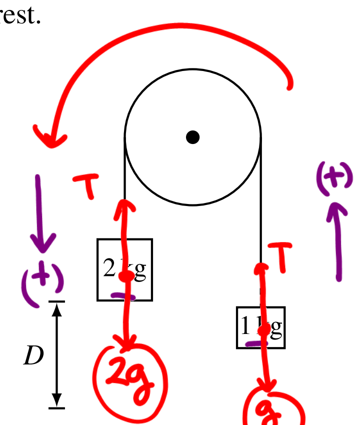
Student #: ____________________________ Student Name: ___________________________________

TOPIC 2: DYNAMICS

1. A small moving block collides with a large block at rest. Which of the following is true of the forces the blocks apply to each other
   (A) The small block exerts twice the force on the large block compared to the force the large block exerts on the small block.
   (B) The small block exerts half the force on the large block compared to the force the large block exerts on the small block.
   (C) The small block exerts exactly the same amount of force on the large block that the large block exerts on the small block.
   (D) The large block exerts a force on the small block, but the small block does not exert a force on the large block.
   (E) The small block exerts a force on the large block, but the large block does not exert a force on the small block.

Questions 2–3

A system consists of two blocks having masses of 2 kg and 1 kg. The blocks are connected by a string of negligible mass and hung over a light pulley, and then released from rest.



2kg $2g - \cancel{T} = 2a$
1kg $\cancel{T} - g = 1a$
$g = 3a$
$a = \frac{1}{3}g$

2. The acceleration of the 2 kg block is most nearly
   (A) $\frac{2}{9}g$
   (B) $\frac{1}{3}g$
   (C) $\frac{1}{2}g$
   (D) $\frac{2}{3}g$
   (E) g

B

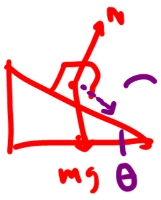
3. The speed of the 2 kg block after it has descended a distance D is most nearly
   (A) $\sqrt{\frac{4gD}{3}}$
   (B) $\sqrt{\frac{2gD}{3}}$
   (C) $\sqrt{\frac{gD}{3}}$
   (D) $\sqrt{\frac{gD}{2}}$
   (E) $\sqrt{\frac{4gD}{6}}$

B

$v^2 = \cancel{v_0^2} + 2aD$
$v = \sqrt{2aD} = \sqrt{\frac{2gD}{3}}$
$\frac{1}{3}g$

4. A wooden block slides down a frictionless inclined plane a distance of 1 meter along the plane during the first second. The distance traveled along the plane by the block during the time between 1 s and 2 s is
   (A) 2 m
   (B) 3 m
   (C) 4 m
   (D) 6 m
   (E) 8 m

B

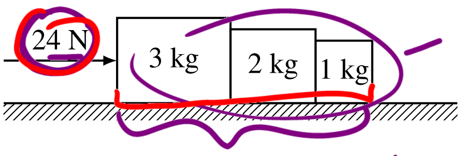


— mgsinθ ← constant

$d = \frac{1}{2}at^2$
constant
1s → 1m
2s → 4m
3m

Questions 5–6

Three blocks of mass 3 kg, 2 kg, and 1 kg are pushed along a horizontal frictionless plane by a force of 24 N to the right, as shown.



— 6kg

same acceleration

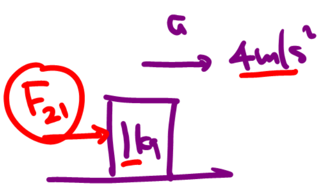
5. The acceleration of the 2 kg block is
   (A) $144\,m/s^2$
   (B) $72\,m/s^2$
   (C) $12\,m/s^2$
   (D) $6\,m/s^2$
   (E) $4\,m/s^2$

E

$\frac{24N}{6kg} = 4m/s^2$

6. The force that the 2 kg block exerts on the 1 kg block is
   (A) 2 N
   (B) 4 N
   (C) 6 N
   (D) 24 N
   (E) 144 N

B

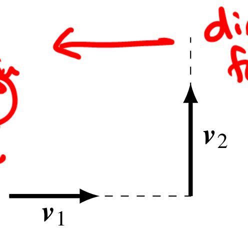


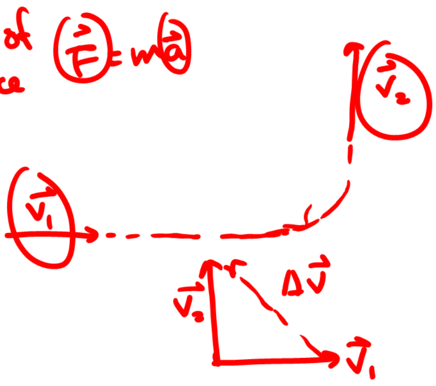
7. A hockey puck slides along horizontal ice with a velocity $\boldsymbol{v}_1$ when it is struck by a hockey stick, changing its direction, as shown. After the puck is struck, it has a velocity $\boldsymbol{v}_2$, which is greater than $\boldsymbol{v}_1$. Which of the following vectors best represents the direction the force of the hockey stick acted on the puck?

$\Delta\vec{v} = \vec{v}_2 - \vec{v}_1$ ← dir. of acceleration

$\vec{v}_2 = \vec{v}_1 + \Delta\vec{v}$ $\quad \vec{a} = \frac{\Delta\vec{v}}{\Delta t}$

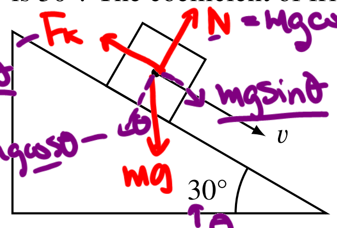
← dir. of force $\vec{F} = m\vec{a}$





(A) ↑ (B) ← (C) → (D) ↖ (E) ↗

8. A block of mass 4 kg slides down a rough incline with a constant speed. The angle the incline makes with the horizontal is 30°. The coefficient of friction acting between the block and incline is most nearly



(A) 0.1
(B) 0.2
(C) 0.3
(D) 0.4
(E) 0.6

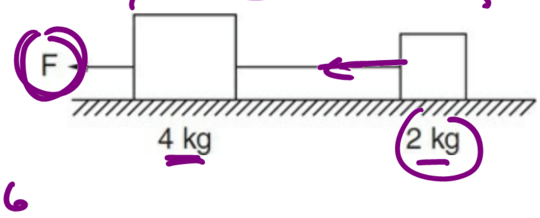
$\vec{a} = 0 \to F_{net} = 0$

$\mu mg\cos\theta = mg\sin\theta$

$\mu = \frac{\sin\theta}{\cos\theta} = \tan\theta = \tan 30° = 0.577$

9. Two blocks are pulled by a force of magnitude F along a level surface with negligible friction as shown. The tension in the string between the blocks is

Same acceleration



$\leftarrow a = \frac{F}{6}$

T ← 2kg

(A) $\frac{1}{4}F$
(B) $\frac{1}{2}F$
(C) $\frac{1}{3}F$
(D) F
(E) $2F$

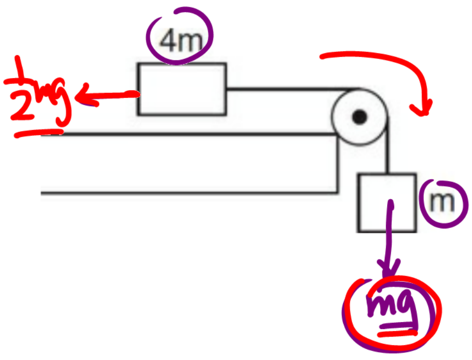
$F = ma$ 6

$a = \frac{F}{6}$

$T = ma$

$= 2\left(\frac{F}{6}\right) = \frac{F}{3}$

10. A block of mass $4m$ can move without friction on a horizontal surface. Another block of mass m is attached to the larger block by a string that is passed over a light pulley. The acceleration of the system is



$\cancel{m}g = (5\cancel{m})a$

$a = \frac{g}{5}$

(A) $\frac{1}{5}g$
(B) $\frac{1}{2}g$
(C) $\frac{2}{3}g$
(D) g
(E) $5g$

11. The block of mass $4m$ in the previous question now moves on a rough surface. The frictional force between the surface and the larger block is equal to $\frac{1}{2}mg$. The acceleration of the system is now

(A) $\frac{1}{16}g$
(B) $\frac{1}{10}g$
(C) $\frac{1}{4}g$
(D) $\frac{1}{2}g$
(E) g

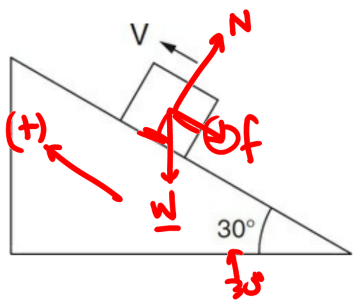
$\underbrace{\cancel{m}g - \frac{1}{2}\cancel{m}g}$ $= 5\cancel{m}a$

$\frac{1}{2}g = 5a \to a = \frac{g}{10}$

Questions 12–13

A 1 kg block is sliding up a rough 30° incline and is slowing down with an acceleration of $-6\,\text{m/s}^2$. The mass has a weight $\boldsymbol{w}$, and encounters a frictional force $\boldsymbol{f}$ and a normal force $\boldsymbol{N}$. The direction up the ramp is positive.

$mg = 10\,N$



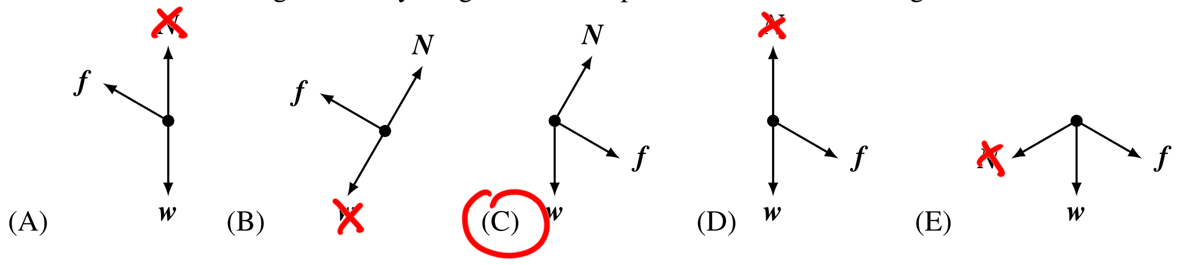
$\sum F_{(+)} = -W\sin\theta - f = ma$

$f = -W\sin\theta - ma$

$= -10\left(\frac{1}{2}\right) - (1)(-6) = -5 + 6$

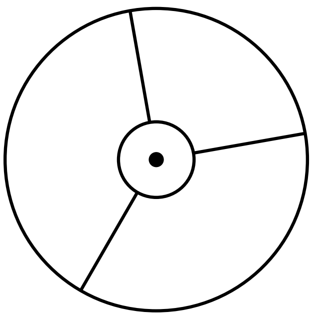
$= \boxed{1\,N}$

12. Which of the following free body diagrams best represents the forces acting on the block as it slides up the plane?



13. The magnitude of the frictional force f between the block and the plane is most nearly
   (A) 1 N
   (B) 2 N
   (C) 3 N
   (D) 4 N
   (E) 5 N

14. Three strings are attached to a ring in the center of a force table. The top view of the force table is shown. For the ring to remain in the center of the table, which of the following must be true?



   (A) The vector sum of the three forces must equal zero.
   (B) The lengths of the strings must be equal.
   (C) The strings must form an angle of 90° relative to each other.
   (D) The magnitudes of two of the tensions in the strings must equal the tension in the third string.
   (E) The tension in each string must be equal to each other.

Questions 15–16

A 10 N block sits atop an inclined plane in the shape of a right triangle of sides 3 m, 4 m, and 5 m, as shown. The block is allowed to slide down the plane with negligible friction.

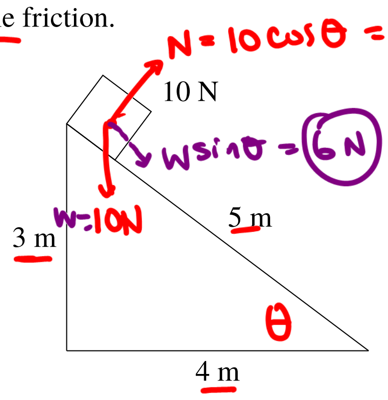
$m = 1\,kg$

$F = ma$

$6 = (1)a$

$a = 6\,m/s^2$

$N = 10\cos\theta = 8\,N$



$\sin\theta = \frac{3}{5}$

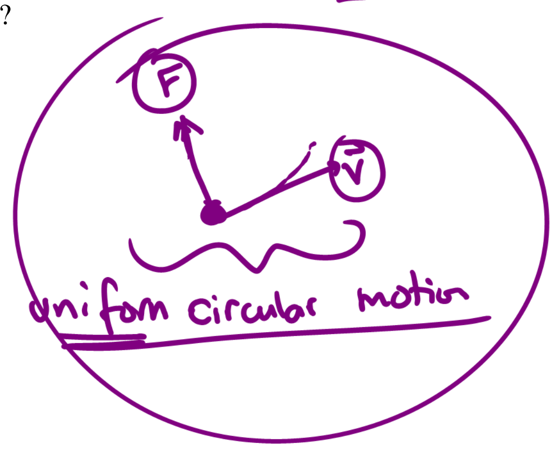
$\cos\theta = \frac{4}{5}$

$\tan\theta = \frac{3}{4}$

15. The acceleration of the block is most nearly
   (A) $2\,\text{m/s}^2$
   (B) $4\,\text{m/s}^2$
   (C) $6\,\text{m/s}^2$
   (D) $10\,\text{m/s}^2$
   (E) $12\,\text{m/s}^2$

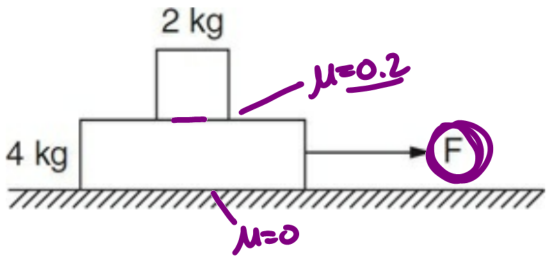
16. The normal force exerted on the block by the plane is most nearly
   (A) 2 N
   (B) 4 N
   (C) 6 N
   (D) 8 N
   (E) 10 N

17. A constant force acts on a particle in such a way that the direction of the force is always perpendicular to its velocity. Which of the following is true of the particle's motion?
   (A) The acceleration of the particle is increasing
   (B) The acceleration of the particle is decreasing.
   (C) The speed of the particle is increasing. x
   (D) The speed of the particle is constant.
   (E) The speed of the particle is decreasing. x



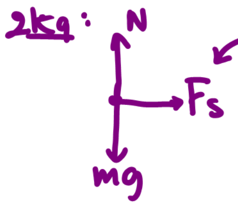
Questions 18–19

A block of mass 2 kg rests on top of a larger block of mass 4 kg. The larger block slides without friction on a table, but the surface between the two blocks is not frictionless. The coefficient of friction between the two blocks is 0.2. A horizontal force ***F*** is applied to the 4 kg mass.



18. What is the maximum force that can be applied such that there is no relative motion between the two blocks?

(A) zero
(B) 1 N
(C) 2 N
(D) 4 N
(E) 12 N



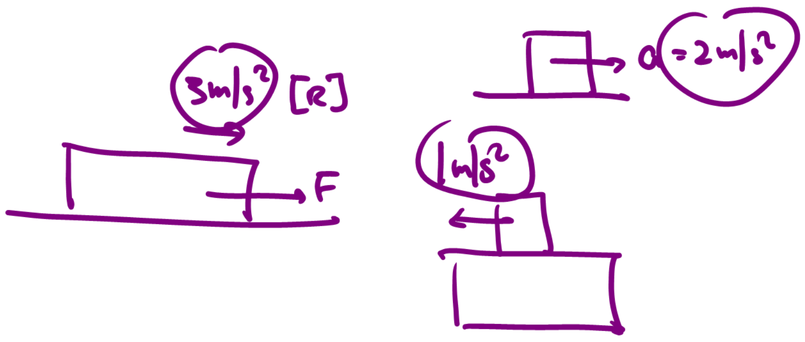
max acceleration at max $F_s = \mu N = \mu mg$

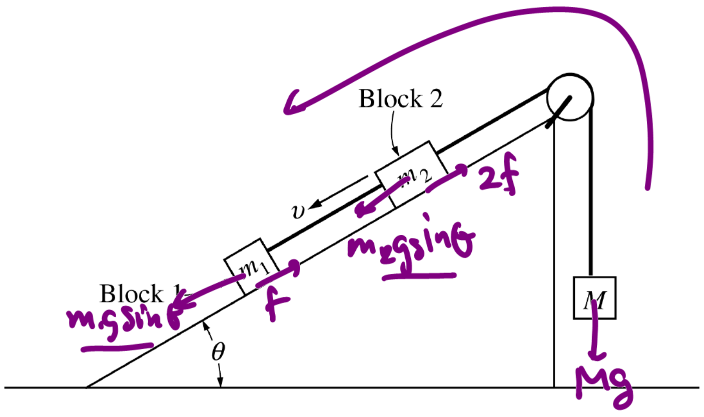
$\mu mg = ma$ $\quad a = \mu g$

$F = m_T a = (2+4)(\mu g) = (6)(0.2)(10) = 12\text{ N}$

19. What is the acceleration of the 2 kg block relative to the 4 kg block if a force is applied to the 4 kg block that causes the 4 kg block to accelerate at 3 m/s^2 to the right?

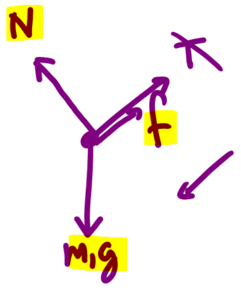
(A) 1 m/s^2 to the right
(B) 1 m/s^2 to the left
(C) 2 m/s^2 to the right
(D) 2 m/s^2 to the left
(E) zero

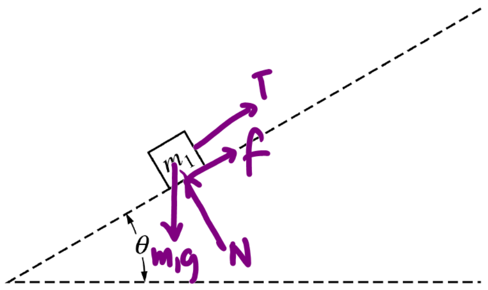




20. Blocks 1 and 2 of masses m_1 and m_2, respectively, are connected by a light string, as shown above. These blocks are further connected to a block of mass M by another light string that passes over a pulley of negligible mass and friction. Blocks 1 and 2 move with a constant velocity v down the inclined plane, which makes and angle θ with the horizontal. The kinetic friction force on block 1 is f and that on block 2 is $2f$.

(a) On the figure below, draw and label all the forces on block m_1.





Express your answers to each of the following in terms of m_1, m_2, g, θ and f.

(b) Determine the coefficient of kinetic friction between the incline plane and block 1.

(c) Determine the value of the suspended mass M that allows blocks 1 and 2 to move with constant velocity down the plane.

(d) The string between blocks 1 and 2 is now cut. Determine the acceleration of block 1 while it is on the inclined plane.

(b) $\mu = \frac{f}{N} = \boxed{\frac{f}{m_1 g \cos\theta}}$

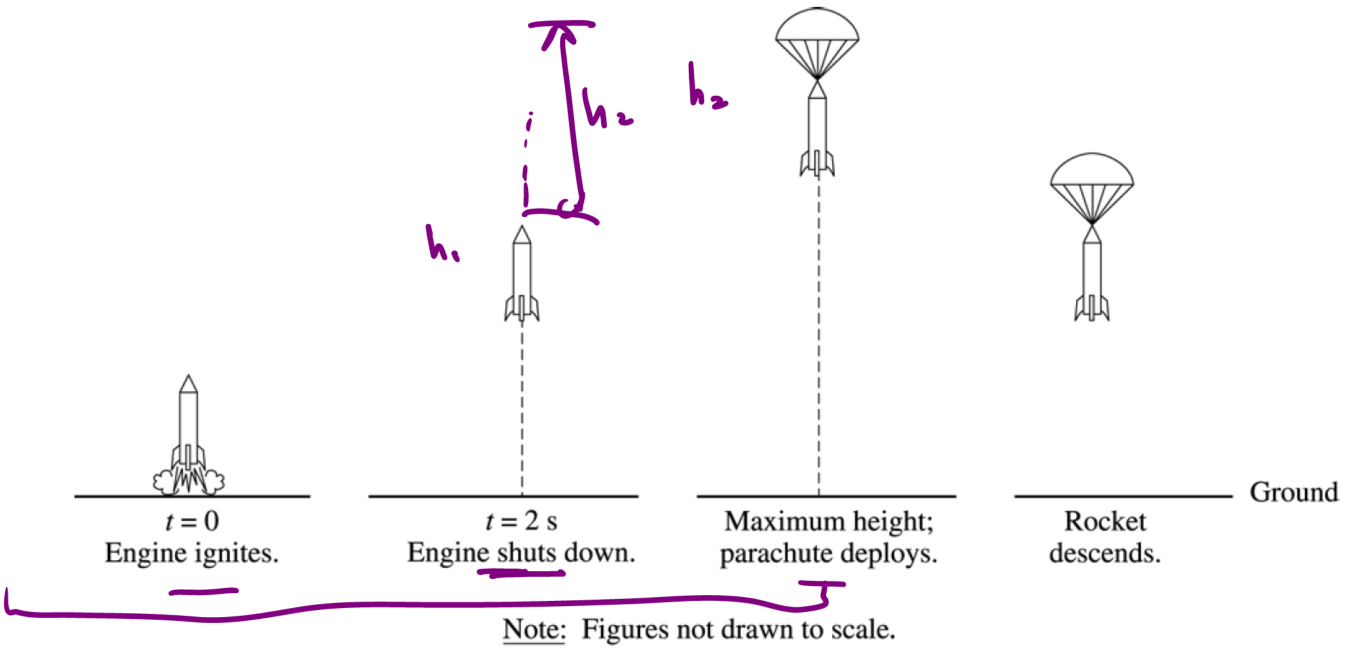
b) $m_1 g \sin\theta + m_2 g \sin\theta = 3f + Mg$

$Mg = (m_1 + m_2) g \sin\theta - 3f$

$\boxed{M = (m_1 + m_2)\sin\theta - \frac{3f}{g}}$

c) $m_1 g \sin\theta - f = m_1 a$

$\boxed{a = g\sin\theta - \frac{f}{m_1}}$

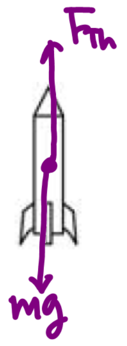


Note: Figures not drawn to scale.

21. A model rocket of mass 0.250 kg is launched vertically with an engine that is ignited at time $t = 0$, as shown above. The engine provides an impulse of 20.0 N · s by firing for 2.0 s. Upon reaching its maximum height, the rocket deploys a parachute, and then descends vertically to the ground.

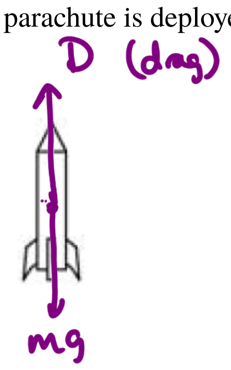
(a) On the figures below, draw and label a free-body diagram for the rocket during each of the following intervals.

i. While the engine is firing



ii. After the engine stops, but before the parachute is deployed

iii. After the parachute is deployed



(b) Determine the magnitude of the average acceleration of the rocket during the 2.0 s firing of the engine.

(c) What is the maximum height the rocket will reach?

(d) At what time after $t = 0$ will the maximum height be reached?

b) $J = F_{th}\Delta t$ $\quad F_{Th} = \frac{J}{\Delta t} = \frac{20.0\,N}{2.0\,s} = 10\,N$ $\quad F_{net} = 7.5\,N = ma$

$W = mg = (0.250)(10) = 2.5\,N$ $\quad a = \frac{F_{net}}{m} = \frac{7.5}{0.25} = \boxed{30\,m/s^2}$

c) $t = 0 \rightarrow 2$ $\quad h_1 = \frac{1}{2}at^2 = \frac{1}{2}(30)(2)^2 = 60\,m$

$t = 2 \rightarrow$ max height $\quad$ at $t = 2$ $\quad v = at = (30)(2) = 60\,m/s$

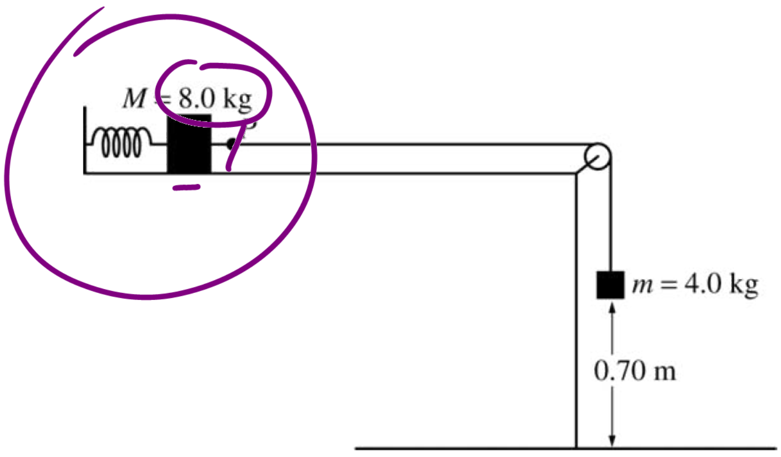
(+) ↑ $v_0 = 60$, $v_f = 0$, $a = -10$ $\quad \cancel{v_f^2} = v_0^2 + 2ah_2$ $\quad h_2 = \frac{-v_0^2}{2a} = \frac{-60^2}{(2)(10)} = 180\,m$

$h = h_1 + h_2 = 60 + 180\,m$ $\quad \boxed{h = 240\,m}$

$0 \rightarrow 60$ $\quad t_1 = 2$

$v_0 = 60$, $v_f = 0$, $a = -10$ $\quad v = v_0 + at$ $\quad t = 6\,s$

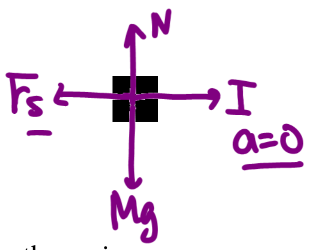
$t = t_1 + t_2 = \boxed{8.0\,s}$



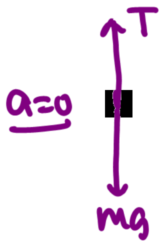
22. An ideal spring of unstretched length 0.20 m is placed horizontally on a frictionless table as shown above. One end of the spring is fixed and the other end is attached to a block of mass $M = 8.0$ kg. The 8.0 kg block is also attached to a massless string that passes over a frictionless pulley. A block of mass $m = 4.0$ kg hangs from the other end of the string. When this spring-and-block system is in equilibrium, the length of the spring is 0.25 m and the 4.0 kg block is 0.70 m above the floor.

   (a) On the figures below, draw free-body diagrams showing and labelling the forces on each block when the system is in equilibrium.

$M = 8.0$ kg



$m = 4.0$ kg



b) $T = mg$
$= (4.0)(10)$
$T = 40\,\text{N}$

   (b) Calculate the tension in the spring.

   (c) Calculate the force constant of the spring.

$T = F_s = kx$

$$k = \frac{T}{x} = \frac{40}{0.25-0.20} = \frac{40}{0.05} = \boxed{800\,\frac{\text{N}}{\text{m}}}$$

The string is now cut at point P.

   (d) Calculate the time taken by the 4.0 kg block to hit the floor

   (e) Calculate the frequency of the oscillation of the 8.0 kg block.

   (f) Calculate the maximum speed attained by the 8.0 kg block.

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$
$$= \frac{1}{2\pi}\sqrt{\frac{800}{8.0}} = \boxed{1.59\,\text{s}}$$

$d = .7\,\text{m}$
$a = 10\,\text{m/s}^2$
$v_0 = 0$

$$d = \cancel{v_0 t} + \frac{1}{2}at^2$$

$$t = \sqrt{\frac{2d}{a}} = \sqrt{\frac{(2)(0.70)}{10}} = \boxed{0.37\,\text{s}}$$

f) after string is cut at P.
new equilibrium position
is the unstretched position
$A = 0.050\,\text{m}$

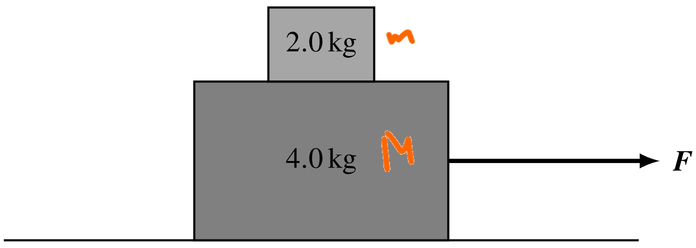
$$E = \underbrace{\frac{1}{2}kA^2}_{\text{at amplitude}} = \underbrace{\frac{1}{2}mv^2}_{\text{at equilibrium}}$$

$$v^2 = \frac{k}{m}A^2$$

$$v = \sqrt{\frac{k}{m}}A = (10)(0.05)$$

$$\boxed{v = 0.50\,\text{m/s}}$$

23. A 2.0 kg block sits on a 4.0 kg block that is resting on a frictionless table, as shown below. The coefficient of friction between the blocks are $\mu_s = 0.30$ and $\mu_k = 0.20$.



(a) What is the maximum force $\boldsymbol{F}$ that can be applied if the 2.0 kg block is not to slide on the 4.0 kg block.

(b) If $\boldsymbol{F}$ is half this value, find the acceleration of each block and the force of friction acting on each block.

(c) If $\boldsymbol{F}$ is twice the value found in (a), find the acceleration of each block.

(a) N, F_s, mg

$N = mg$

$F_s = ma$ max $F_s \rightarrow$ max a

$\mu N = ma$

$\mu \cancel{m} g = \cancel{m} a$

$a = \mu g = (0.30)(10)$

$a = 3.0\,m/s^2$

$F = (M+m)a$

$= (4+2)(3) = \boxed{18N}$

b) if $F < 18N \rightarrow$ no sliding

$F_N = mg$

$a = \frac{F}{M+m} = \frac{9}{6} = \boxed{1.5\,m/s^2}$

c) m: N, F_k, mg

$F_k = ma$

$\mu_k mg = ma$

$a = \mu_k g = (0.20)(10) = \boxed{2.0\,m/s^2}$

2kg block

$F_k = \mu mg$

$= (0.2)(2)(10)$

$= 4N$

$N = (M+m)g$

F_k, $F = 36N$, mg, Mg

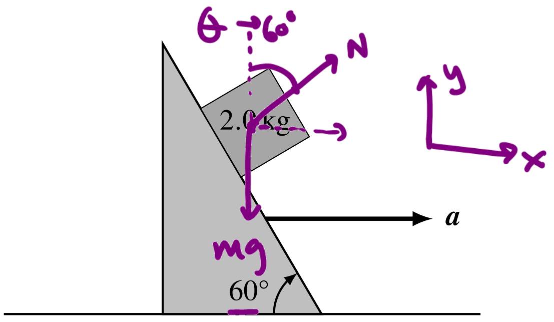
$F - F_k = Ma$

$36 - 4 = 4a$

$32 = 4a$

$\boxed{a = 8\,m/s^2} \leftarrow$ for 4.0 kg block.

24. A 2.0 kg body rests on a smooth wedge that has an inclination of 60° and an acceleration $\boldsymbol{a}$ to the right such that the mass remains stationary relative to the wedge.



(a) Find acceleration $\boldsymbol{a}$.

(b) What would happen if the wedge were given a greater acceleration?

(a) $\Sigma F_y = 0$ no vertical motion

$N\cos\theta - mg = 0$

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

$N\sin\theta = ma$

$\frac{\cancel{m}g}{\cos\theta}\sin\theta = \cancel{m}a$

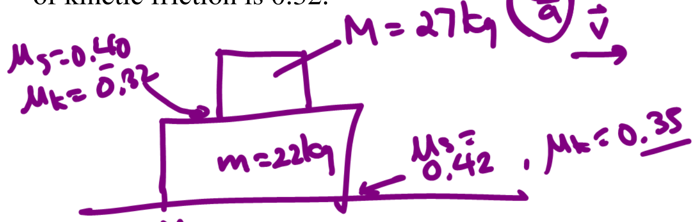
$a = g\tan\theta = \boxed{17.3\,m/s^2}$

(b) higher acceleration → higher normal force

→ net force along vertical direction.

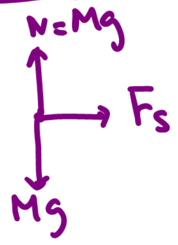
*→ block will accelerate upwards along the ramp.

25. A pick-up truck with two stacked crates in the truck bed brakes quickly. The crate on the bottom just barely stays put on the bed of the truck. Does the top crate stay put or does it fall off? The top crate has a mass of 27 kg and the mass of the bottom crate is 22 kg. The coefficient of static friction between the bottom crate and the truck is 0.42, and the coefficient of kinetic friction for that surface is 0.35. The coefficient of static friction between the crate is 0.40, and the coefficient of kinetic friction is 0.32.



- max. acceleration without the top crate sliding on the bottom crate

M:



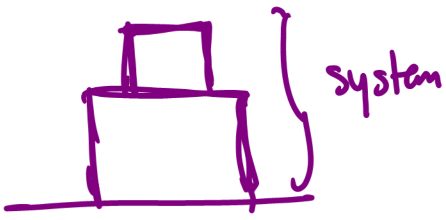
$F_s = Ma$

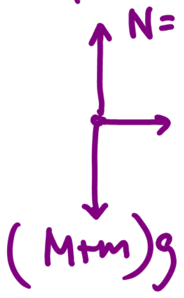
max $F_s = M(\max a)$

$\mu_s \cancel{M} g = \cancel{M} a$

$a = \mu_s g = (0.40)(10) = \underline{4.0 m/s^2}$

- max acceleration of bottom crate with sliding on the truck. (assuming that the top blocks don't slide)





max $F_s = (M+m)a$

$a = \mu g = (0.35)(10) = \underline{3.5 m/s^2}$

- assumption is ok. → $\boxed{\text{top crate stays put}}$