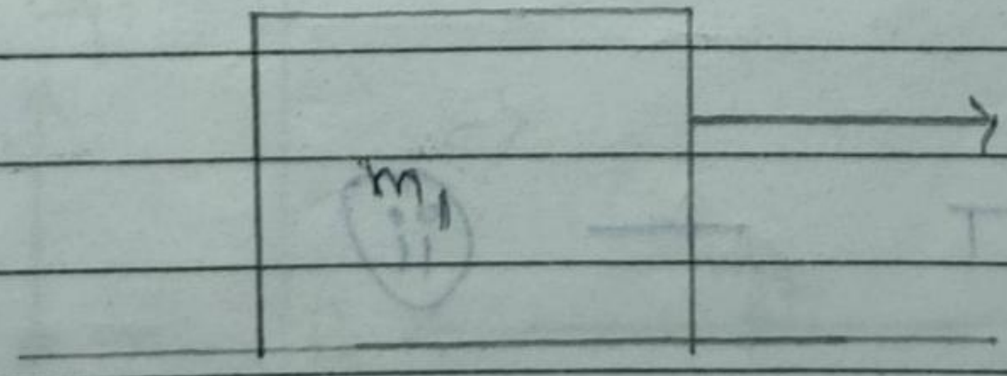
Solving Problems in mechanique :-

(1)

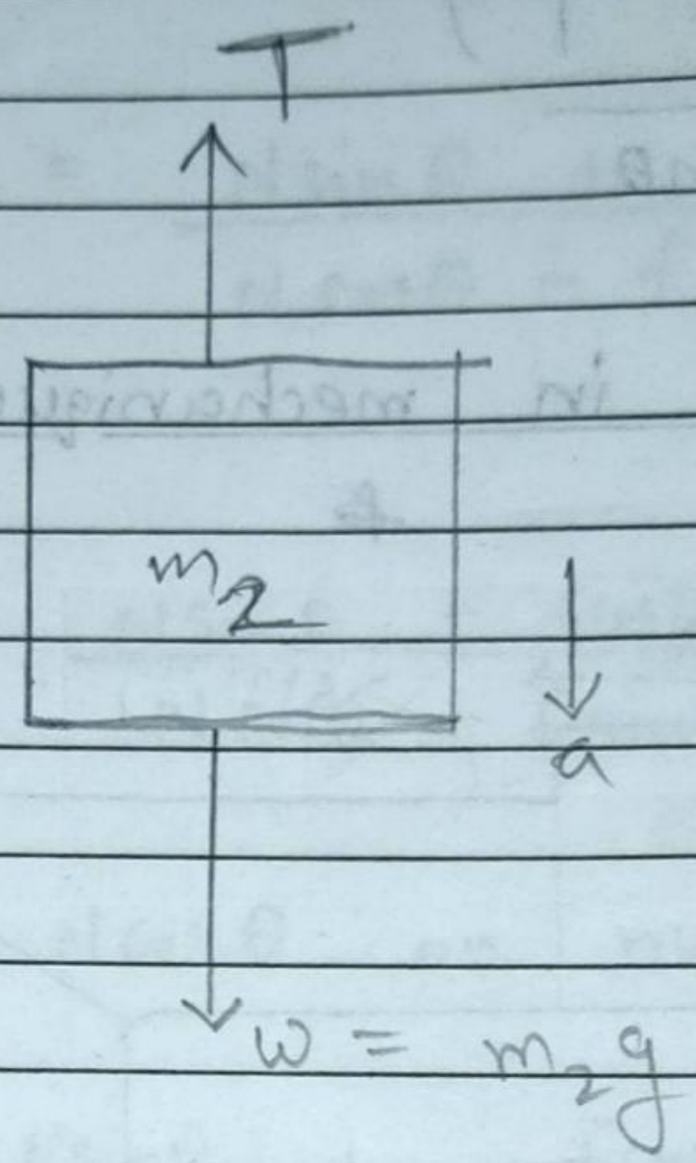


* here we are ignoring the f.

(2) conside m_1 block $\Rightarrow$



③ Consider m_2 block ⇒



We know that,
According to Newton's second law,

$$\boxed{F = ma,}$$

for m_1 block,

$$F = T$$
$$\boxed{m_1 a = T} \quad \text{——— (i)}$$

for m_2 block,

$$F = w - T$$
$$m_2 a = m_2 g - T \quad \text{——— (ii)}$$

Adding eqⁿ (i) and (ii),

$$m_1 a + m_2 a = T + m_2 g - T$$

$\Rightarrow a(m_1 + m_2) = m_2 g$

$$\Rightarrow \boxed{a = \frac{m_2 g}{m_1 + m_2}}$$

Taking eq^n (i),

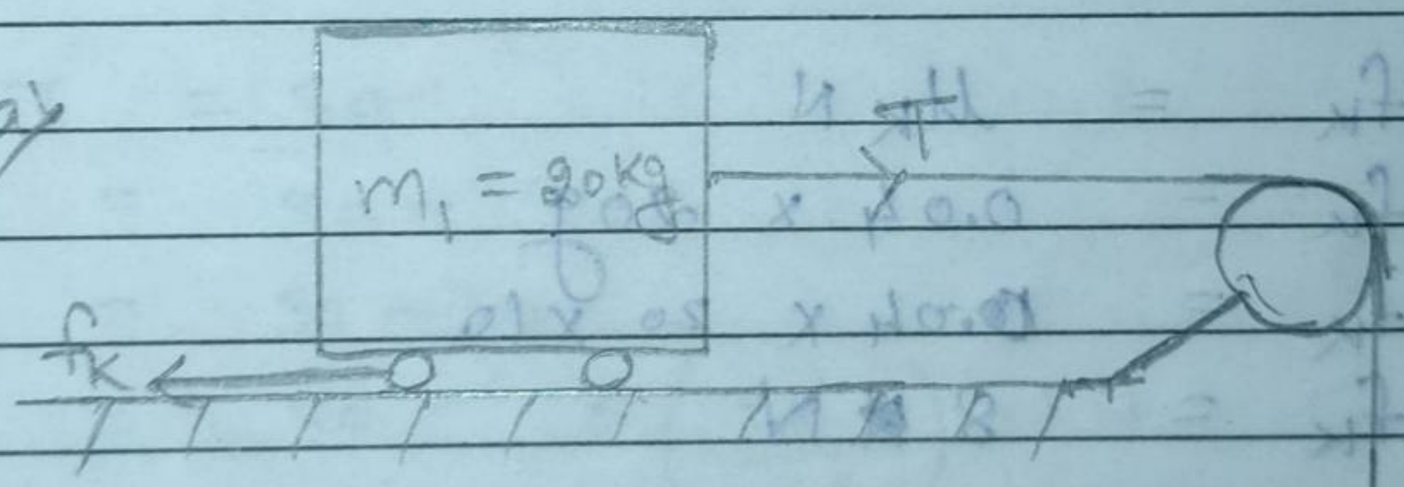
$m_1 a = T$

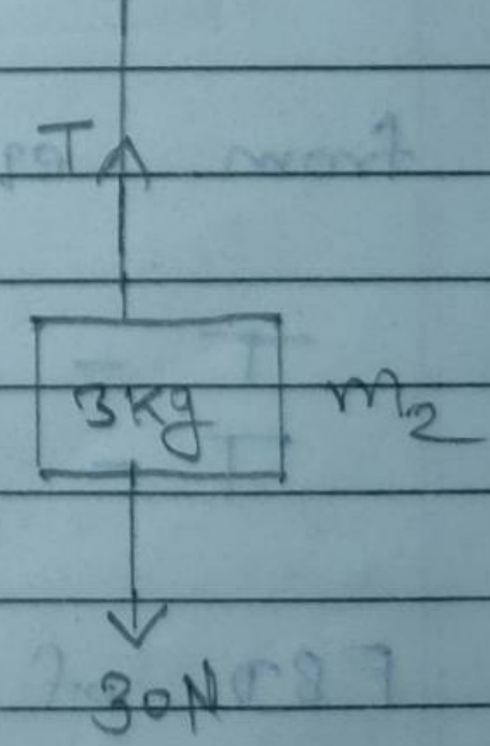
$$\Rightarrow m_1 \left(\frac{m_2 g}{m_1 + m_2}\right) = T$$

$$\Rightarrow \frac{m_1 m_2 g}{m_1 + m_2} = T$$

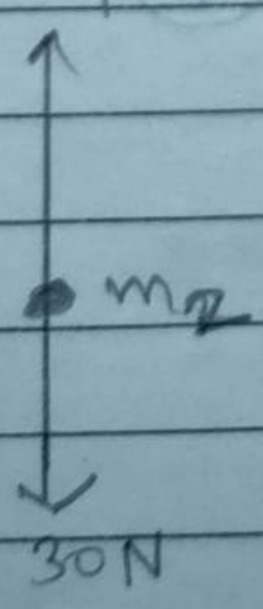
Exam. 5.9

a)

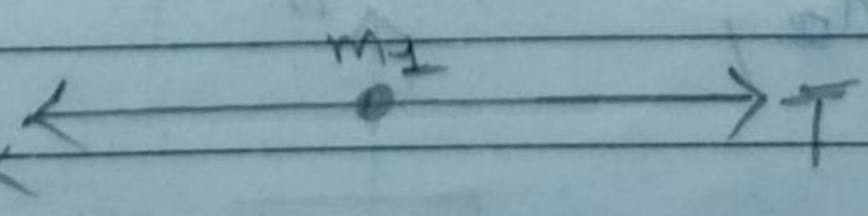




b)

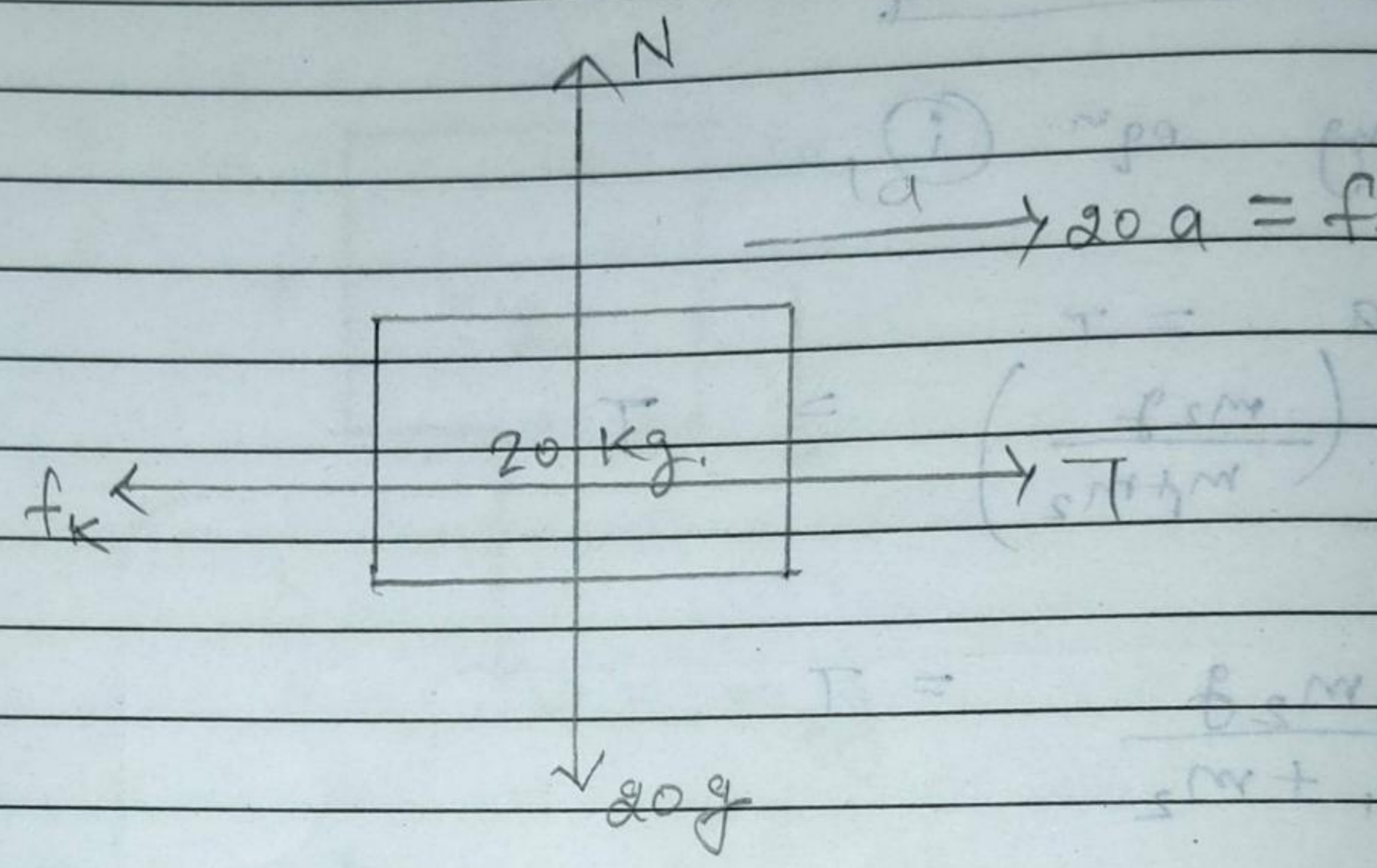


c)



Here, we Neglect the mass of the string.

FBD of m_1,



$$T - f_k = 20a \quad \text{— (i)}$$

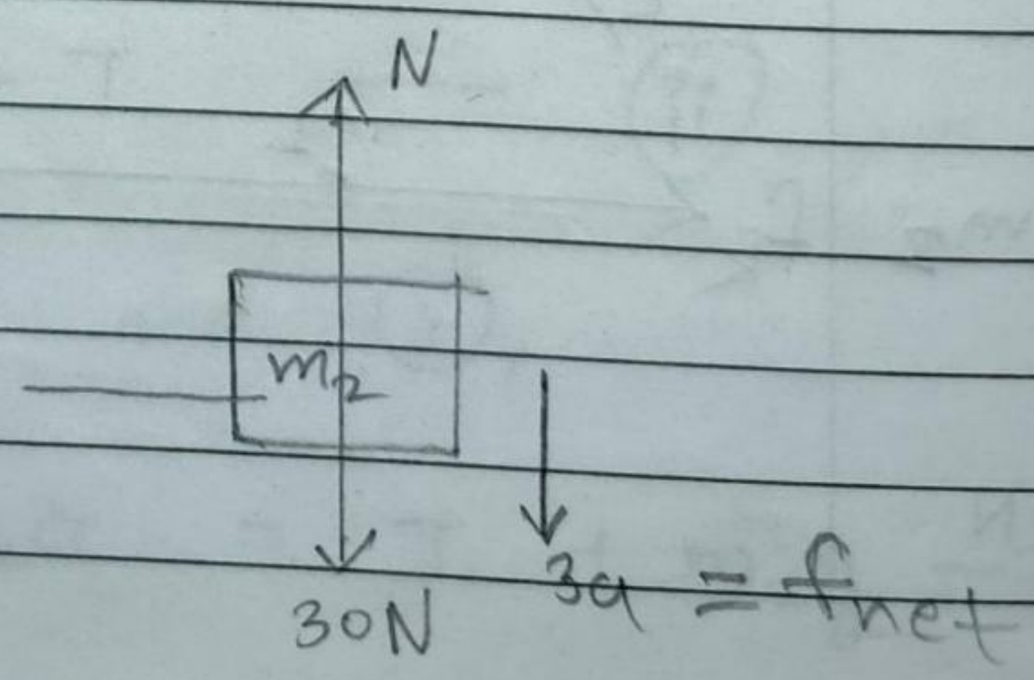
<u>and,</u>

$$f_k = \mu_k N$$
$$f_k = 0.04 \times 20g$$
$$f_k = 0.04 \times 20 \times 10$$
$$f_k = 8 N$$

from eq^n (i)

$$T - f_k = 20a$$
$$T - 8 = 20a \quad \text{— (ii)}$$

FBD of m_2,



$\Rightarrow \quad 30 - T = 3a$ [Newton's second law of motion]

(iii)

eq^n (ii) + (iii)

$$(T - 8) + (30 - T) = 20a + 3a$$

$$-8 + 30 = 23a$$

$$-8 + 30 = 23a$$

$$22 = 23a$$

$$a = \frac{22}{23}$$

from eq^n (iii)

$$30 - T = 3a$$

$$-T = 3a - 30$$

$$T = 30 - 3a$$

$$T = 30 - 3\left(\frac{22}{23}\right)$$

$$T = 27.2\,N$$ Ans.