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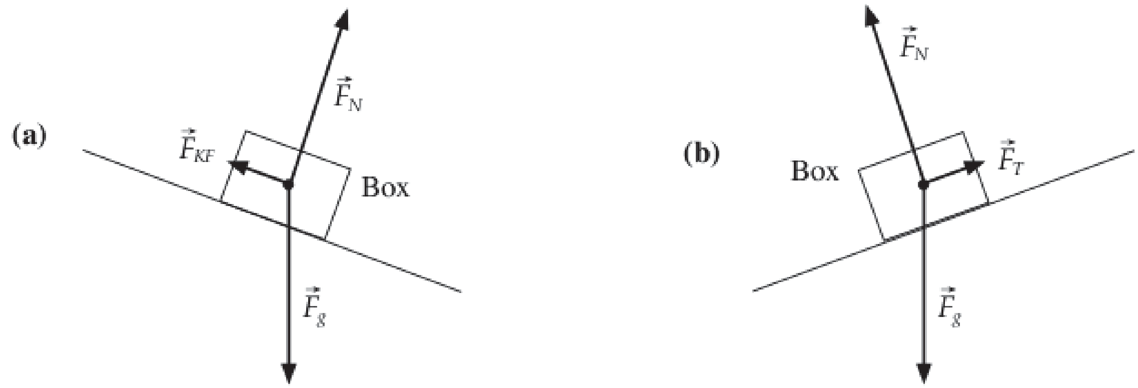
N2B.2



(In both cases, the vectors should be drawn so that they add up to zero.)

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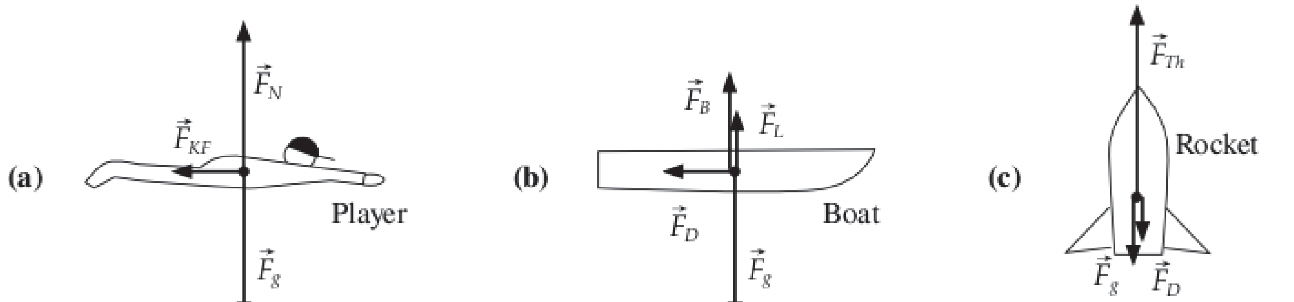
N2B.3



(Vertical forces should cancel.) (Vertical forces should cancel.) (Vectors should add up to something upward)

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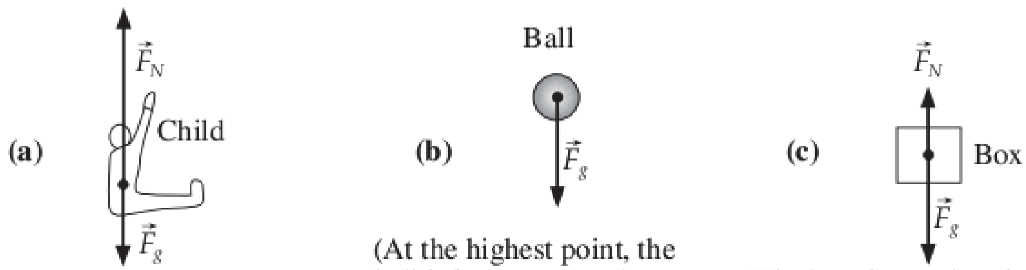
N2B.4



(a) (Because child is accelerating upward, $|\vec{F}_N| > |\vec{F}_g|$)

(b) (At the highest point, the ball is instantaneously at rest, so $\vec{F}_D = 0$)

(c) (The box is accelerating downward, so $|\vec{F}_g| > |\vec{F}_N|$)

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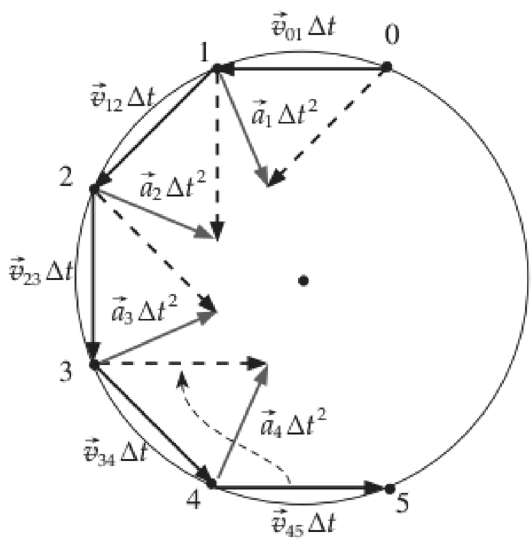
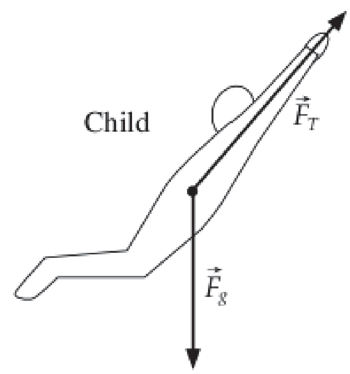
N2B.5 A motion diagram and a free body diagram appear below.

Motion Diagram (Top View)



Free-Body Diagram (Side View)



The child hanging on for dear life undergoes uniform circular motion (assuming a constant speed) around the merry-go-round's center, so the child's acceleration will be toward the center of the merry-go-round, as the motion diagram shows. The child interacts gravitationally with the earth, but does not touch anything but the air (which we will ignore) and the merry-go-round. So there is no *normal* force arising from a contact interaction. What must be keeping the child off the ground is the *tension* force that merry-go-round exerts on the child (to resist their separation). This force must have an upward component to cancel the gravitational force as well as a horizontal component toward the center of the merry-go-round to cause the child's observed acceleration in that direction.

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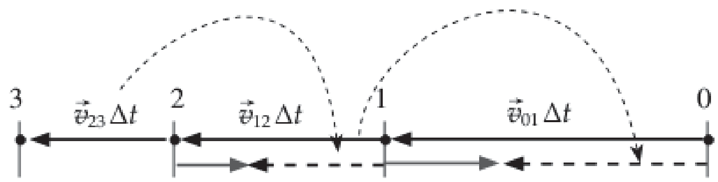
N2B.9 If we construct acceleration arrows (see the drawing below) using the method described in figure N2.3, we see that the acceleration arrows all point to the right.



Alternatively, if we define the direction of motion to be the $-x$ direction, then since the object is slowing down as it moves in the $-x$ direction, the object's initial x-velocity v_{ix} is a larger negative number than its final x-velocity v_{fx} (that is $|v_{ix}| > |v_{fx}|$) during any given time interval. Therefore $a_x \approx (v_{fx} - v_{ix}) / \Delta t = \left(-|v_{fx}| + |v_{ix}|\right) / \Delta t$ is positive, implying that the acceleration is in the $+x$ direction, which is to the right.

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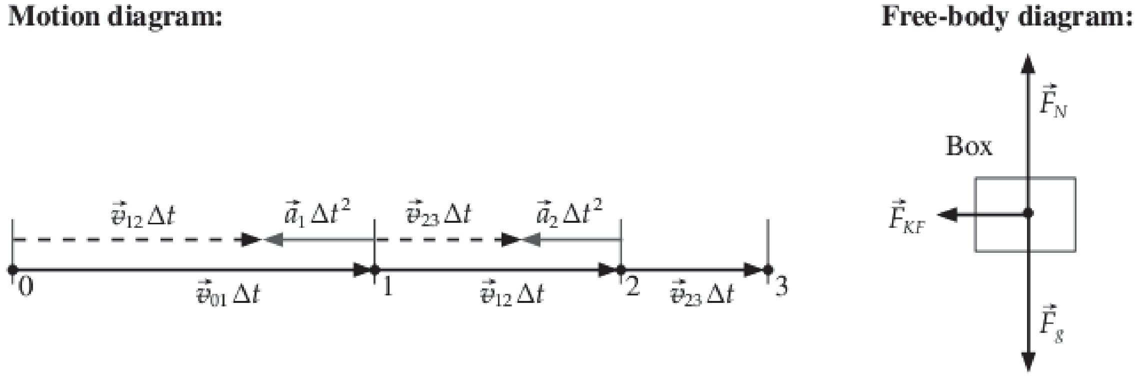
N2M.2 **(a)** Assume that the van is moving to the right. A motion diagram and free-body diagram for the box look like this:



If box slides forward relative to the van, it will experience a rearward kinetic friction force that opposes the relative motion of the box and van. This means, as the motion diagram illustrates, that although the box is moving to the right, it is accelerating to the left, that is, slowing down as it moves to the right.

(b) The box would move at a constant velocity if it could (by Newton's first law) while the van slows down. But the sliding of the box on the van floor creates a kinetic friction force that opposes the forward motion of the box relative to the van. So even though the box *is* slowing down, the kinetic friction force is apparently not strong enough to make the box slow down quite as quickly as the van does, so it moves forward relative to the van. The net force on the box is toward the back of the van and is what causes it to slow down with respect to the ground. We know that the normal force arising from the contact interaction with the floor of the van and the force arising from the box's gravitational interaction with the earth cancel each other out because the box does not accelerate vertically.

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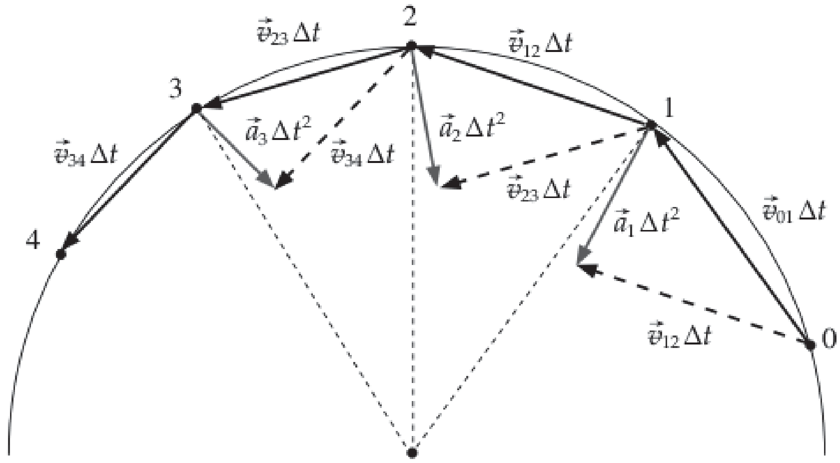
N2M.3 **(a)** The motion diagram for the car near the peak looks as follows:

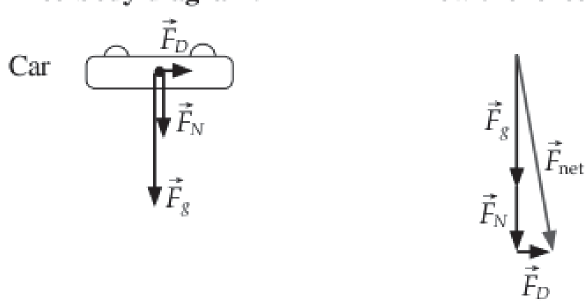
Motion diagram:



Note that the velocity vectors get smaller as the car progresses because we are not ignoring air friction. We can see quite clearly from the diagram that at the very peak (point 2 above), the roller-coaster car is accelerating *downward and a bit rearward*, mostly toward the center of its (temporarily) circular motion, but also a bit backward.

(b) The free-body diagram for the car appears below.

Free-body diagram: **How the forces add:**

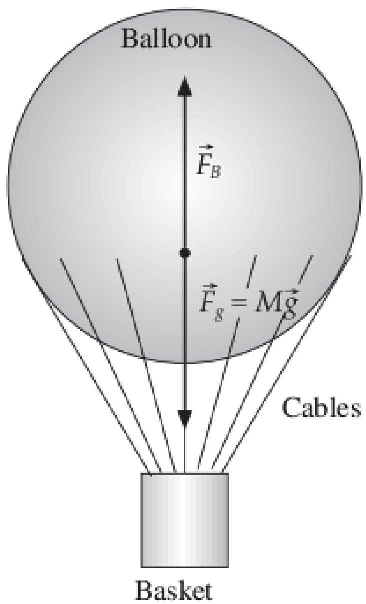


Since the normal force arising from the contact interaction between the car's wheels and the rails always acts to *oppose* the interacting objects from getting any closer, the normal force will be *downward* here as long as the car is in contact with the rails. As shown in the diagram to the right above, the normal, drag, and gravitational forces act together to provide a downward force component that keeps the roller-coaster car following its circular path around the loop. The drag force also causes the net force to lean slightly backward, as the motion diagram requires. Everything is consistent!

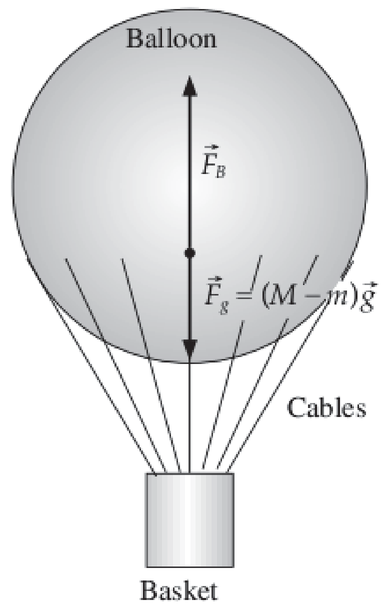
(c) There is no outward force here, because neither the air nor the track (the only thing the car touches) can exert an outward force. Moreover, no outward force is needed: as the motion diagram shows, the car needs an *inward* (and slightly backward) force to follow the path we observe it to follow.

N2M.7 The drawings below show the situation before and after the ballast is thrown out. In the free-body diagrams, I cam considering the balloon, basket, and cables to be a single object.

Free-body diagram (Before):



Free-body diagram (After):



(a) If the balloon is initially floating "at rest," then its acceleration is zero, and the forces on it must cancel out. The important forces acting on the balloon are an upward buoyant force and a downward gravitational force. Before the ballast is thrown out, the gravitational force has a magnitude of $M|\vec{g}|$ (where M is the balloon's original mass and $|\vec{g}|$ is the gravitational field strength near the earth's surface), so the buoyancy force must have this magnitude also. After we throw ballast of mass m out, the gravitational force has a magnitude of only $(M-m)|\vec{g}|$. The buoyance force, however, does not change (it depends only on the size of the balloon), so its magnitude is still $M|\vec{g}|$, and (as the second net force diagram shows) the balloon experiences a upward net force:

$$\vec{F}_{\text{net}} = M|\vec{g}|\,\text{upward} + (M-m)|\vec{g}|\ \text{downward} = [M-(M-m)]|\vec{g}|\,\text{upward} = m|\vec{g}|\,\text{upward} \qquad (1)$$

This is linked to the balloon's acceleration by Newton's second law. Since the problem statement "gives" us M and $|\vec{a}|$, and we know $|\vec{g}|$, we can solve for the mass. The mass of the balloon after the ballast is thrown out is $M - m$, so the magnitude of Newton's second law here implies that

$$m|\vec{g}| = |\vec{F}_{\text{net}}| = (M-m)|\vec{a}| \ \Rightarrow\ \frac{|\vec{g}|}{|\vec{a}|} = \frac{M-m}{m} = \frac{M}{m} - 1 \ \Rightarrow\ \frac{|\vec{g}|}{|\vec{a}|} + 1 = \frac{M}{m} \ \Rightarrow\ m = \frac{M}{(|\vec{g}|/|\vec{a}|+1)} \qquad (2)$$

The sign is positive, which is appropriate. Note that $|\vec{g}|/|\vec{a}|$ is unitless, so adding this to 1 makes sense and m clearly has the same units as M. Finally, note that if $|\vec{a}| \to 0$ then $m \to 0$, which makes sense, and very large $|\vec{a}|$ corresponds to throwing nearly the entire mass overboard, which also makes sense. So everything looks good!

(b) Once the balloon picks up a significant upward velocity, there will be an increasingly large downward force of drag. Moreover, as the balloon reaches higher altitudes, the air becomes thinner, and will exert a smaller upward buoyant force. Both will serve to reduce the net upward force on the balloon. Eventually, the balloon will come to rest at a new higher altitude where the buoyant force is equal in magnitude to the lower balloon mass.