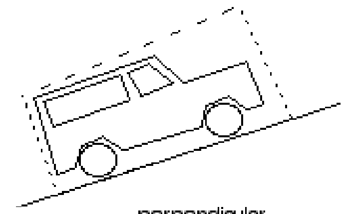
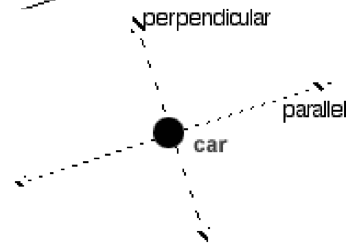
# Free Particle Model Reading 2: Forces and Force Diagrams

Let us now look at a more complicated example: A car parked on a hill.

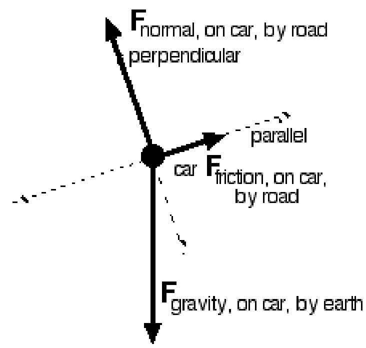


**Step 1.** Sketch the system and its surroundings.

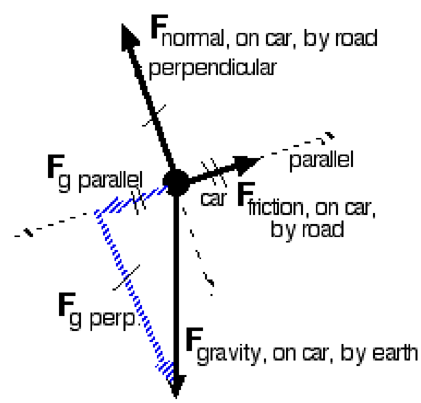
**Step 2.** Enclose the system within a system boundary.




**Step 3.** Shrink the system to a point at the center of coordinate axes with one axis parallel to the direction of motion. Although the car isn't moving, if it did, it would slide down the hill. Therefore, the coordinate axes have been aligned parallel and perpendicular to the hill. Although it may seem strange, rotating the coordinate axis will make the rest of the analysis easier.



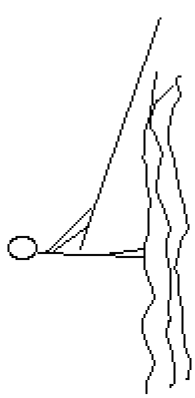

**Step 4.** Represent all relevant forces (across the system boundary) with a labeled vector. Gravity always points toward the center of the earth (down). The normal force is perpendicular to the road/tire surface and the friction force is parallel to the road/tire surface. Friction exerts a force up the hill to resist the tendency of the car to slide down the hill due to gravity.




**Step 5.** Indicate which forces (if any) are equal in magnitude to other forces. Here's where the parallel/perpendicular coordinate axis helps. Since the car is motionless, the forces must be balanced along each coordinate axis. Gravity isn't along either coordinate axis, but we can represent gravity with two **component vectors**. $F_g$ parallel is how much of the gravitational force tends to pull the car along the slope and $F_g$ perpendicular is how much of the gravitational force tends to pull the car to the road. For the forces to be balanced, $F_g$ parallel must be equal in size to $F_{friction}$ and $F_g$ perpendicular must be equal in size to Fnormal, as indicated by the hash marks. Note that no hash marks are placed on $F_g$ since we have replaced it with its equivalent component vectors.

Here's a very different looking situation, but the analysis is very similar. In fact, turning the previous force diagram 180 degrees results in the force diagram shown. Realizing that all force diagrams have many similarities can be a relief. You don't need to memorize a bunch of different approaches to be able to draw a wide variety of force diagrams.

***A rock climber on a cliff standing still:***



In each of the following situations, represent the object with a particle. Sketch all the forces acting upon the object, making the length of each vector represent the magnitude of the force. Also use congruency marks to indicate which vectors are equal in magnitude.

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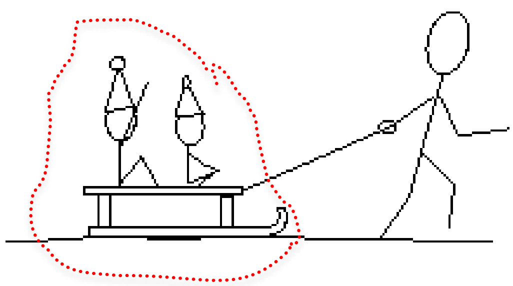
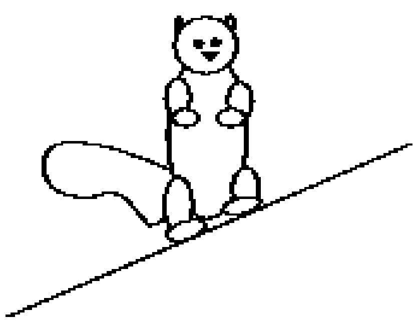
1. Draw a force diagram for the sled and kids moving at constant velocity. Note that the pull on the sled is at an angle. Label the force vectors and use equality marks on the vectors.



2. Draw a force diagram for a squirrel sitting still on a roof. Label the force vectors and use equality marks on the vectors.



3. Draw a force diagram for the skier who slides (accelerates) with negligible friction. (That means you can ignore the friction force.) Label the force vectors and use equality marks on the vectors.