A block of mass *m* sits on a ramp without friction. A force F is exerted to stop it from sliding down.

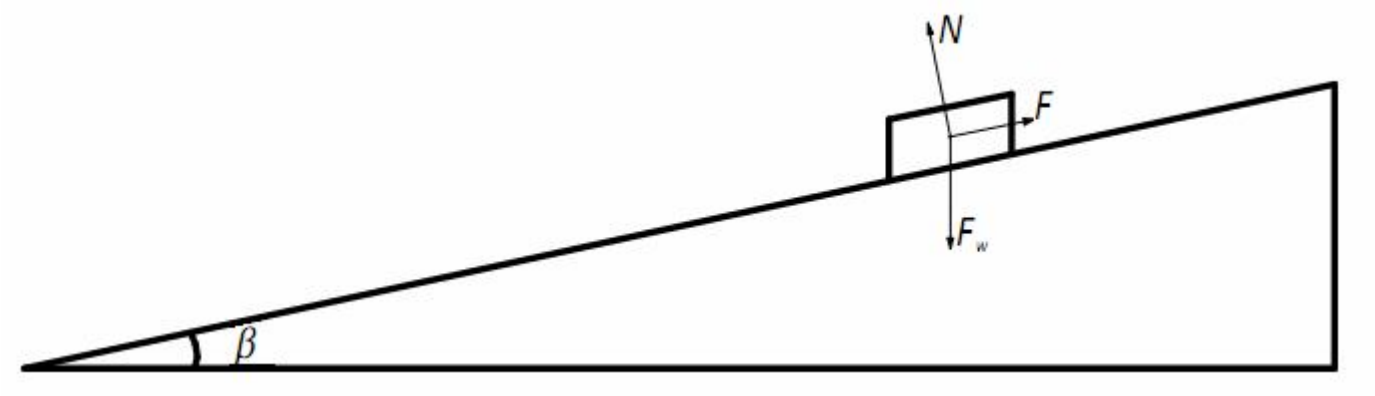
1) What's the magnitude of F?

2) At a certain time F is withdrawn and *m* starts to slide down. What is the acceleration of *m*? How long does it take for *m* to reach the bottom of the ramp?

3) What is the velocity and kinetic energy at the bottom of the ramp?

4) After it comes down from the ramp, *m* starts to slide on the horizontal ground. If the coefficient of friction is μ, how much further can *m* move?

Solution: The force diagram is shown on the picture below:



$F_w = m \cdot g$ – weight force; g = 9.81 m/s^2 – standard gravity.

N – support reaction normal force; β – angle of the ramp slope.

1) According to the third Newton's law, stopping force F is equal to the projection of weight force on the axis of same direction: $F = F_w \cdot \sin\beta = m \cdot g \cdot \sin\beta$

2) After the stopping force is withdrawn, the block will move under the influence of its weight force projection in the same direction. According to the second Newton's law, acceleration of the block is:

$a = F/m = m \cdot g \cdot \sin\beta / m = g \cdot \sin\beta$;

We can calculate the time of sliding: $l = v_0 \cdot t + \frac{a \cdot t^2}{2}$, where l = h/sinβ – distance of movement of the block on the ramp, m; h – height of the block on the ramp, m; $v_0 = 0$ – initial velocity of the block;

then, $l = \frac{a \cdot t^2}{2}$; $t = \sqrt{\frac{2l}{a}} = \sqrt{\frac{2h}{g \cdot (\sin\beta)^2}}$

3) According to the law of conservation of energy, kinetic energy of the block at the bottom of the ramp will be equal to the reduction of potential energy of the block: $E_k = \Delta U$, $E_k = \frac{m \cdot v^2}{2} = mgh$, then:

$v = \sqrt{2gh}$;

4) Work of the force of friction is equal to the reduction of kinetic energy of the block, because it stops and all kinetic energy reduces to zero: $W_{fr} = F_{fr} \cdot d = E_k$, where d is the distance of movement of the block on the horizontal ground, m;

Force of friction can be calculated as: $F_{fr} = \mu \cdot N = \mu mg$; (on the horizontal surface support reaction normal force is equal to the weight of the block).

Then, $\mu mgd = \frac{mv^2}{2} = mgh,\ d = \frac{mgh}{\mu mg} = \frac{h}{\mu}$;

Answer: 1) F = m·g·sinβ; 2) a = g·sinβ; $t = \sqrt{\frac{2h}{g \cdot (\sin \beta)^2}}$; 3) $E_k = mgh,\ v = \sqrt{2gh}$; 4) $d = \frac{h}{\mu}$;

where β – angle of the ramp slope; h – height of the block on the ramp, m;