

In your work in Tutorial, please remember to

- 1) Draw pictures and/or diagrams of the situation before beginning a solution
- 2) Write down the known quantities and the desired unknown(s)
- 3) Start your solution by writing down a fundamental relation or equation that you think is relevant.

Equations and Relations:

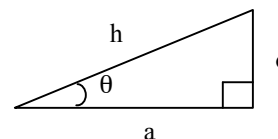
- Average Speed = distance traveled / time elapsed
- Instantaneous Velocity = slope of tangent to x-t curve
- Instantaneous Acceleration = slope of tangent to v-t curve

Trigonometry:

$$\sin \theta = o/h$$

$$\cos \theta = a/h$$

$$\tan \theta = o/a$$



$$a^2 + o^2 = h^2$$

Average Velocity: $\bar{v} = \Delta x / \Delta t = (x_2 - x_1) / \Delta t$

Average Acceleration: $\bar{a} = \Delta v / \Delta t = (v_2 - v_1) / \Delta t$

Newton's Laws:

Motion with Constant Acceleration:

$$v = v_0 + at$$

$$x = x_0 + v_0t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2a(x - x_0)$$

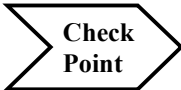
$$\bar{v} = (v + v_0) / 2$$

$$g = 9.80m / s^2 \approx 10m / s^2$$

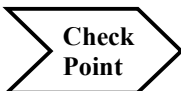
- 1st: An object will stay at rest or in motion with constant velocity unless acted on by a net force.
- 2nd: $\Sigma F_x = ma_x$, $\Sigma F_y = ma_y$
- 3rd: Forces come in pairs. If A exerts a force on B, then B exerts a force on A with the same magnitude but in the opposite direction.

Weight: $F_g = mg$

1. On a horizontal road, a Lamborghini Diablo can accelerate from 0-60 mph with an average acceleration of about 6.8 m/s².
 - (a) Assuming the mass of the car to be 1000 kg, what is the average net force on it as it accelerates, and how does this compare to the car's weight?
 - (b) Approximately how many *pounds* of force is this? (Recall that 1 N \approx ¼ lb.)
 - (c) Think carefully before answering the following: describe and name the force that causes the car to accelerate forward. How does this force know to push the car forward?

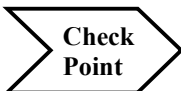


- (d) Draw a sketch of the car and use an arrow to represent each force acting on it as it accelerates. Neglect air resistance, and don't include forces exerted *by the car* on other things. [A sketch like this is called a free-body diagram (FBD).]
- (e) Determine the magnitude (size) of each force on your sketch by applying Newton's 2nd Law to your FBD. Give your answers in Newtons.



2. Make free-body diagrams showing the forces on the Lamborghini in the following situations:

- (a) The car is on a horizontal road, slowing down in order to stop at a red light.
- (b) The car is going down an uncurved hill at constant speed.
- (c) The car is parked on a steep hill in San Francisco, facing uphill.
- (d) Johnny has accidentally driven the car over the side of a bridge. Make your diagram for the time during which the car is falling through the air.



3. A heavy lifting crane is being used to stack cargo containers on the deck of a ship. The heaviest container weighs 10 tons (= 20,000 pounds = 89,000 Newtons). How much force should the crane's cable be able to support if it lifts this container with an upward acceleration of 1 m/s^2 ? (Hint: make a FBD of the container.)

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4. A ball bounces on the ground.
- (a) What force is responsible for the ball's upward motion?
- (b) Make a FBD for the ball as it bounces (while it is in contact with the ground). Is the normal force on the ball greater than, less than or equal to the ball's weight? Prove your answer using Newton's 2nd Law.

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5. A dog musher asks his dogs to pull the sled. The dogs refuse, referring to Newton's 3rd Law in their defense. They feel that since the sled will pull on them with the same force that they exert on it, they won't be able to go anywhere. "If we can never exert a forward force on the sled which is greater than the backward force it exerts on us, how can we ever get the sled moving?", asks the lead dog. Discuss the validity of this defense with your group, and construct a counterargument using Newton's Laws.

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Additional Questions

- 1) If an object is sitting motionlessly on your dining room table, what is the *minimum* number of forces that can be acting on that object? What is the *maximum* number?
- 2) You see a \$20 bill on the ground, and run forward to get it. What force accelerated you forward, and why?
- 3) Describe a universe in which the two members of each action/reaction pair of forces always act on the same object.