Free Body Diagram Checklist

Here is a checklist for creating a good Free Body Diagram (FBD). When grading your exams and other coursework, we will use a rubric derived from this checklist to evaluate your work. In describing the elements of a good FBD, we shall refer to the figure below.

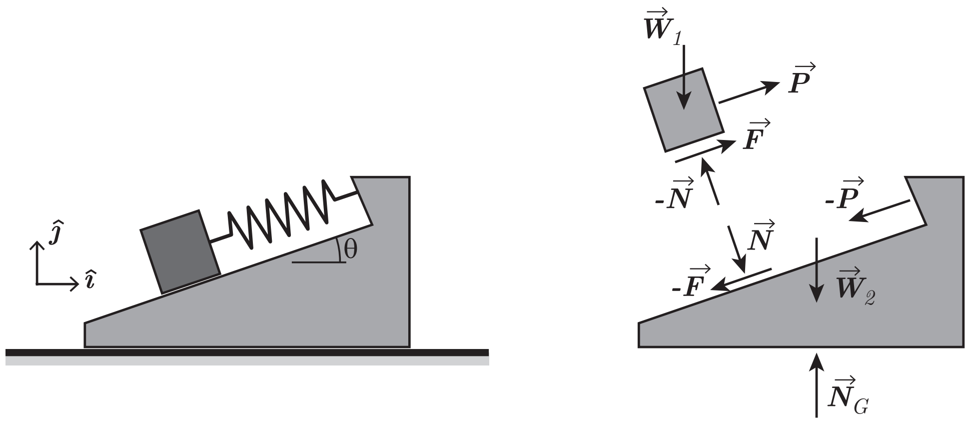

Figure 1: Two interacting blocks and free body diagrams for each of the blocks.

The drawing on the left shows a rectangular block on top of a sloped surface of a wedge-shaped block. Both blocks are connected by a spring. Assume that there is no friction between the wedge-shaped block and the floor. But there is friction between the two blocks. On the right of the figure are two free body diagrams, one for each body.

1. An FBD should contain vectors depicted as arrows representing all relevant *external* forces and curved arrows representing all relevant *external* moments acting on a body.

2. When possible, arrows representing force vectors should be placed where the actual forces are applied. For example, in the figure above, it is easy to see that:

   - $\vec{W}_1$ and $\vec{W}_2$ are the weights of the two bodies.
   - $\vec{P}$ and $-\vec{P}$ are forces from the spring acting on the two blocks.
   - $\vec{F}$ and $-\vec{F}$ are friction forces acting between the two blocks.
   - $\vec{N}$ and $-\vec{N}$ are normal forces acting between the two blocks.
   - $\vec{N}_G$ is the normal force from the ground acting on the bottom body.

   Note that the two bodies in the diagram above are separated. Therefore, the forces between the bodies are considered external.

   Placing forces in the proper location is particularly important for problems in which you have to consider moments.

3. Internal forces and moments should *not* be on an FBD. If we had considered the two blocks as one body, then the spring forces $\vec{\boldsymbol{P}}$ and $-\vec{\boldsymbol{P}}$, friction forces $\vec{\boldsymbol{F}}$ and $-\vec{\boldsymbol{F}}$, and normal forces $\vec{\boldsymbol{N}}$ and $-\vec{\boldsymbol{N}}$, would be considered *internal* (forces within the body) and would not appear the the FBD.

4. Note that only forces acting directly on the body appear on the FBD for that body. For example, in the FBD of the wedge-shaped block, the weight $\vec{\boldsymbol{W}}_1$ is *not* included. This is because the gravitational pull of the Earth only directly acts on the top rectangular block. However, the lower block "feels" the upper block through the normal force $\vec{\boldsymbol{N}}$ due to contact between the bodies. Likewise, the FBD for the bottom block is the only one that receives the normal force from the ground $\vec{\boldsymbol{N}}_G$, since it is the only block in direct contact with the ground.

5. Other dynamic quantities such as velocities and accelerations should *not* be on an FBD.

6. Often times, you will decompose a vector into components. For example, you might want to write the spring force in Figure 1 as $\vec{\boldsymbol{P}} = P\cos(\theta)\,\hat{\boldsymbol{\imath}} + P\sin(\theta)\,\hat{\boldsymbol{\jmath}}$. On the free body diagram, you may draw the force vector as two vectors, representing the two components, or one single resultant vector as depicted in Figure 2 below. Do not draw both sets of arrows for the single spring force.

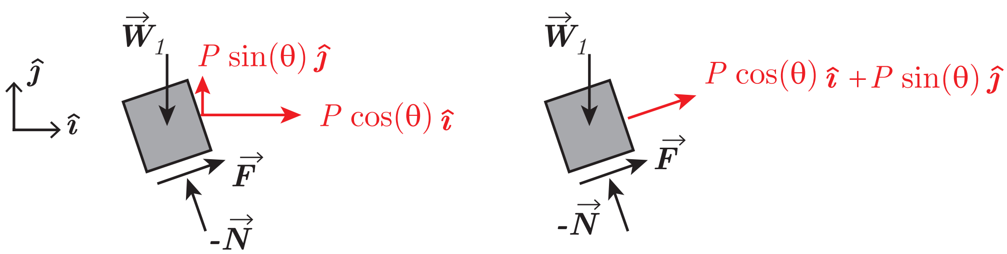

Figure 2: Valid free body diagrams splitting a force into components.

7. All vectors on an FBD must be labeled and must be labeled as vectors. The following are examples of *acceptable* labels for force vectors: $\underset{\sim}{F}$, $\vec{F}$, $F_x\,\hat{\boldsymbol{\imath}} + F_y\,\hat{\boldsymbol{\jmath}}$, and $F\cos(\theta)\,\hat{\boldsymbol{e}}_1 + F\sin(\theta)\,\hat{\boldsymbol{e}}_2$.

   The following example labels are *not acceptable*: F (scalar), $\vec{F}\,\hat{\boldsymbol{\imath}}$ (improper product of two vectors).

8. Any two *different* vectors should have *different* labels. For example, in Figure 1, there are two different normal forces. There is a normal force between the two blocks. And there is a normal force between the wedge-shaped block and the ground. Although both are normal forces, it is important to give them different names. In the diagram, you see that one is called $\vec{\boldsymbol{N}}$ while the other is called $\vec{\boldsymbol{N}}_G$.

   The distinction is important because the FBD is used to derive equations of motion. If the same symbol is used for the two different forces in the equations of motion, the equations will likely be incorrect and produce erroneous solutions.

9. Newton's Third Laws states that reaction forces between bodies come in equal (in magnitude) and opposite (indirection) pairs. Labeling these forces must reflect that fact. We see several examples of this in Figure 1

   - Friction forces $\vec{\boldsymbol{F}}$ and $-\vec{\boldsymbol{F}}$,
   - Normal forces $\vec{\boldsymbol{N}}$ and $-\vec{\boldsymbol{N}}$,
   - Spring forces $\vec{\boldsymbol{P}}$ and $-\vec{\boldsymbol{P}}$.

   And if you decompose the equal and opposite forces into horizontal and vertical components, the pairs would look like:

   - Friction forces $F\cos(\theta)\,\hat{\boldsymbol{\imath}} + F\sin(\theta)\,\hat{\boldsymbol{\jmath}}$ and $-F\cos(\theta)\,\hat{\boldsymbol{\imath}} - F\sin(\theta)\,\hat{\boldsymbol{\jmath}}$,
   - Friction forces $N\sin(\theta)\,\hat{\boldsymbol{\imath}} - N\cos(\theta)\,\hat{\boldsymbol{\jmath}}$ and $-N\sin(\theta)\,\hat{\boldsymbol{\imath}} + F\cos(\theta)\,\hat{\boldsymbol{\jmath}}$,
   - Friction forces $P\cos(\theta)\,\hat{\boldsymbol{\imath}} + P\sin(\theta)\,\hat{\boldsymbol{\jmath}}$ and $-P\cos(\theta)\,\hat{\boldsymbol{\imath}} - P\sin(\theta)\,\hat{\boldsymbol{\jmath}}$,

   Again, the objective here, is to properly encode Newton's Third Law into your equations of motion.

10. An FBD must be neat, sufficiently large, and easy to read.