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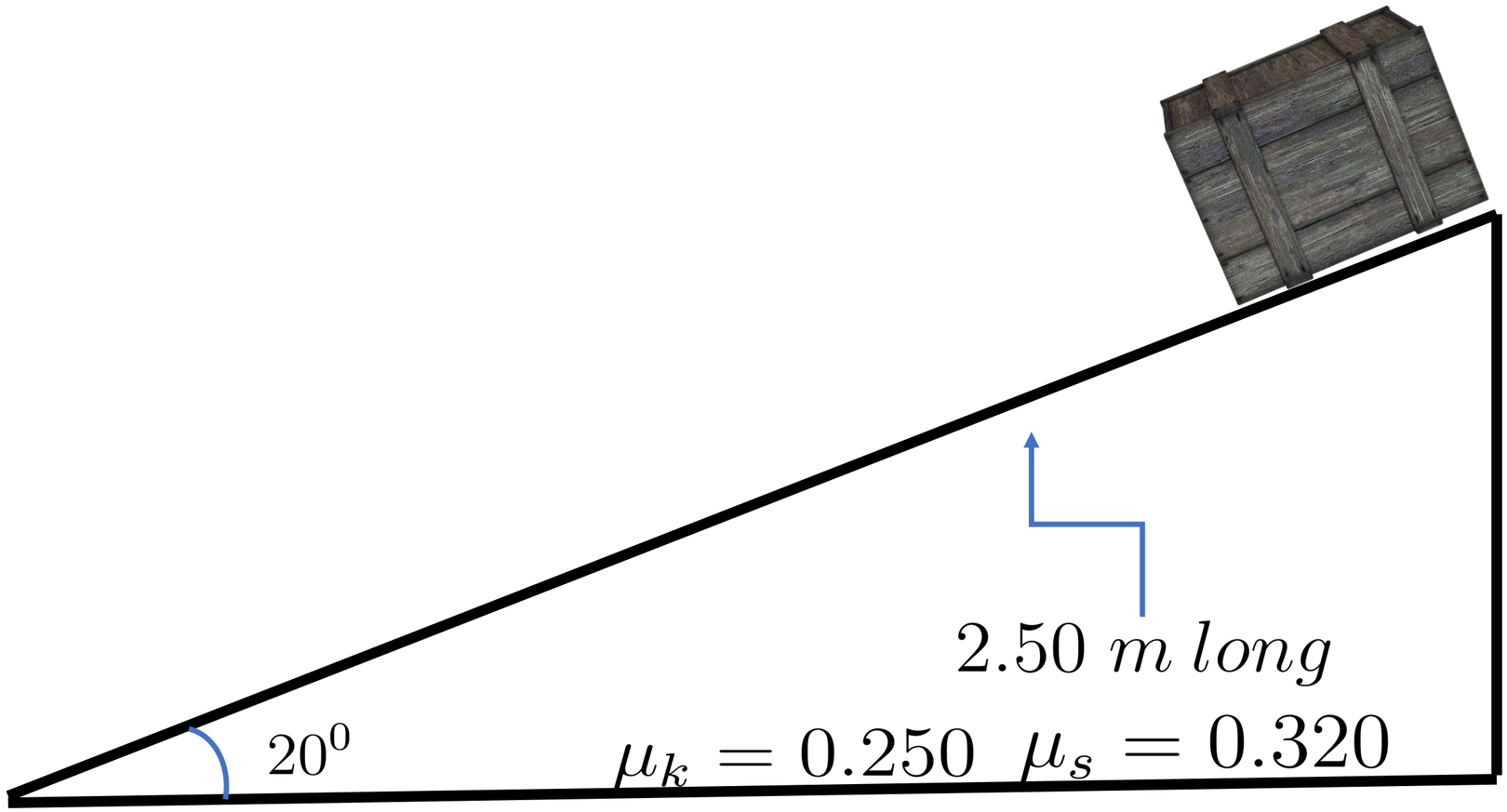
Object Moving on a Ramp with friction

A wooden crate, mass 11.0 kg, is at rest at the top of a ramp as shown.
The ramp and the crate have a kinetic friction coefficient $\mu_k = 0.250$
and static friction coefficient $\mu_s = 0.320.$
The ramp is inclined 20^0 angle and it's 2.50 m long.
A) Find all forces acting on the crate.
B) Find the acceleration of the crate.
C) Find the final velocity of the crate at the end of the ramp.



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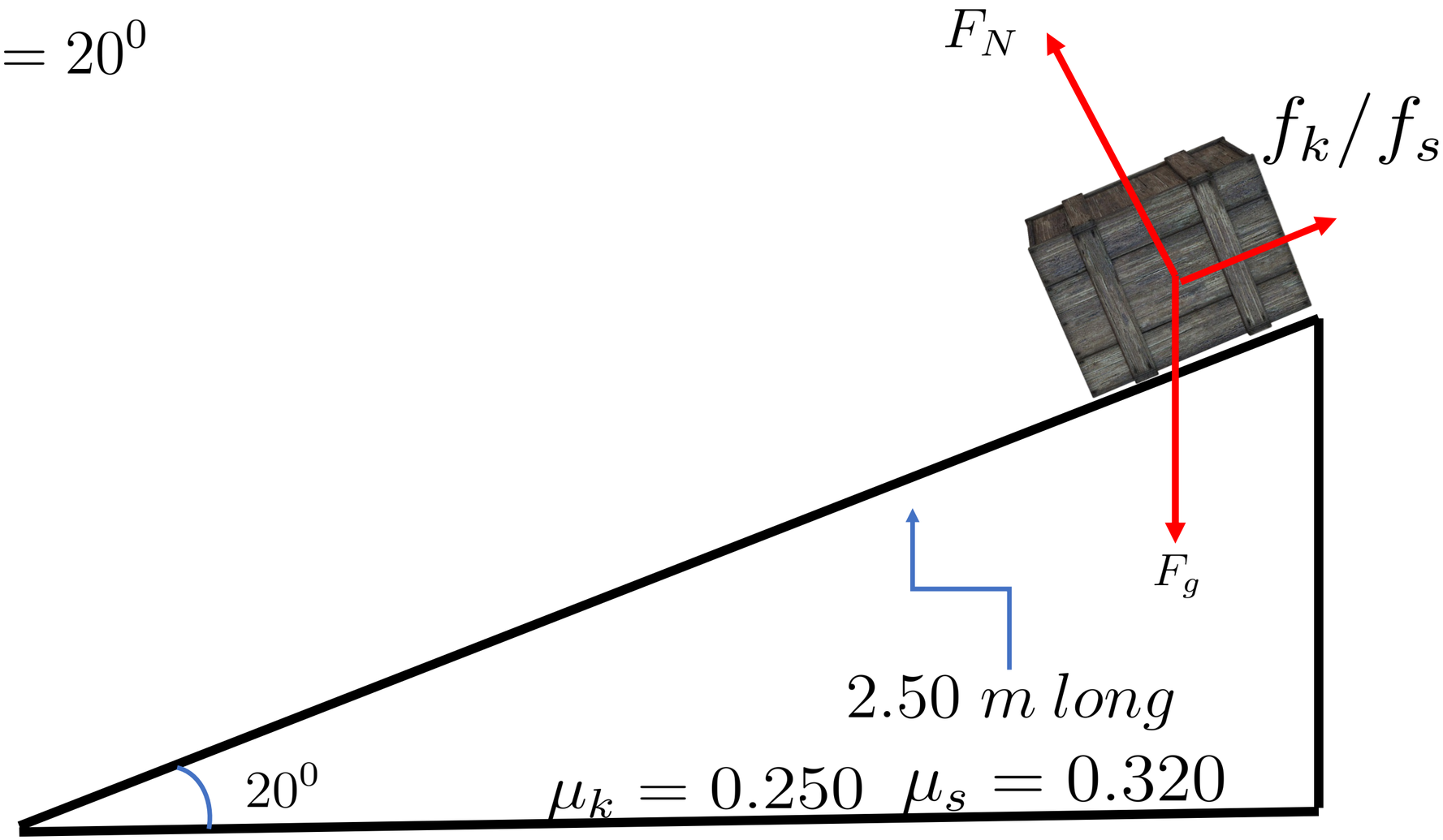
A) Find all forces acting on the crate

$$m = 11.0\ kg$$
$$l = 2.50\ m$$
$$\theta = 20^0$$



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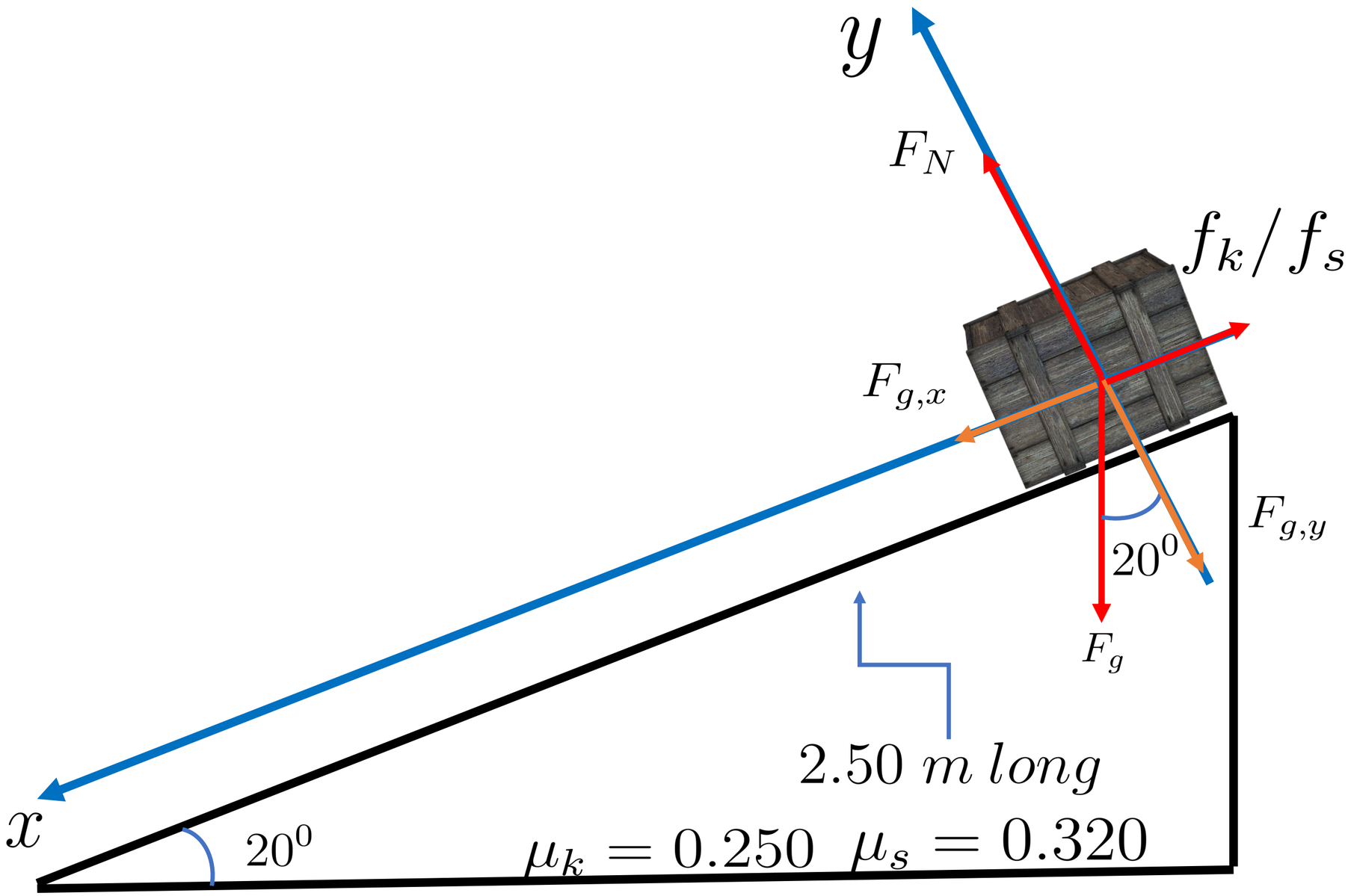
Find x and y components of F_g



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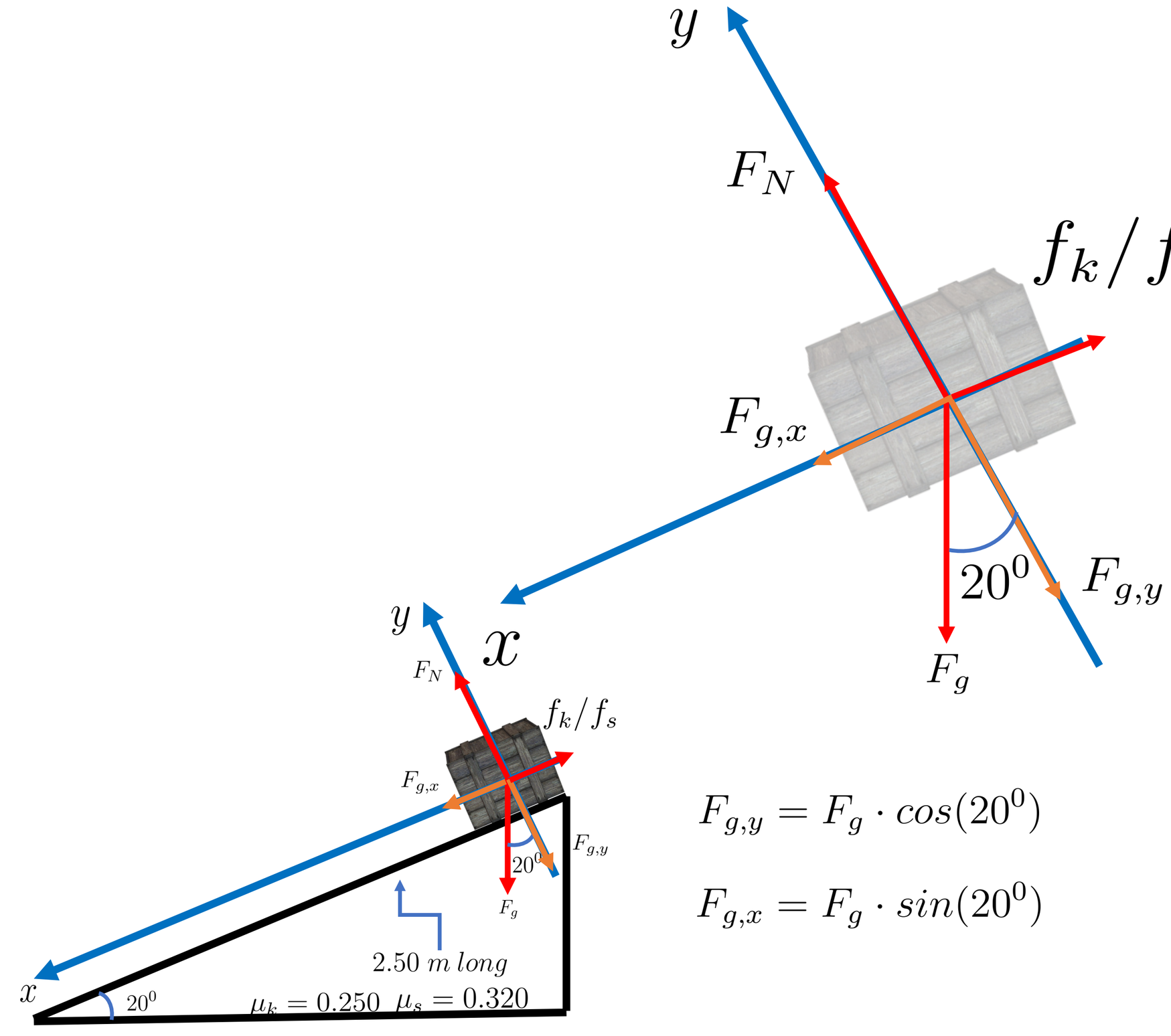
Free Body Diagram (FBD)



$$F_{g,y} = F_g \cdot cos(20^0)$$

$$F_{g,x} = F_g \cdot sin(20^0)$$

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Newton's 2nd Law
Y axis

$$\sum F_{ext,y} = m \cdot a_y$$

Solve for Normal Force

$$\sum F_{ext,y} = 0$$

$$F_N - F_{g,y} = 0$$

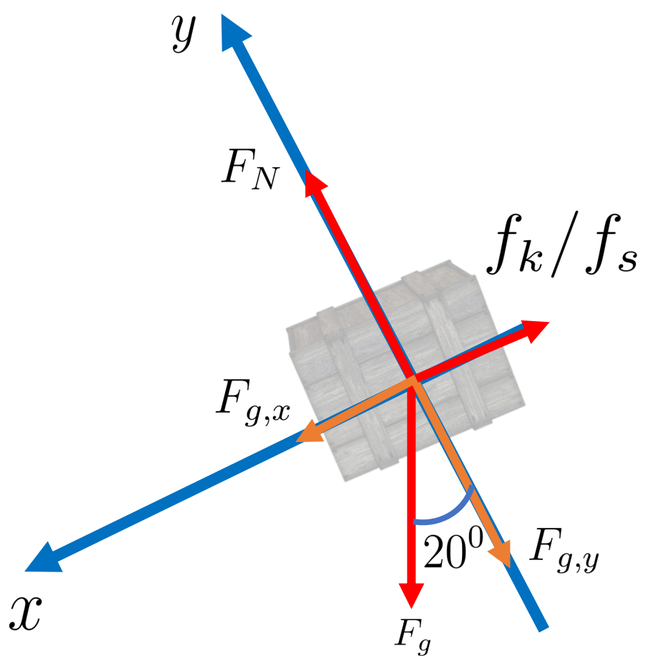
$$F_N = F_{g,y}$$

$$F_N = F_g \cdot cos(20^0)$$

$$F_N = m \cdot g \cdot cos(20^0)$$

$$F_N = 11.0\ kg \cdot 9.81\ \frac{m}{s^2} \cdot cos(20^0)$$

$$\boxed{F_N = 101.\ N}$$



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Find Kinetic Friction Force

$$f_k = \mu_k \cdot F_N$$

$$f_k = 0.250 \cdot (101\ N)$$

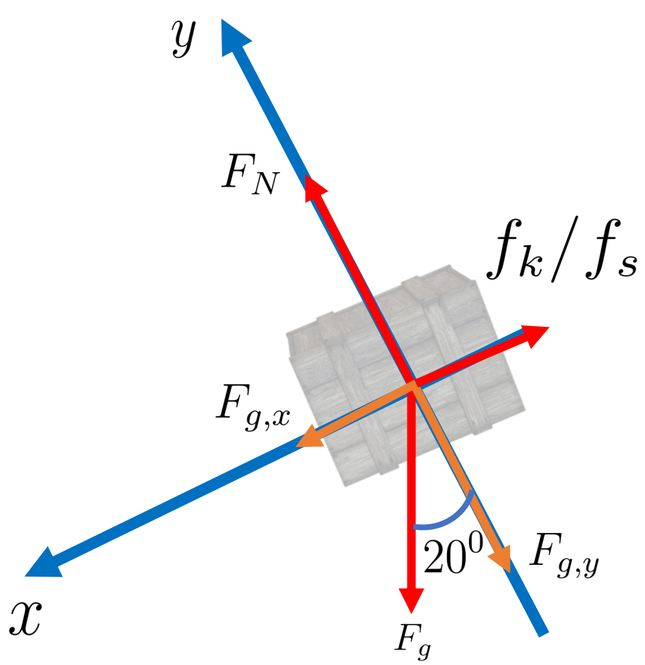
$$\boxed{f_k = 25.3\ N}$$

Find Max Static Friction Force

$$f_{s,max} = \mu_s \cdot F_N$$

$$f_{s,max} = 0.320 \cdot (101 N)$$

$$\boxed{f_{s,max} = 32.3\ N}$$



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Find X component of F_g

$$F_{g,x} = F_g \cdot sin(20^0)$$

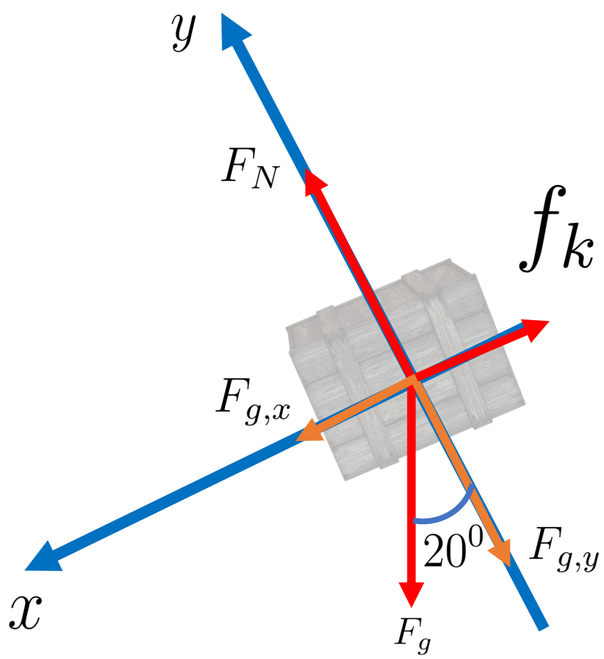
$$F_{g,x} = m \cdot g \cdot sin(20^0)$$

$$F_{g,x} = 11.0\ kg \cdot 9.81\ \frac{m}{s^2} \cdot sin(20^0)$$

$$\boxed{F_{g,x} = 36.9\ N}$$

Since $F_{g,x}$ is larger that $f_{s,max}$

$$F_{g,x} > f_{s,max}$$



Object is moving down the ramp

Friction is Kinetic friction

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B) Find the acceleration of the crate.

Newton's 2nd Law

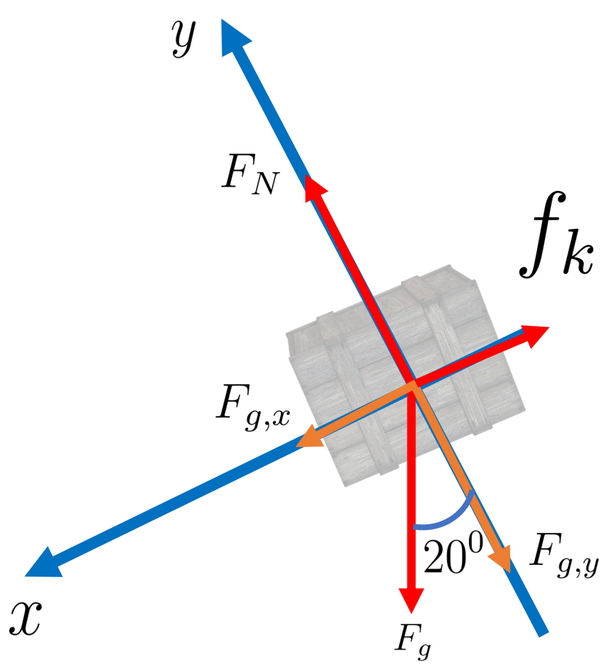
X axis

$$\sum F_x = m\ a_x$$

$$F_{g,x} - f_k = m \cdot a_x$$

$$36.9\ N - 25.3\ N = 11.0\ kg \cdot a_x$$

$$\boxed{a_x = 1.05\ \frac{m}{s^2}}$$



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C) Find the final velocity of the crate at the end of the ramp.

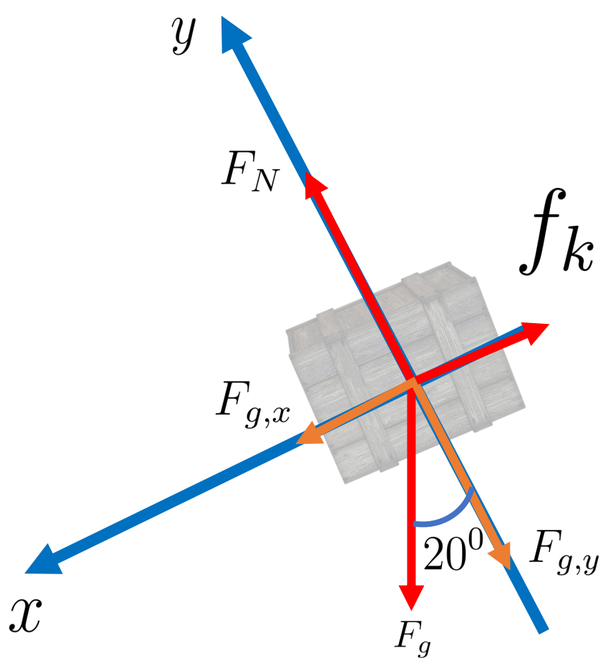
$$a_x = 1.05\ \frac{m}{s^2} \qquad v_i = 0 \qquad \Delta x = 2.50\ m$$

$$v_f^2 = v_i^2 + 2 \cdot a_x \cdot \Delta x$$

$$v_f = \sqrt{v_i^2 + 2 \cdot a_x \cdot \Delta x}$$

$$v_f = \sqrt{2 \cdot 1.05 \frac{m}{s^2} \cdot 2.50\ m}$$

$$\boxed{v_f = 2.29\ \frac{m}{s}}$$



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