PHYS 225
Fundamentals of Physics: Mechanics

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Fall 2024

Lecture 15: Free body diagram: Examples of inclines

CALIFORNIA STATE UNIVERSITY
FULLERTON

Learning goals

- Free body diagram
- Example of forces on an incline

A brief review

Annotated slides

$\vec{v} = \frac{d\vec{x}}{dt}$; $\vec{a} = \frac{d\vec{v}}{dt}$

- **Chapter 1:** Unit conversion: chain-link rule
- **Chapter 2:** 1D motion: Scalar vs. vector, average vs. instantaneous displacement, velocity and acceleration, graphs for 1D motion, 4 kinematics equations, stopping distance
- **Chapter 3:** Vectors: Vector decomposition, **unit vector notation**, vector addition, multiplication
  $\hat{i}$ $\hat{j}$ $\hat{k}$ Head-tail Ch. 7
  x y z By components
- **Chapter 4:** Projectile motion; Uniform circular motion, reference frames
  2D/3D UCM
- **Chapter 5 (part):** Force and motion: Newton's three laws, weight and force of gravity, free body diagram
- **Midterm1:**
  - Closed book, closed notes, however, you can bring a 1-page 1-sided cheat sheet
  - Calculators are allowed
  - Academic integrity is important. Academic dishonesty will lead to a zero to the midterm.

Clicker question

Question

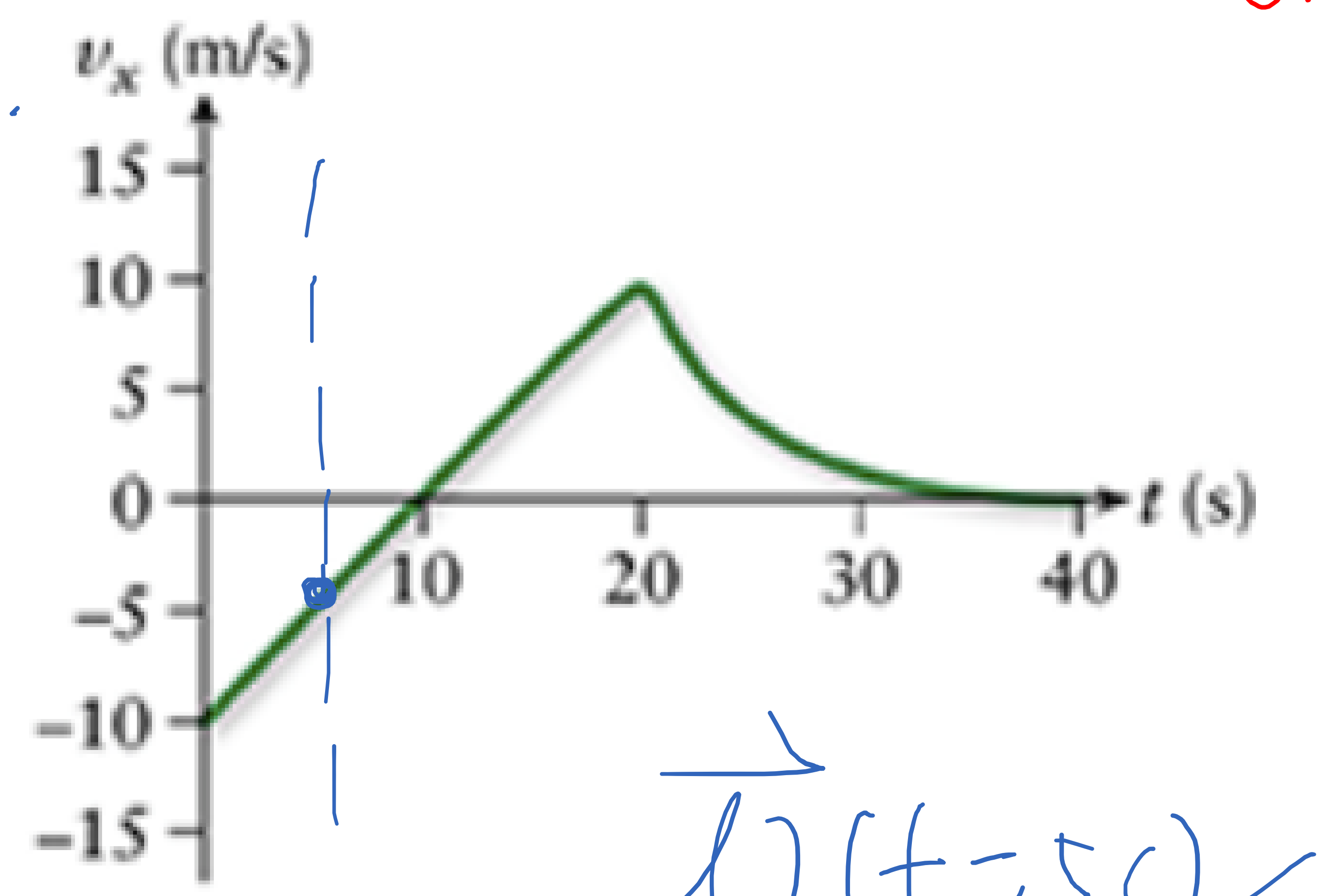
If $\vec{a}$ & $\vec{v}$ have the same sign: Speed up

$\vec{a}$ & v oppo. sign: Slow down

Which statement about the motion depicted in the figure below is correct?

(b) v_x-t graph

vel.



$+x$ $\hat{i}$

Slope

$$\boxed{\vec{a} = \frac{d\vec{v}}{dt}}$$

$\vec{v}(t=5s) < 0$

$\vec{v}(t=10s) = 0$

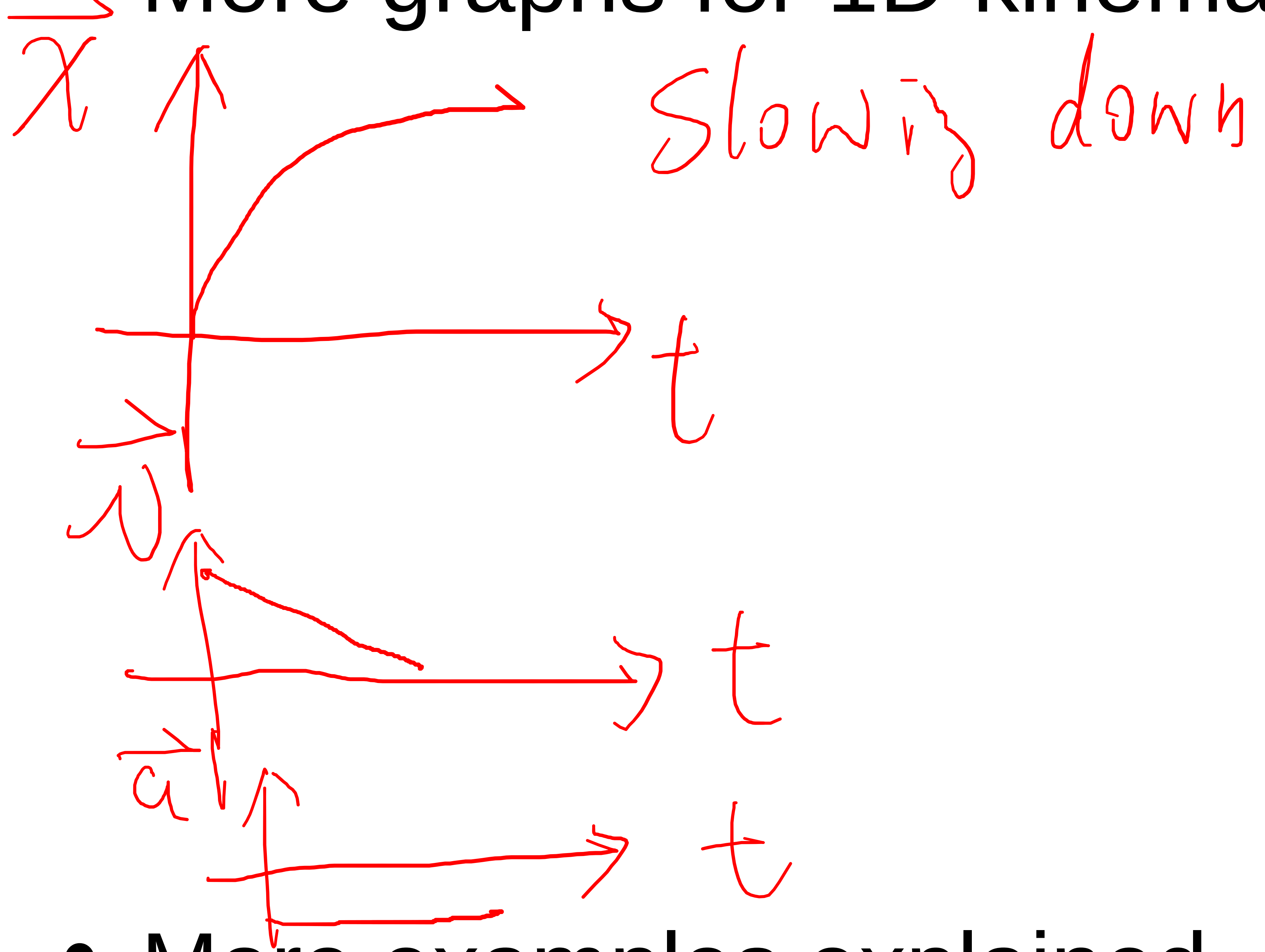
Speed ↓

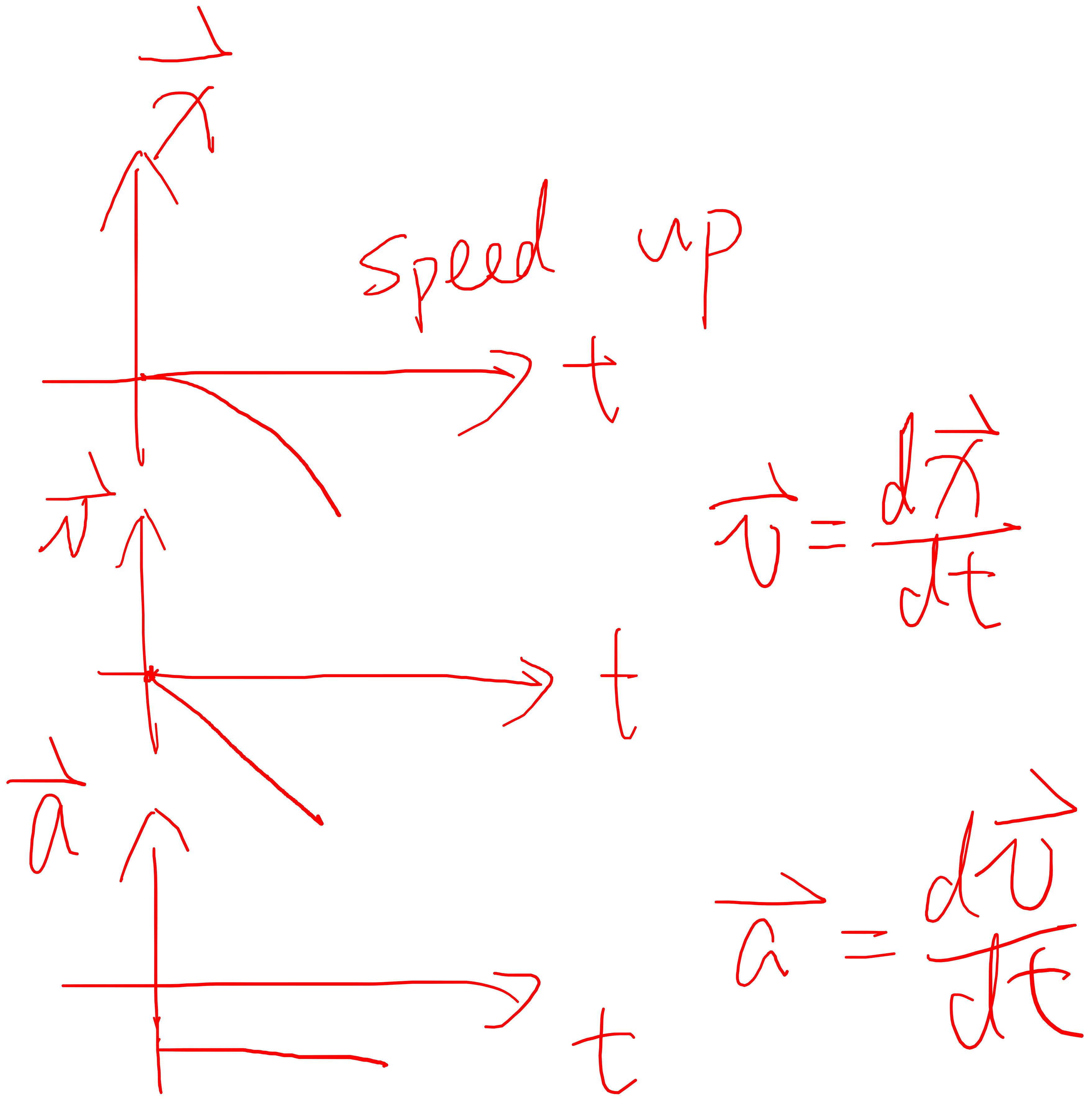
- A At $t = 5s$, a_x is positive and the object is speeding up
- B At $t = 5s$, a_x is positive and the object is slowing down
- C At $t = 5s$, a_x is negative and the object is speeding up
- D At $t = 5s$, a_x is negative and the object is slowing down

Submit

More examples

- More graphs for 1D kinematics

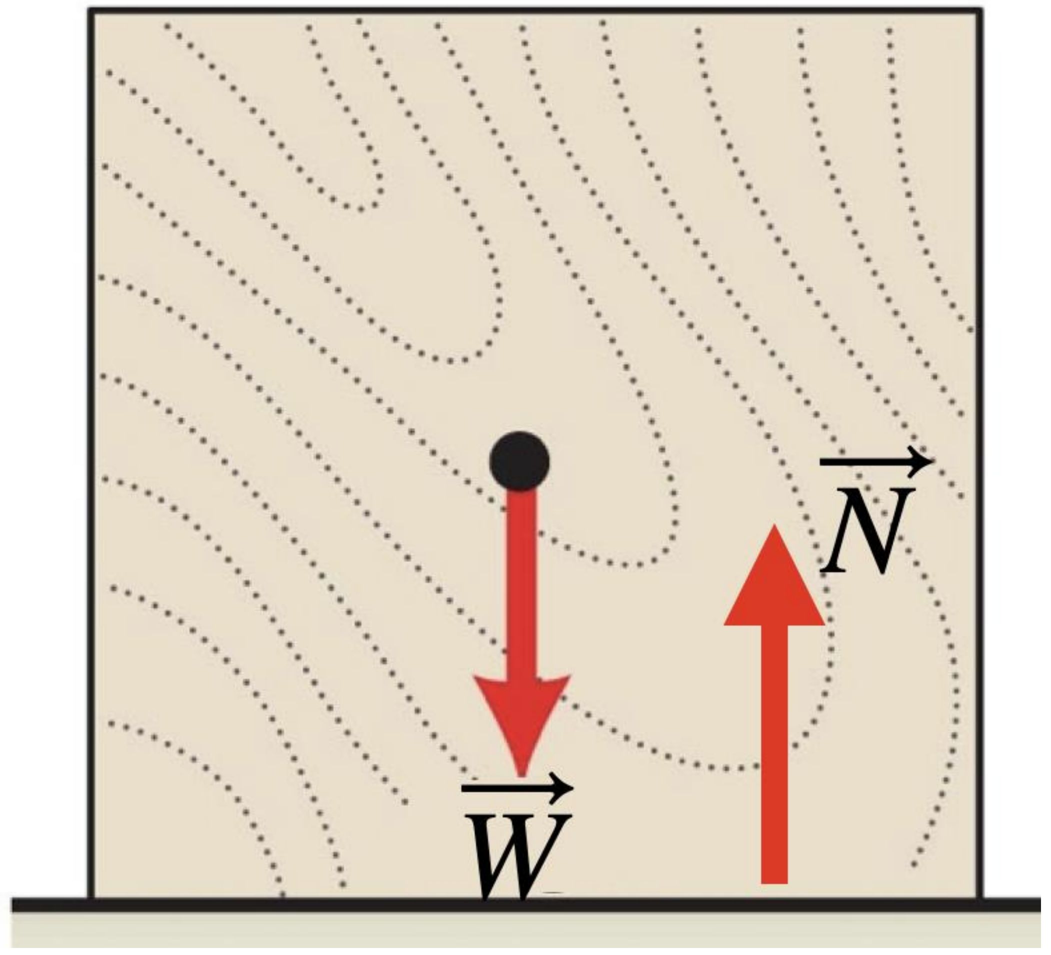




- More examples explained
  - Canvas module: Review for Midterm 1 -> Explained concepts and examples

Recap: 3. Normal force

- Normal force: The support force when two objects are in contact
  - Direction: perpendicular to surface
  - Magnitude: exactly enough so object remains on surface

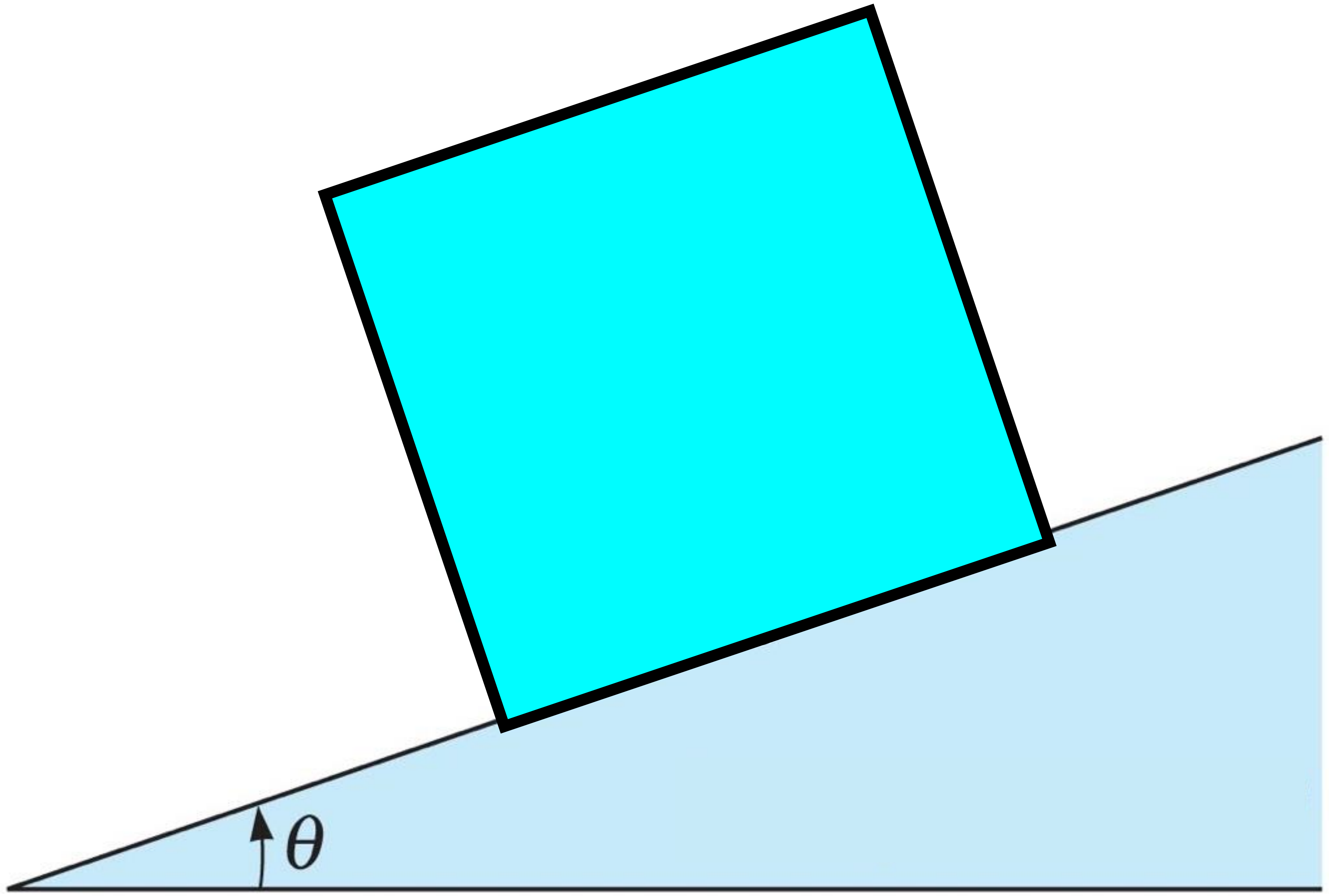


Steps to draw a Free Body Diagram (FBD)

- **Step 1:** Draw the coordinate system (Axes)
- **Step 2:** Draw the forces on the object or system (F's)
- **Step 3:** Decompose the forces that are not along the coordinate axes

Example 2: Incline

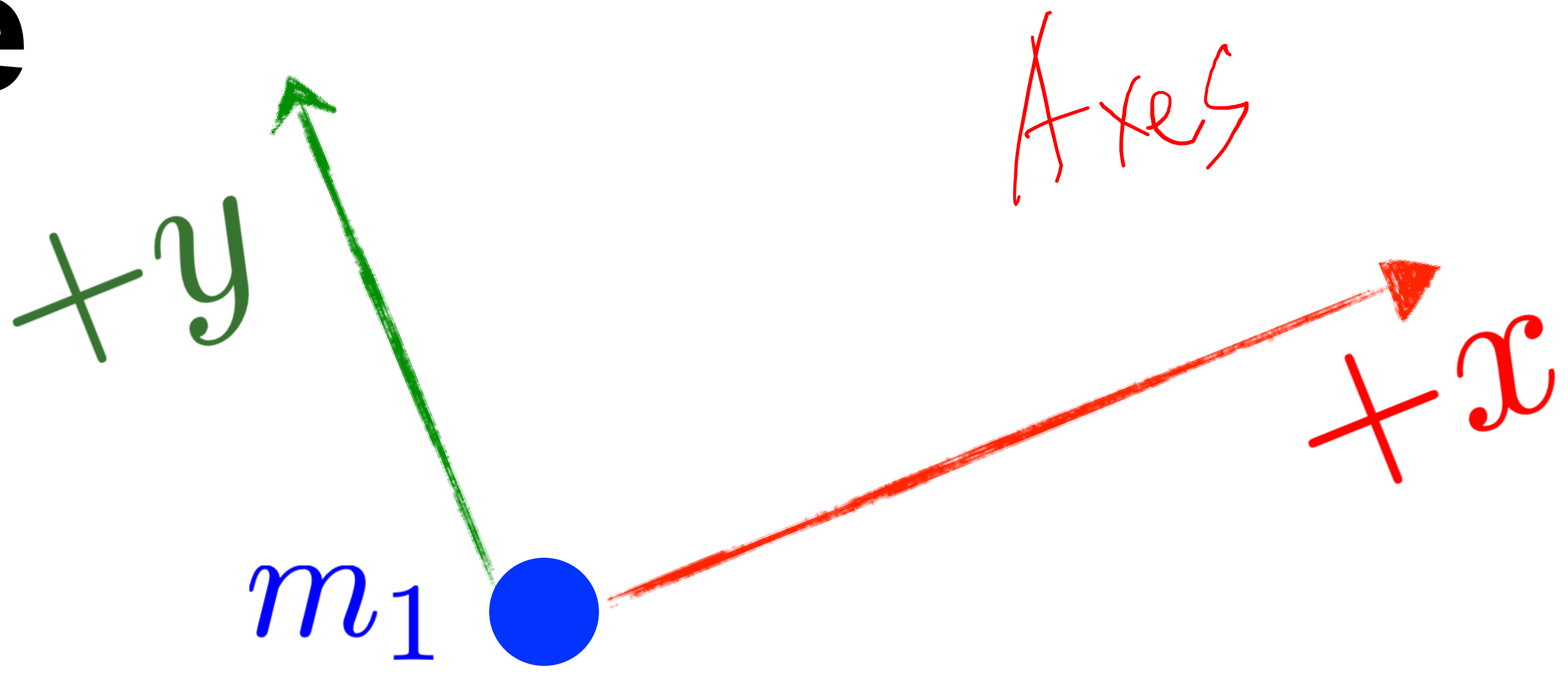
Drawing free-body diagram for the block on an incline.
(No friction/air resistance)



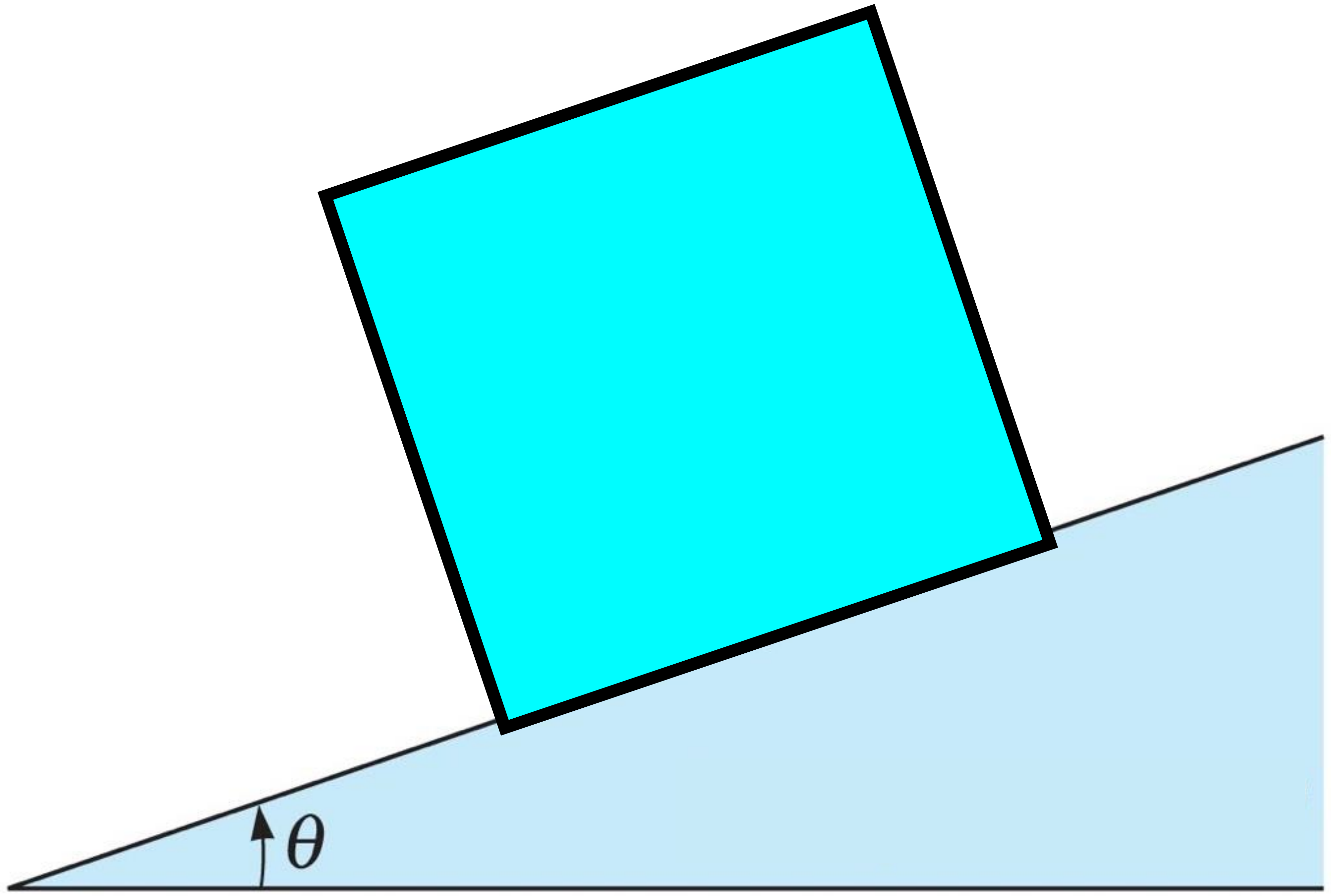
Given: m_1, θ

Goal: $\vec{a}$

Clicker question 1: Incline



The block is released from rest to slide on a frictionless incline. (No friction/air resistance)
What is the direction of its acceleration?



A Point vertically down:

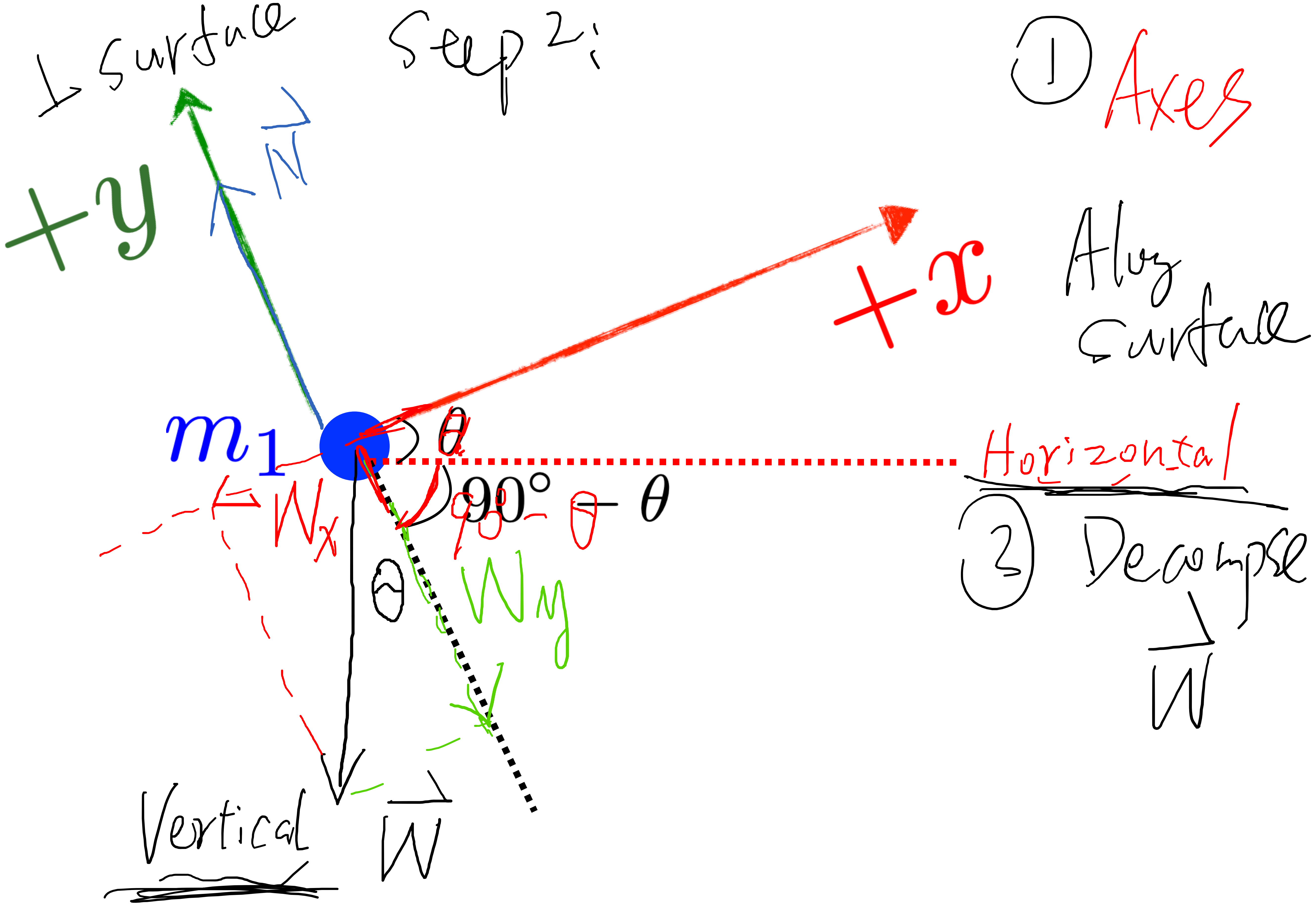
B Point downward along the incline:

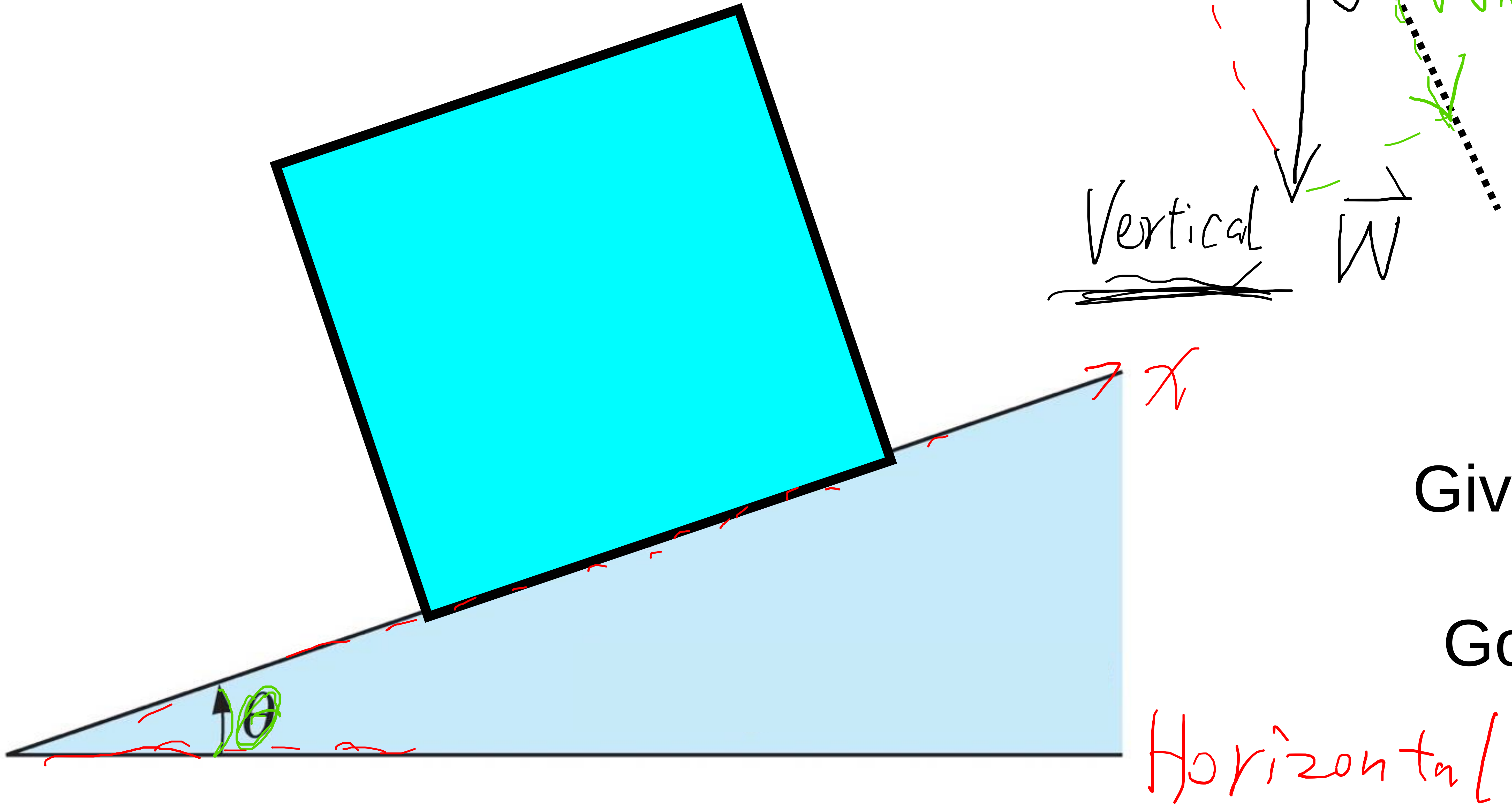
C Point horizontal to the left:

FBD

Example 2: Incline

Drawing free-body diagram for the block on an incline.
(No friction/air resistance)



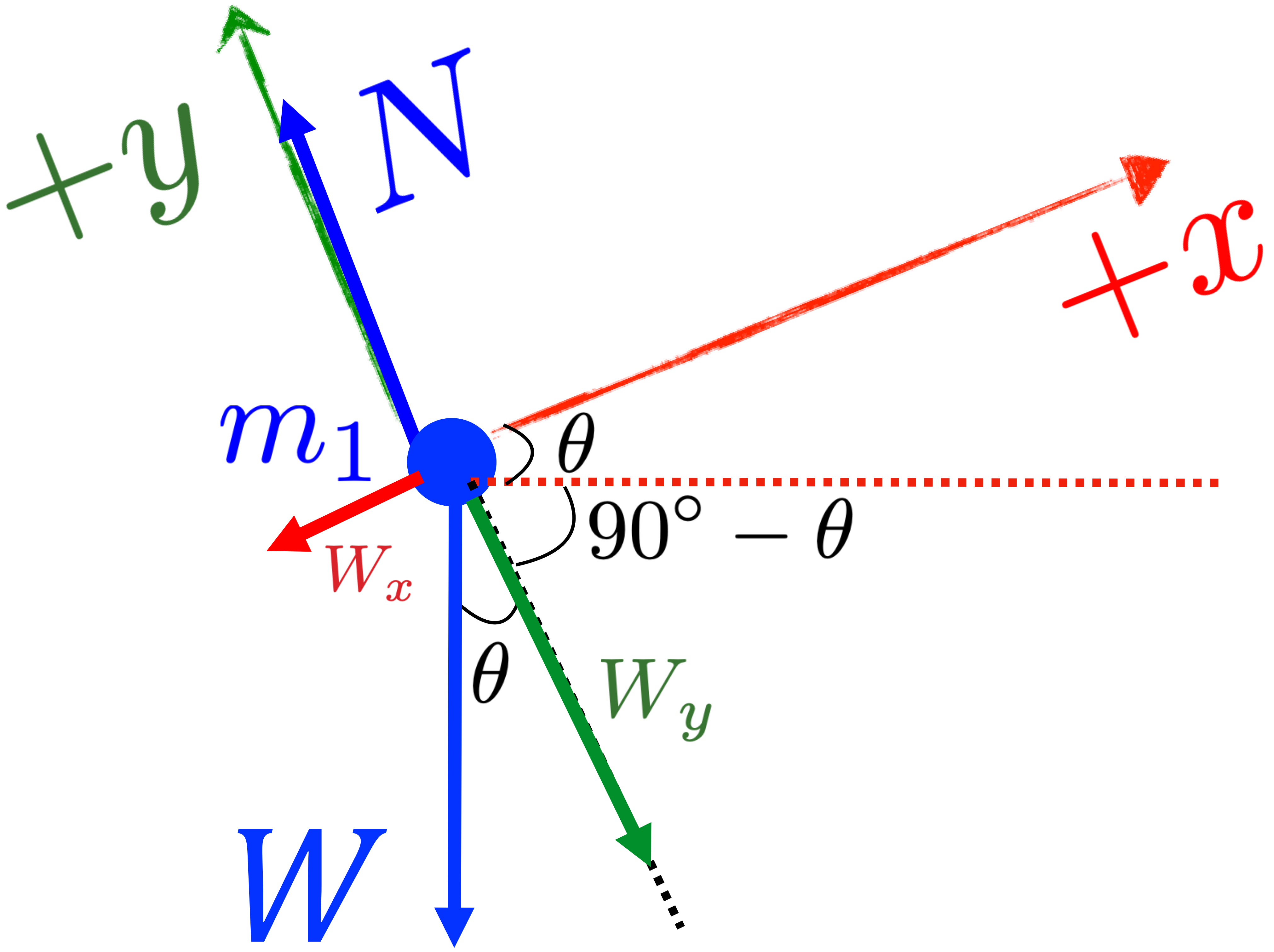


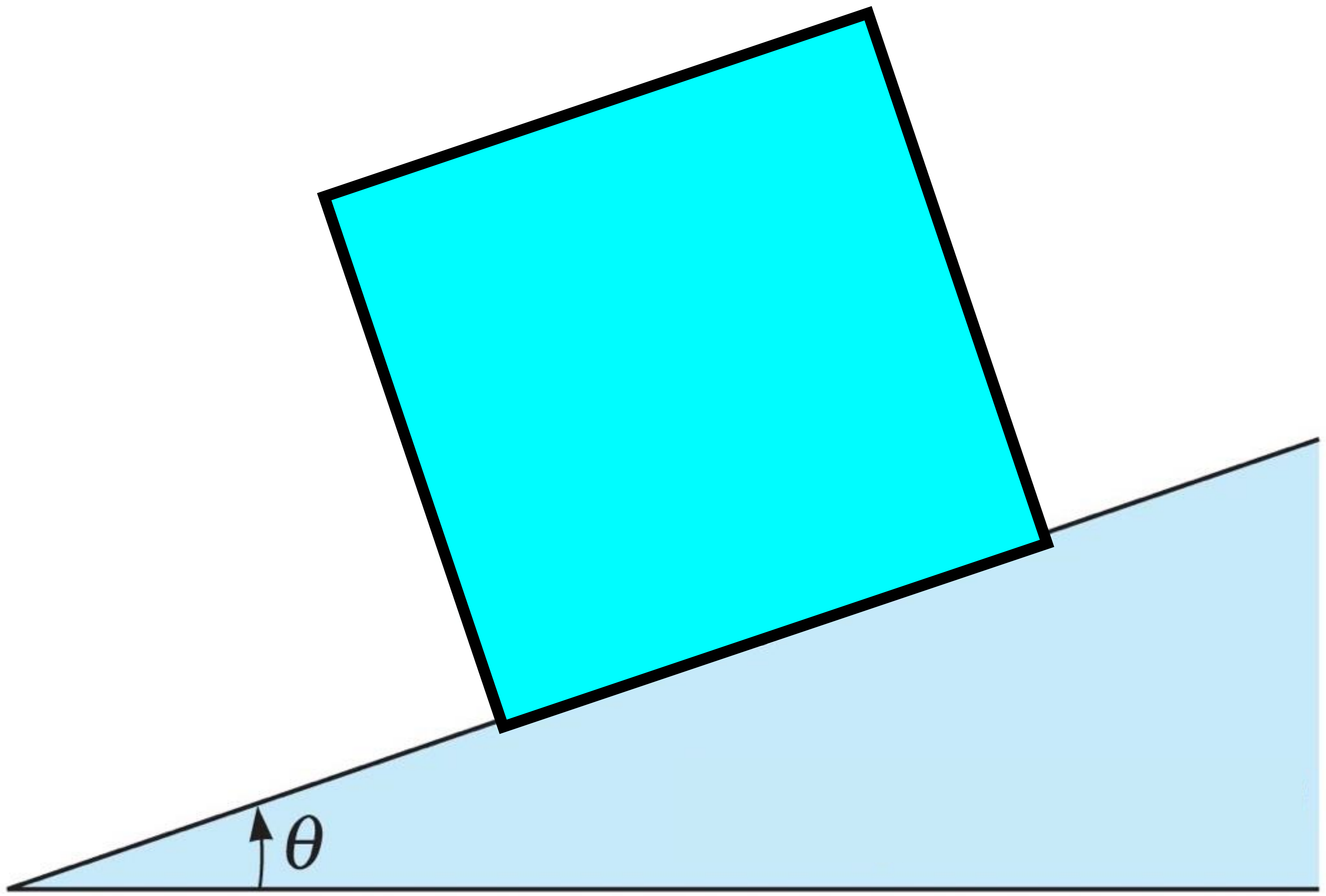
Given: m_1, θ

Goal: $\vec{a}$

Example 2: Incline

Drawing free-body diagram for the block on an incline.
(No friction/air resistance)





Given: m_1, θ

Goal: $\vec{a}$

FBD

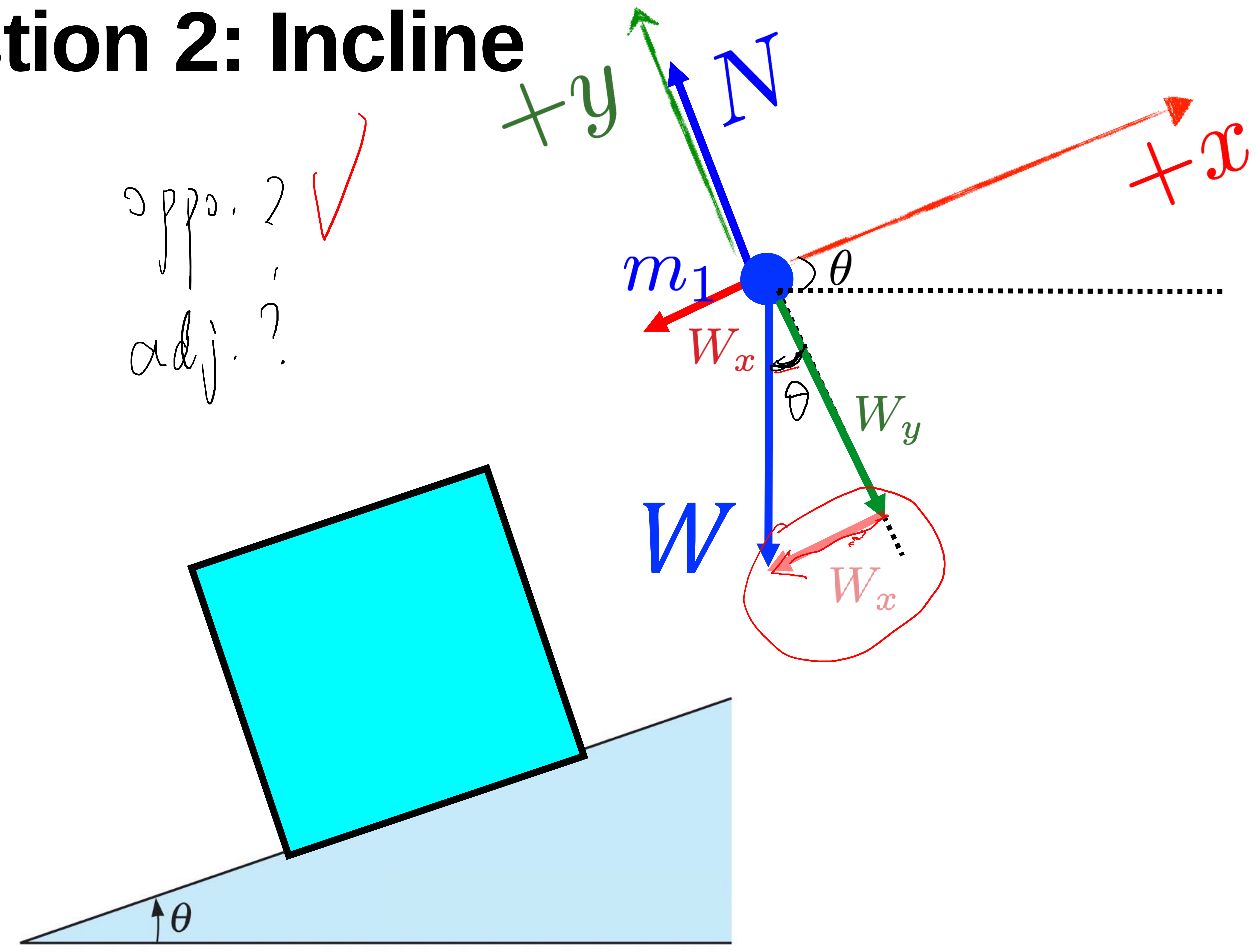
Clicker question 2: Incline

What is W_x?

- A $m_1 g \cos\theta\, \hat{\imath}$
- B $-m_1 g \sin\theta\, \hat{\imath}$
- C $m_1 g \sin\theta\, \hat{\imath}$
- D 0

oppo. ? ✓

adj. ?

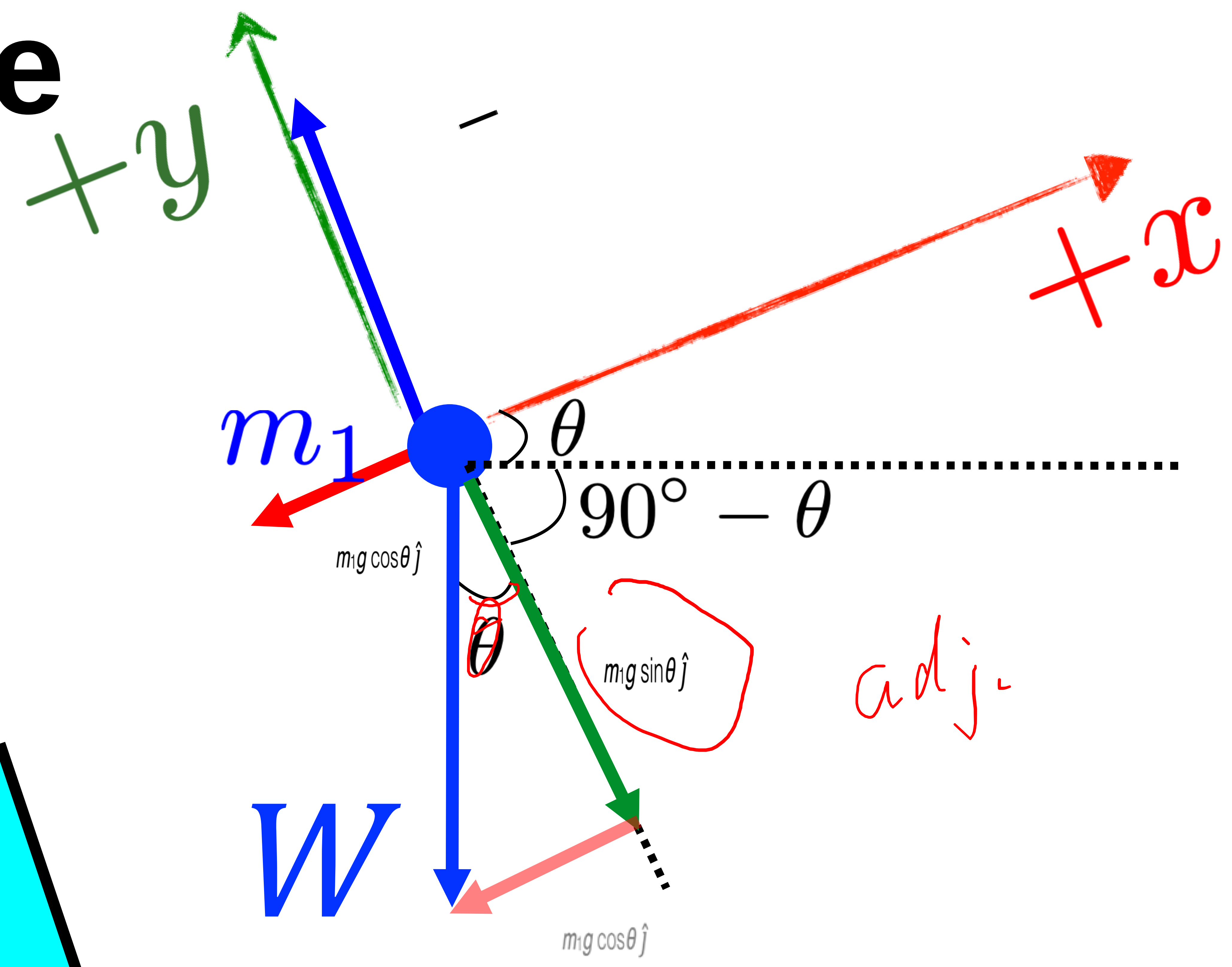


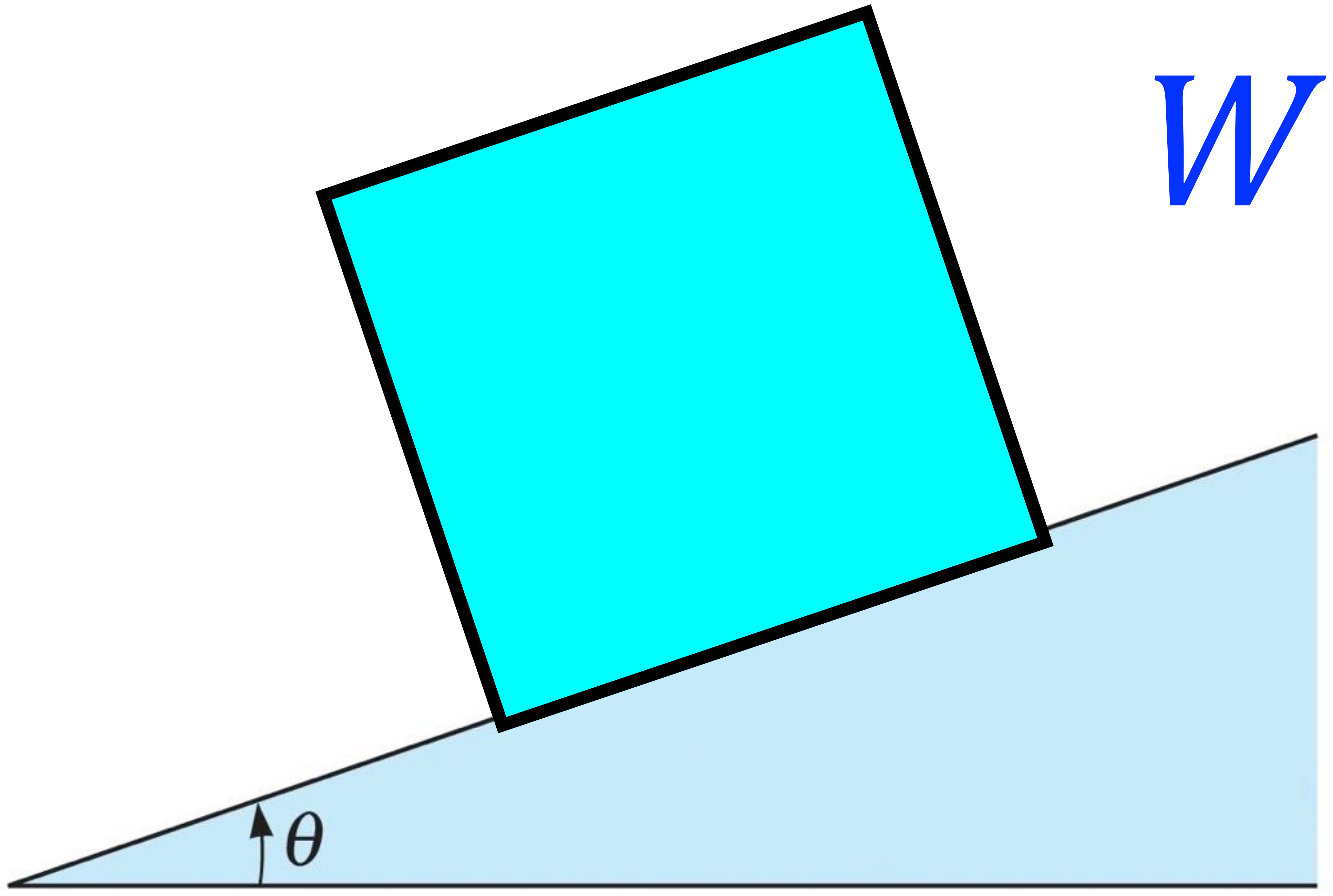
Clicker question 3: Incline

What is W_y?

- A $-m_1 g \cos\theta\,\hat{j}$
- B $m_1 g \sin\theta\,\hat{j}$
- C $m_1 g \cos\theta\,\hat{j}$
- D 0

FBD

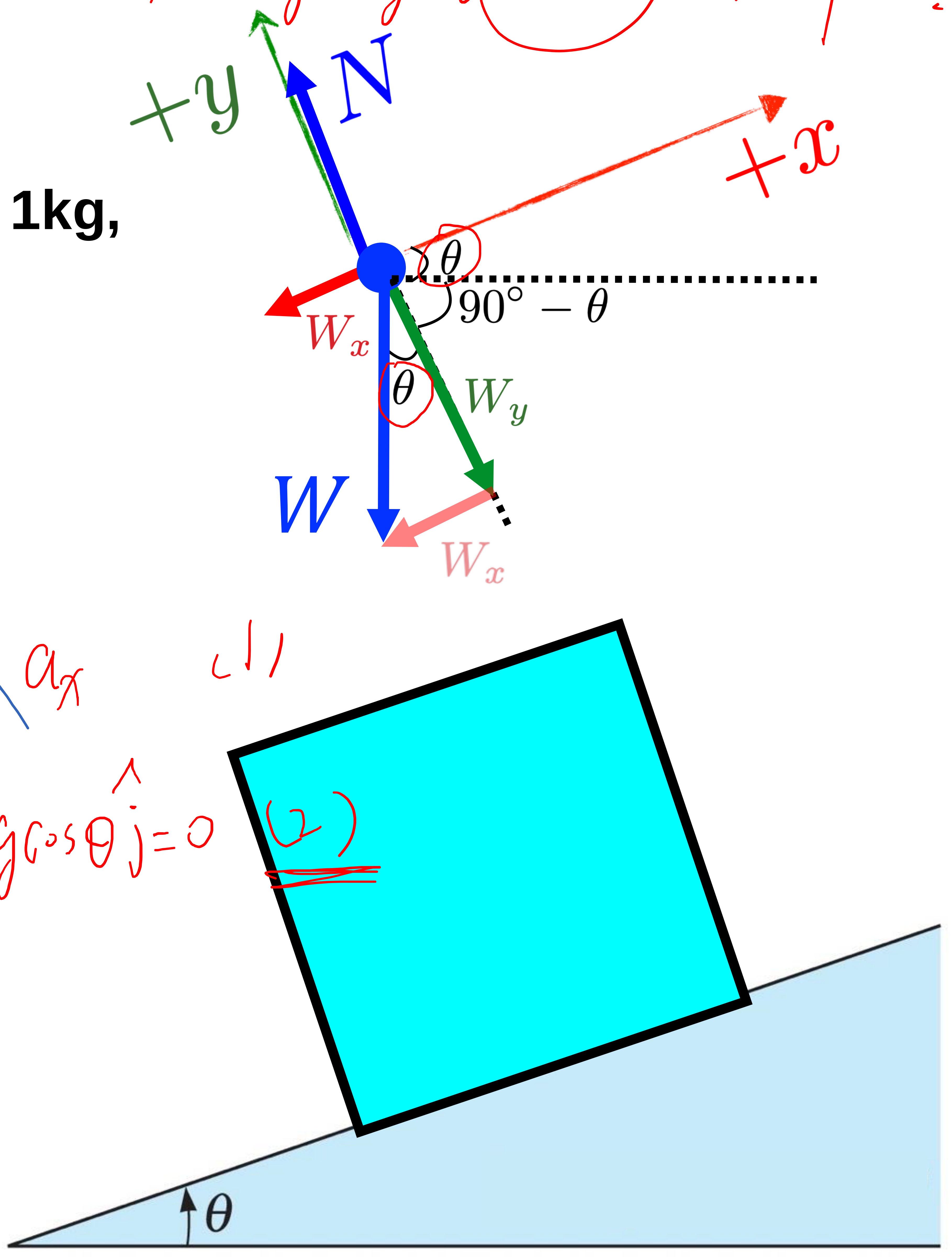




$W_x = -mg\sin\theta$, $W_y = -mg\cos\theta$ FBD Step 0.

Example 2: Frictionless Incline

Given the incline angle, $\theta = 30^\circ$, and mass of box, m_1 = 1kg, what is acceleration of the box? Frictionless.
What is the normal force on the box?



Step 1: Given: θ, m_1, g

Goal: $\vec{a}$, $\vec{N}$

Step 2: $\vec{F}_{net} = m_1 \vec{a}$

Decompose 2nd law $\begin{cases} \vec{F}_{net,x} = m_1 \vec{a}_x \\ \vec{F}_{net,y} = m_1 \vec{a}_y = 0 \quad (a_y = 0) \end{cases}$ $\rightarrow$ $\begin{cases} W_x = -\cancel{m_1} g\sin\theta = \cancel{m_1} a_x \quad (1) \\ 0 = \vec{N} + \vec{W}_y = \vec{N} - m_1 g\cos\theta\,\hat{j} = 0 \quad (2) \end{cases}$

(1) $a_x = -g\sin\theta \approx -9.8\,\mathrm{m\,s^{-2}}\,\sin 30^\circ = -4.9\,\mathrm{m\,s^{-2}}$

(2) $\vec{N} = m_1 g\cos\theta\,\hat{j} = 1\,\mathrm{kg}\cdot 9.8\,\mathrm{m\,s^{-2}}\cos 30^\circ\,\hat{j}$

$\approx 8.49\,\mathrm{N}\,\hat{j}$

Frictionless Incline: Equations

What is acceleration of the box?

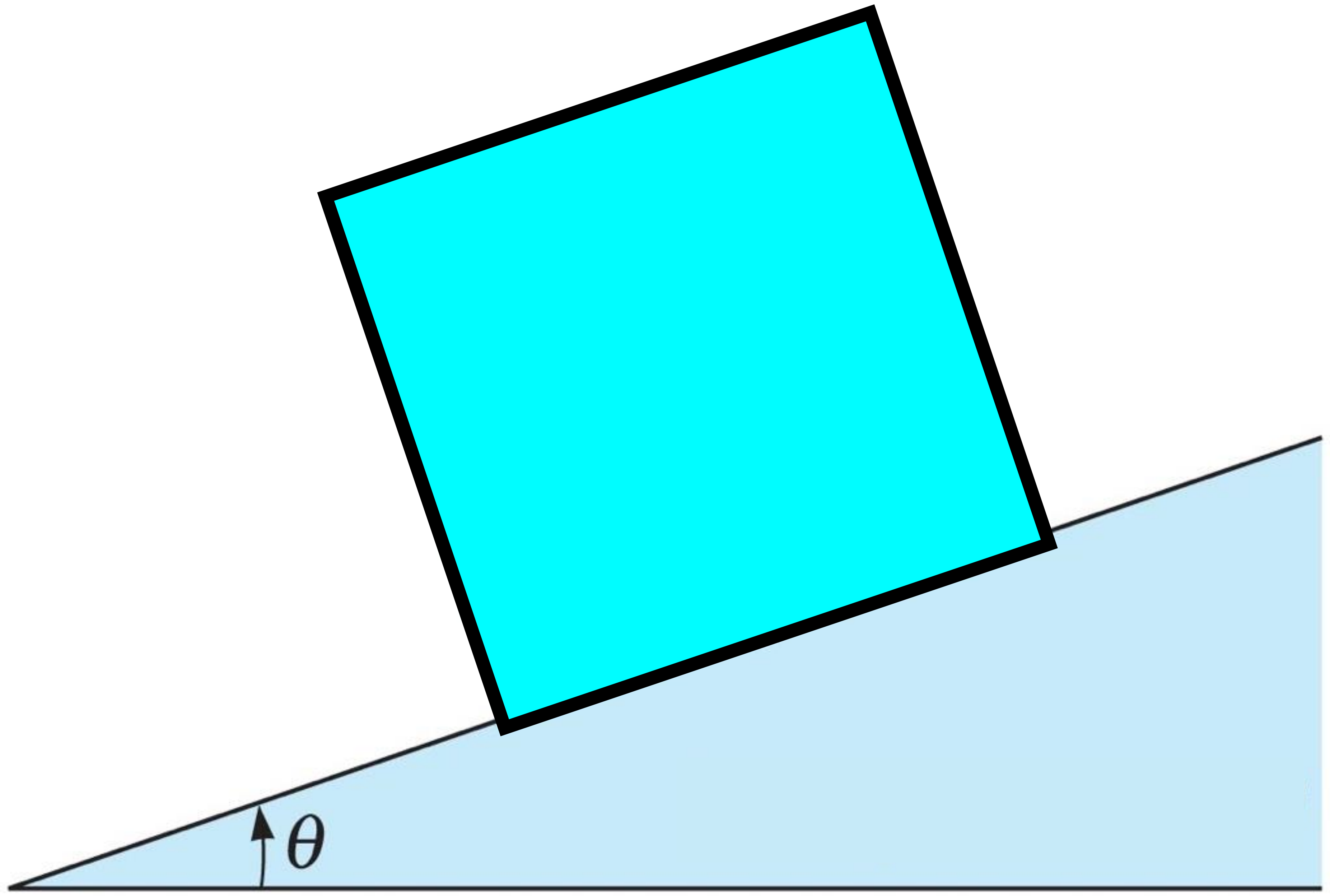
What is the normal force on the box?

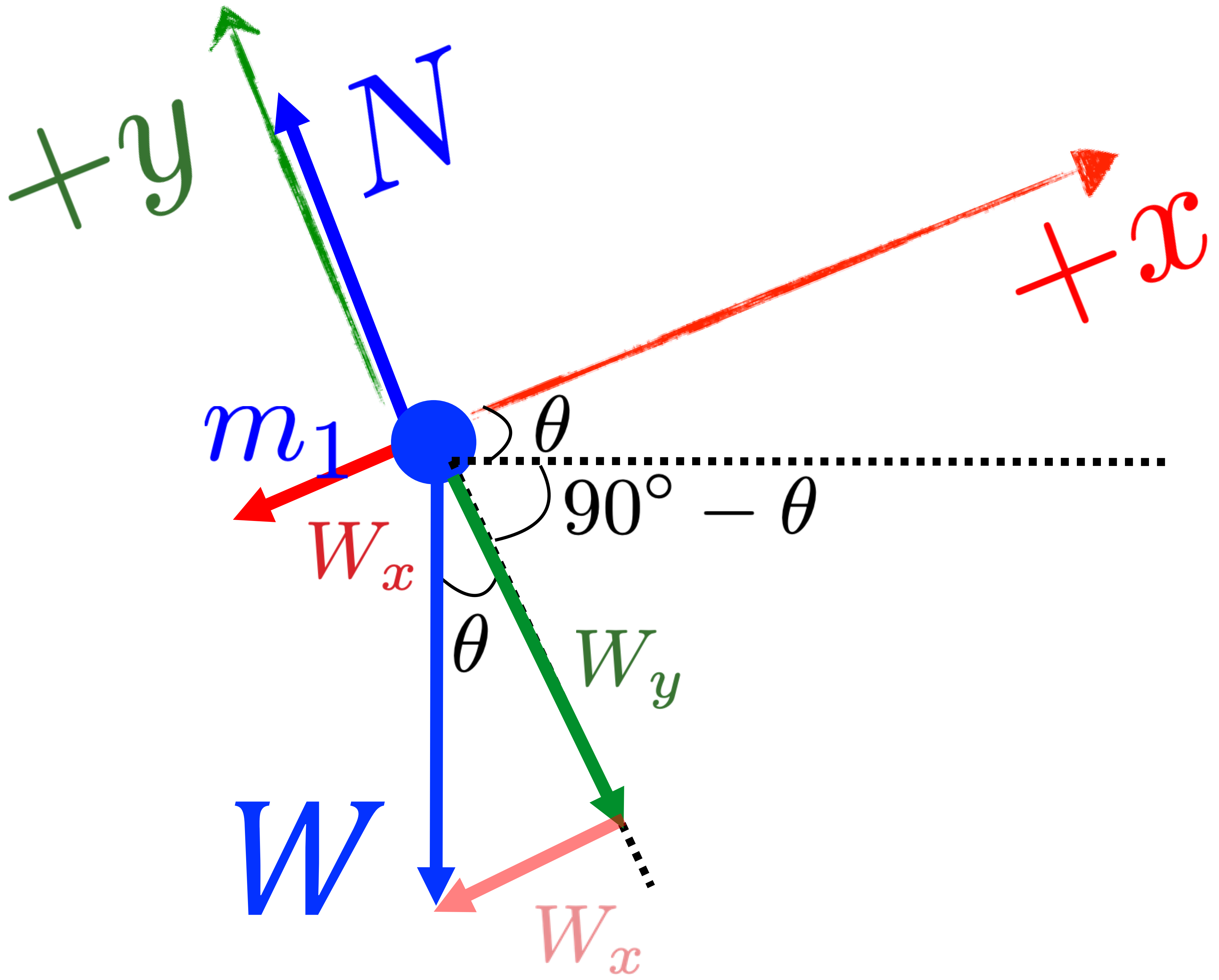
1. Newton's 2nd law along x axis

$$-m_1 g \sin\theta = m_1 a$$

2. Newton's 2nd law along y axis

$$N - m_1 g \cos\theta = 0$$





$$-g \sin\theta = a$$

$$N - m_1 g\cos\theta = 0$$

Clicker question 4: Incline

Question 4.11 On an Incline

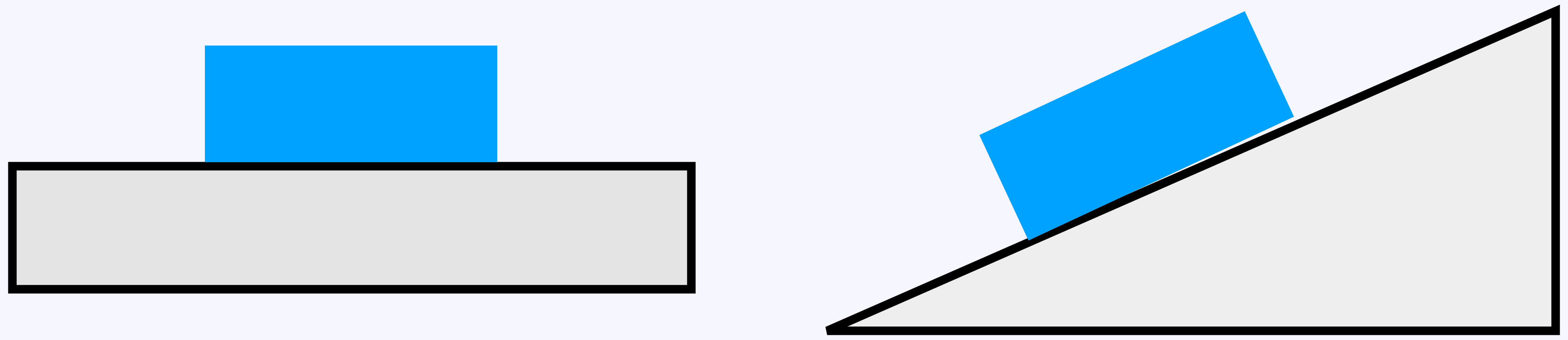
Consider two identical blocks, one resting on a flat surface and the other resting on an incline. For which case is the normal force greater in magnitude?

A For the block on the flat surface

B For the block on the incline

C both the same ($N = mg$)

D both the same ($0 < N < mg$)



Flat | Incline