a place of mind

FACULTY OF EDUCATION

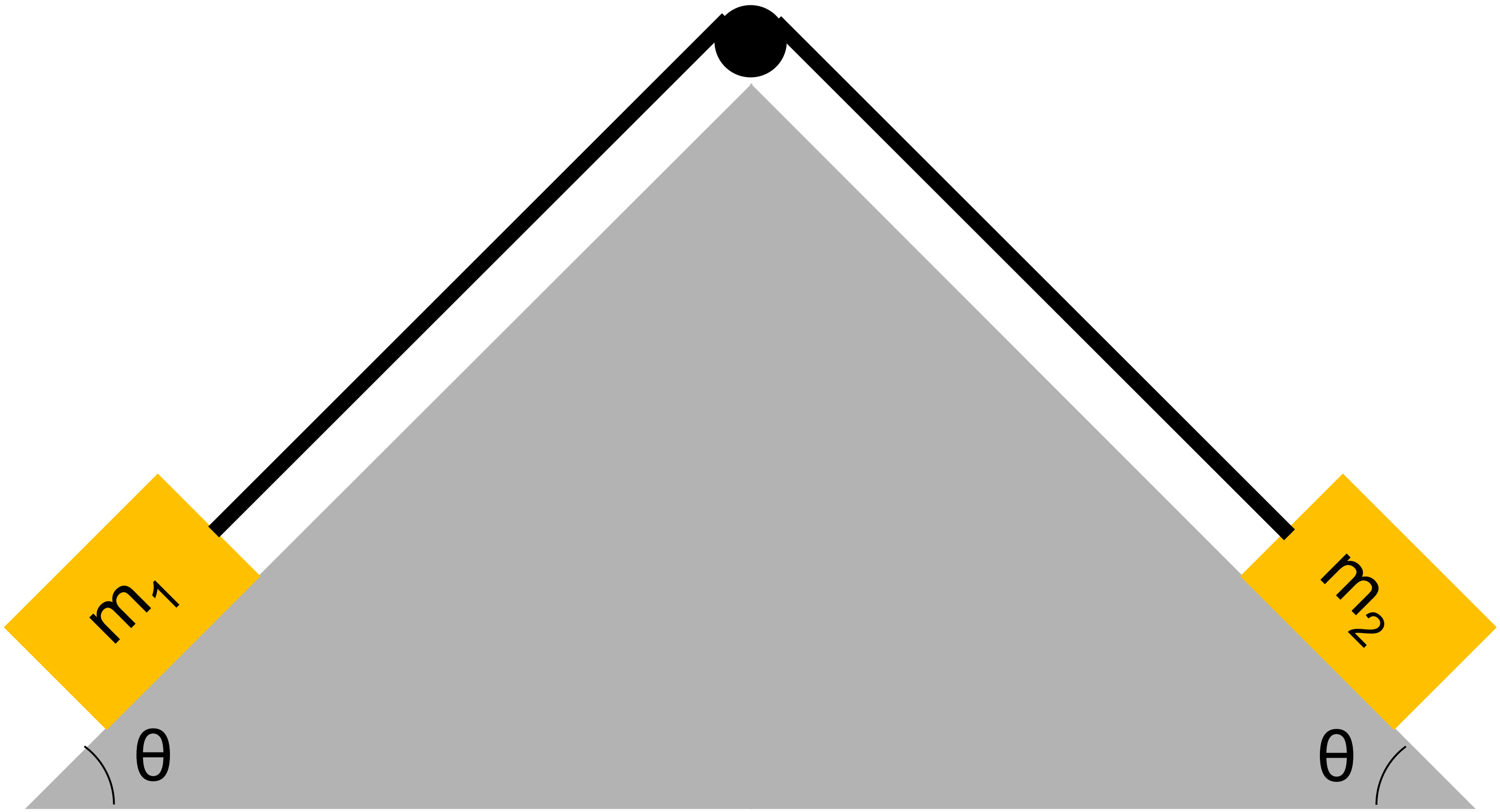
Department of
Curriculum and Pedagogy

Physics
Dynamics: Forces

Science and Mathematics
Education Research Group

Supported by UBC Teaching and Learning Enhancement Fund 2012-2013

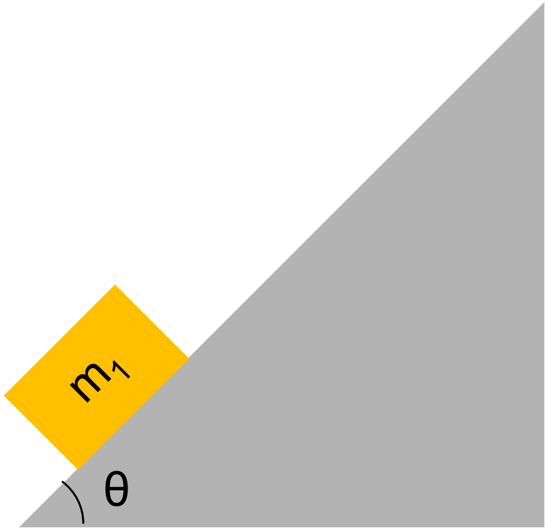
Blocks on a Pyramid



Blocks on a Pyramid I

A block is at rest on the rough surface of a pyramid. What is the normal force acting on the block if its mass is m_1 and the slope is θ degrees?

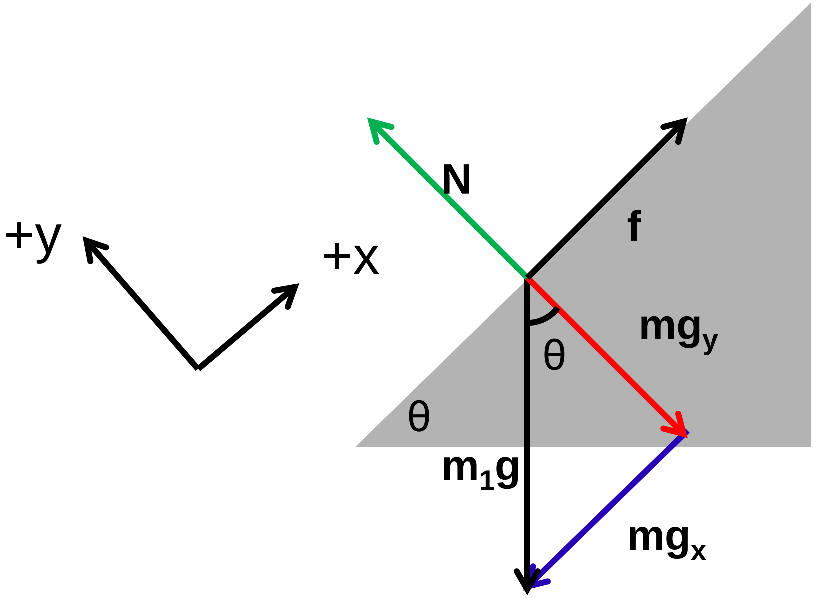
A. $m_1 g$
B. $m_1 g \sin\theta$
C. $m_1 g \cos\theta$
D. m_1
E. No idea



Solution

Answer: C

Justification: From a free body diagram of the block (shown below), we see that the normal force must be equal to the y-component of the force due to gravity, in order to maintain a net force along the y-axis of 0.



mg_y is adjacent to the angle, so:

$mg_y = m_1 g\cos\theta$

Blocks on a Pyramid II

If the coefficient of friction is μ, what is the net force acting on the block?

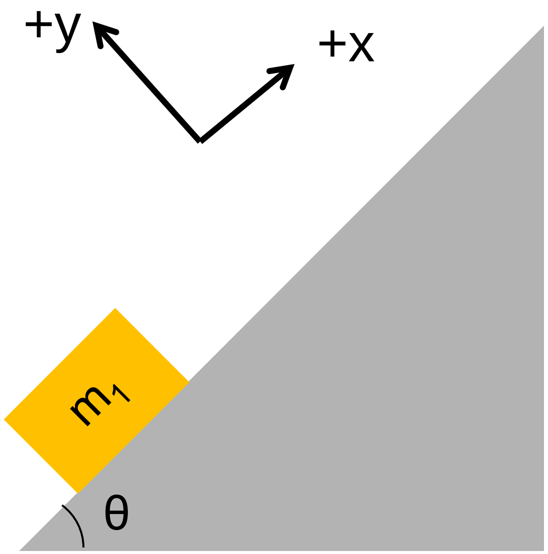
A. $m_1 g$

B. $m_1 g(\mu\cos\theta - \sin\theta)$

C. $m_1 g(\sin\theta + \mu\cos\theta)$

D. $m_1 g\sin\theta$

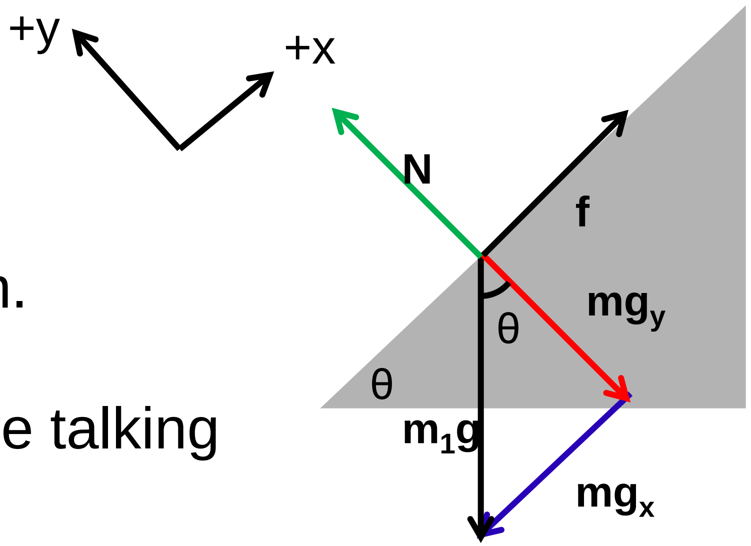
E. No idea



Solution

Answer: B

Justification: Using the free body diagram in the last question, we see that the force acting on the block is mostly contributed by the component of gravity parallel to the ramp (since the perpendicular component is cancelled by the normal force), which has a value of $m_1 g\sin\theta$. The normal force is $m_1 g\cos\theta$ and the coefficient of friction is μ, giving a friction force of $\mu m_1 g\cos\theta$.



The friction force and gravity force are in opposite directions, with the friction force pointing in the positive x direction.

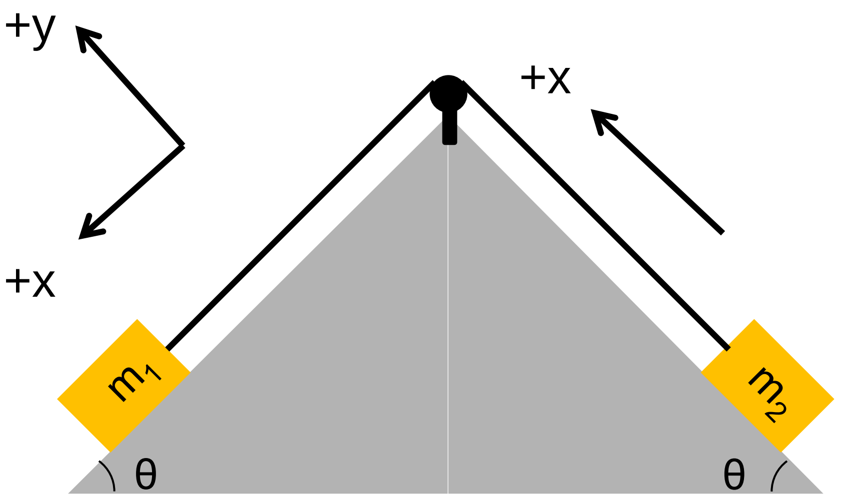
$F_{net} = m_1 g(\mu\cos\theta - \sin\theta)$

Notice, since the block is at rest, we are talking About static friction and μ_s.

Blocks on a Pyramid III

Here we have the same situation except there are now two masses connected by a wire and a pulley. The angles and coefficients of friction are the same. If $m_1>m_2$, what would be the net force on m_1?

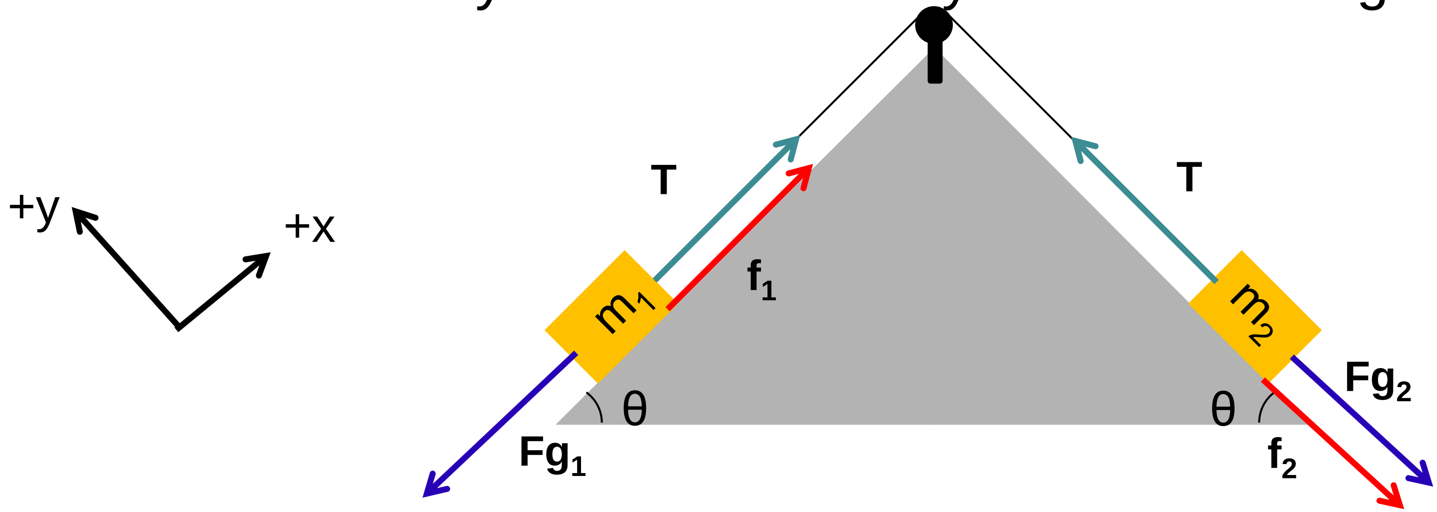
A. F_{g1x}
B. $F_{g1}\sin\theta - F_{fric1}$
C. $F_{g1}\sin\theta - F_{fric1} - F_{g2} + F_{fric2}$
D. $F_{g1}\sin\theta - F_{fric1} - F_{g2} - F_{fric2}$
E. No idea



Solution

Answer: D

Justification: The information $m_1 >> m_2$ means that the m_1 will go down the ramp while m_2 will go up the ramp. Thus, the forces on block 1 due to gravity and friction oppose each other, while the forces of gravity and friction on m_2 will be directed in the same direction. The forces on block 2 are in the same direction, because friction always opposes the direction of motion. The forces of tension T are the same on both blocks as they are connected by the same string.



Blocks on a Pyramid IV

Here we have the same situation except there are now two masses connected by a wire and a pulley. The angles and coefficients of friction are the same. If $m_1 > m_2$, what would be the magnitude of the net force on m_1?

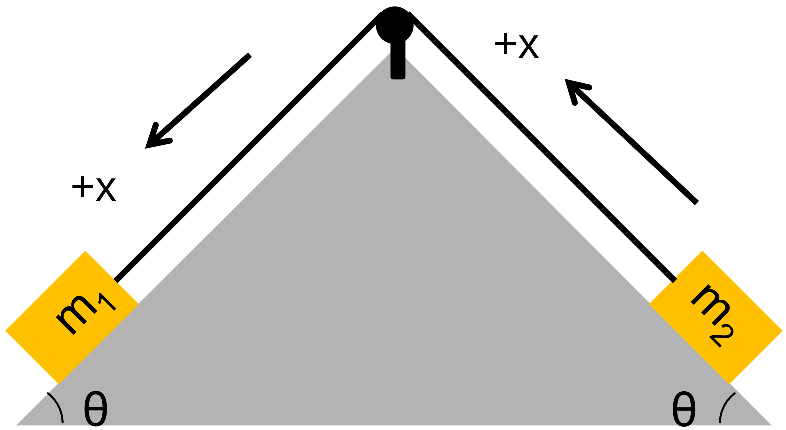
A. $m_1 g$

B. $m_1 g(\sin\theta - \mu\cos\theta)$

C. $m_1 g(\sin\theta - \mu\cos\theta) - m_2 g(\sin\theta - \mu\cos\theta)$

D. $m_1 g(\sin\theta - \mu\cos\theta) - m_2 g(\sin\theta + \mu\cos\theta)$

E. No idea



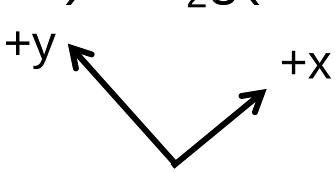
Solution

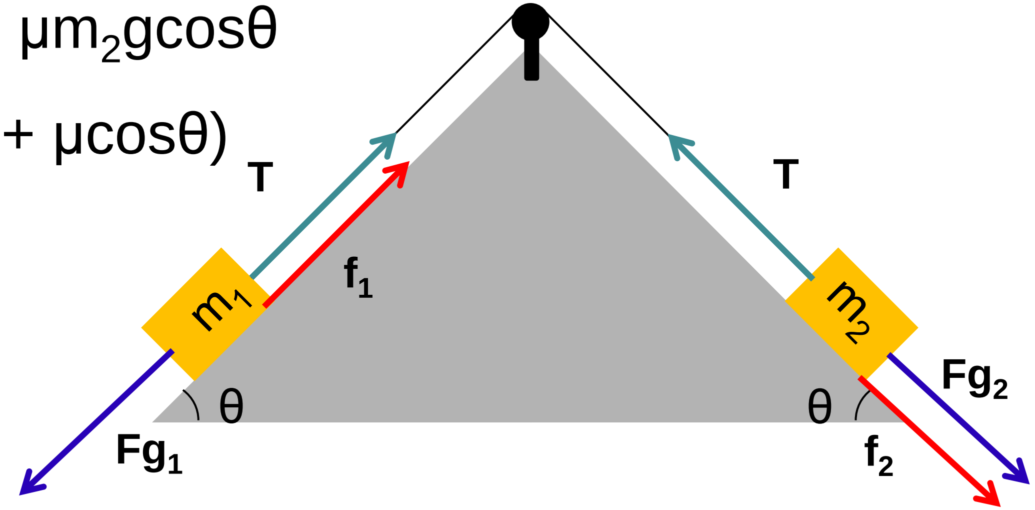
Answer: D

Justification: The force going forward is $m_1 g\sin\theta$ (gravity on m_1), while the three forces opposing it are $\mu m_1 g\cos\theta$ (friction on m_1), $m_2 g\cos\theta$ (gravity on m_2), and $\mu m_2 g\cos\theta$ (friction on m_2). The signs in front of the three forces opposing the gravity on m_1 are all negative, but since m_2 is taken out of the brackets along with the negative sign in front of it, D is the correct answer.

$$m_1 g\sin\theta - \mu m_1 g\cos\theta - m_2 g\cos\theta - \mu m_2 g\cos\theta$$

$$= m_1 g(\sin\theta - \mu\cos\theta) - m_2 g(\cos\theta + \mu\cos\theta)$$





Blocks on a Pyramid V

There are two masses connected by a wire and pulley resting on a pyramid. The angles and coefficients of friction are the same. If $m_2>m_1$, what would be the magnitude of the net force on m_1?

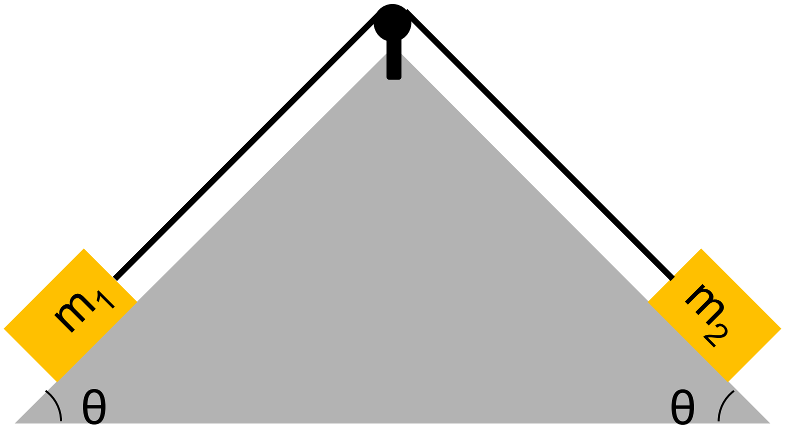
A. $F_{g2}\sin\theta$

B. $F_{g2}\sin\theta - F_{fric2}$

C. $F_{g2}\sin\theta - F_{fric2} - F_{g1} + F_{fric1}$

D. $F_{g2}\sin\theta - F_{fric2} - F_{g1} - F_{fric1}$

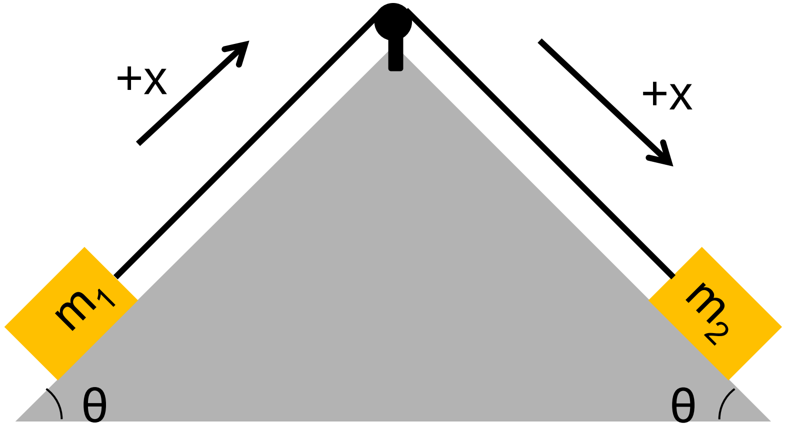
E. No idea



Solution

Answer: D

Justification: This is essentially the same question as number 3, except the roles of m_1 and m_2 are reversed. Friction always opposes The direction of the positive x-axis has also been reversed.



Blocks on a Pyramid VI

There are two masses connected by a wire and pulley resting on a pyramid. The angles and coefficients of friction are the same. What is the maximum value of m_2/m_1 that allows the masses to stay still?

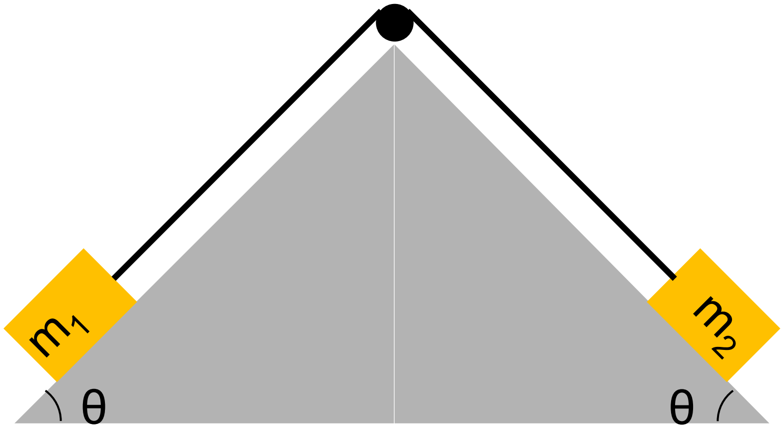
$A.\ \tan\theta$

$B.\ m_2 g(\sin\theta - \mu\cos\theta)$

$C.\ \dfrac{\sin\theta + \mu\cos\theta}{\sin\theta - \mu\cos\theta}$

$D.\ \dfrac{\sin\theta - \mu\cos\theta}{\sin\theta + \mu\cos\theta}$

$E.$ None of the above



Solution

Answer: C

Justification: We only need to consider the case of $m_2 > m_1$ because it asks for the maximum value of m_2/m_1

The contraption will be at rest if the driving force is less than or equal to the opposing forces:

$m_2 g\sin\theta \leq \mu m_1 g\cos\theta + m_1 g\sin\theta + \mu m_2 g\cos\theta$.

Regrouping, we find that this is true if

$m_2(\sin\theta - \mu\cos\theta) \leq m_1(\sin\theta + \mu\cos\theta)$.

Therefore,

$$\frac{m_2}{m_1} < \frac{\sin\theta + \mu\cos\theta}{\sin\theta - \mu\cos\theta}$$

Blocks on a Pyramid VII

There are two masses connected by a wire and pulley resting on a pyramid. The angles and coefficients of friction are the same. What is the minimum value of ${}^{m_1}\!/\!{}_{m_2}$ that allows the masses to stay still?

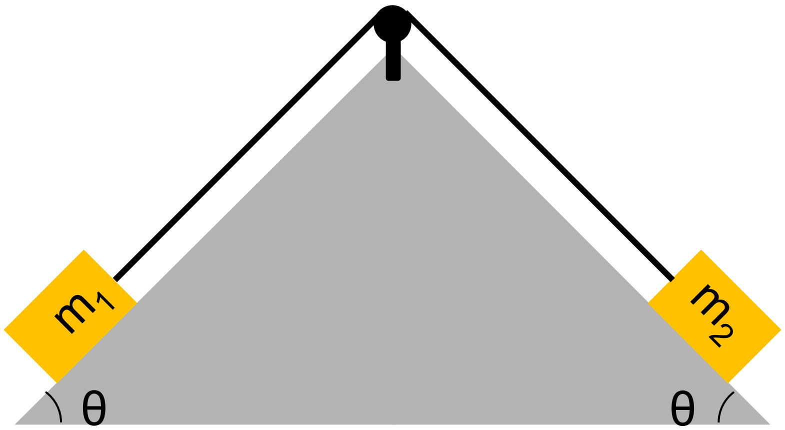
$A.\ \tan\theta$

$B.\ m_2 g(\sin\theta - \mu\cos\theta)$

$C.\ \dfrac{\sin\theta + \mu\cos\theta}{\sin\theta - \mu\cos\theta}$

$D.\ \dfrac{\sin\theta - \mu\cos\theta}{\sin\theta + \mu\cos\theta}$

$E.$ None of the above



Solution

Answer: D

Justification: This is simply a reversal of question 5, except this time m_1 is the "dominant" block.

Because the system is symmetric, for $m_1 > m_2$,

$$\frac{m_1}{m_2} < \frac{\sin\theta + \mu\cos\theta}{\sin\theta - \mu\cos\theta}$$

(reverse the roles of m_1 and m_2 in question 5).

We then find the answer by simply taking the reciprocal (while noting the greater than sign reverses).

$$\frac{m_1}{m_2} < \frac{\sin\theta - \mu\cos\theta}{\sin\theta + \mu\cos\theta}$$