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Good Strategies to Avoid Bad FBDs

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Good Strategies to Avoid Bad FBDs

Abstract

Drawing a good free-body diagram (FBD) is generally acknowledged by mechanics instructors as a critical step in solving mechanics problems. In this paper we will summarize recommended procedures and mnemonics that have been developed to help students draw good FBDs. In spite of the fact that every Statics book we examined presented a step-by-step procedure for drawing free-body diagrams, they all included what the authors consider to be poor practices that can lead to misconceptions and difficulties when students take Dynamics. We will discuss these pitfalls in Statics textbooks, show examples from popular Statics textbooks that illustrate them, and discuss how the consistent use of effective FBD drawing strategies can be used to avoid them. We surveyed experienced instructors who use free-body diagrams and asked them to rate, in their opinion, the importance of each element of a FBD we identified from the procedures presented in Statics books, and we also asked them to choose between two mnemonics for drawing FBDs: "The ABC's of FBD's" and "BREAD." We found that, in general, faculty members agreed on most of the elements, although there was no consensus on the importance of including dimensions on a FBD. Of the mnemonics, 57% of the respondents preferred "BREAD," 24% preferred "The ABC's of FBD's," and 19% had no preference.

Introduction

Free-body diagrams (FBDs) are a visual representation of the forces and moments acting on a body that is set aside for analysis. They are used in many courses such as Statics, Dynamics, Strength of Materials, and any other classes that use Newton's 2nd law. A search of the ASEE PEER Document Repository using the key words "free-body diagram" resulted in over 1000 results. These results include papers discussing software tools to help students draw FBDs, papers on the assessment of FBDs, and papers on techniques to help students draw FBDs.

Tools that have been developed to help students draw FBDs include an app [1], and animated GIFs to guide students in a step-by-step procedure for drawing FBDs [2]. Free-body diagram errors that have been reported include ones that demonstrate a misunderstanding of the physics such as forces drawn at the centroid [3], incorrect or missing friction forces [3, 4, 5], and incorrect direction of the weight [4, 5]. Other errors in drawing FBDs include missing arrows [6], missing axes [4], and misaligned or unlabeled vectors [7]. Davis and Lorimer [8] developed a rubric for assessing FBDs in six separate categories: overall quality, forces/moments, body, axes, dimensions, and resulting equations. They found that 67% of errors found in equilibrium equations were a result of errors found in the students' FBDs.

A Google search of "How to draw a free-body diagram" resulted in over 30,000 hits. These results included YouTube videos and step-by-step procedures, and the top results seemed to come from the physics community. In this paper, we will motivate the use of a consistent and complete approach to drawing FBDs by showing some examples from popular Statics textbooks that illustrate poor practices, we will summarize the approaches presented in textbooks and extract the important common features, and we will discuss how the consistent use of effective FBD drawing strategies can be used to avoid pitfalls. Finally, we will present several mnemonics that have been developed and results from surveying faculty members as to which mnemonic they prefer.

Summary of textbook approaches

Physics: A 4-step procedure was given on a physics website [9] as shown below:

1. Identify the object you will draw a diagram for.
2. Identify all the forces acting **directly** on the object and the object exerting them.
3. Draw a dot to represent the object of interest.
4. Draw a vector to represent each force.

The website includes some clarifying information for each step, but the key step that leads to confusion when students take Dynamics is step 3, which tells students to represent the body as a point. This is valid for particles, although we believe that this is a very bad practice since it is not valid for rigid bodies and leads to bad habits.

Statics: Most of the Statics books we examined [10−17] presented two procedures for drawing free-body diagrams; one for particles and one for rigid bodies. Rather than listing the procedures shown in each book (we do this for several books in Appendix A), we will summarize the common elements these books indicate should be in a correctly drawn FBD. We will focus on the procedure for rigid bodies since we believe the same procedure should be used for particles. A summary of the key elements of a free-body diagram is shown below:

1. Define the body, that is, what is being isolating for analysis. This is sometimes called the system, or the free-body.
2. Draw a diagram that represents the system's complete external boundary.
3. Represent all external forces and moments on the free-body diagram as vectors with arrows. These include body and surface forces as well as known and unknown forces. The forces should be drawn where they act.
4. Include appropriate dimensions.
5. Show the choice of coordinates.

Each of these elements was not included in every textbook we examined, but they were common to many of them. Some books recommend drawing a system boundary on the original figure to define the system, but most do not. In spite of the procedures provided in all the Statics books, every book we examined includes in some of their example problems bad practices that can lead to difficulties when students take Dynamics.

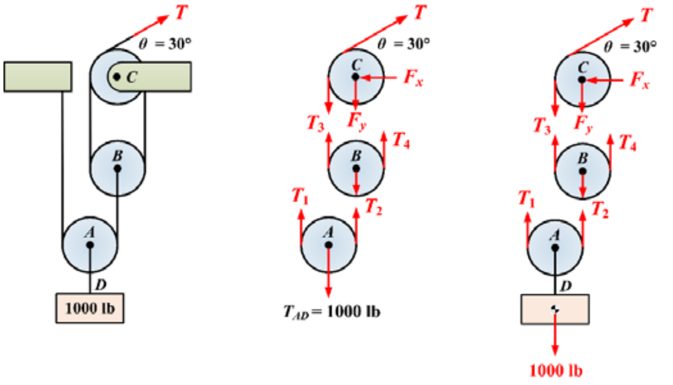
Poor free-body diagram drawing practices in Statics and Physics textbooks

Since free-body diagrams are the fundamental tools used in analyzing mechanical systems, special attention must be paid to introducing good practices for drawing them in Physics and Statics classes. Most students encounter FBDs for the first time in these classes and may develop poor habits that are not easily corrected in later courses such as Dynamics or Machine Design. It is therefore incumbent upon Physics and Statics instructors to emphasize good habits in drawing FBDs from the early stages of introducing the concept to students.

We have identified three common poor habits in drawing FBDs after reviewing eight Statics textbooks (Beer and Johnston [10], Hibbeler [11], Bedford and Fowler [12], Sheppard and Tongue [13], Meriam and Kraige [14], Constanzo and Plesha [15], Riley and Sturges [16], and Pytel and Kiusalaas [17]) and three introductory Physics texts (Giancoli [18], Young and Freedman [19], and Halliday and Resnick [20]). The common pitfalls associated with each case will be highlighted as well.

Poor practice #1: Tension in a rope or cable is equal to the weight, which is otherwise unaccounted for: One of the most common bad habits when drawing FBDs is to assume that the tension in a cable connected to a weight is equal to the weight. While this is correct from a statics perspective, it is not at all a correct assumption in a dynamic setting and should be discouraged at the introductory level. Examples of this poor habit were found in each of the Statics books. One example is shown below (Sample Problem 3/2 from Meriam and Kraige [14]).

> *Example*: Calculate the tension *T* in the cable which supports the 1000-lb load with the pulley arrangement shown in Figure 1(a). Each pulley is free to rotate about its bearing, and the weights of all parts are small compared with the load.



(a) (b) (c)

Figure 1. (a) Problem statement figure, (b) Meriam and Kraige's FBDs, (c) Better FBDs

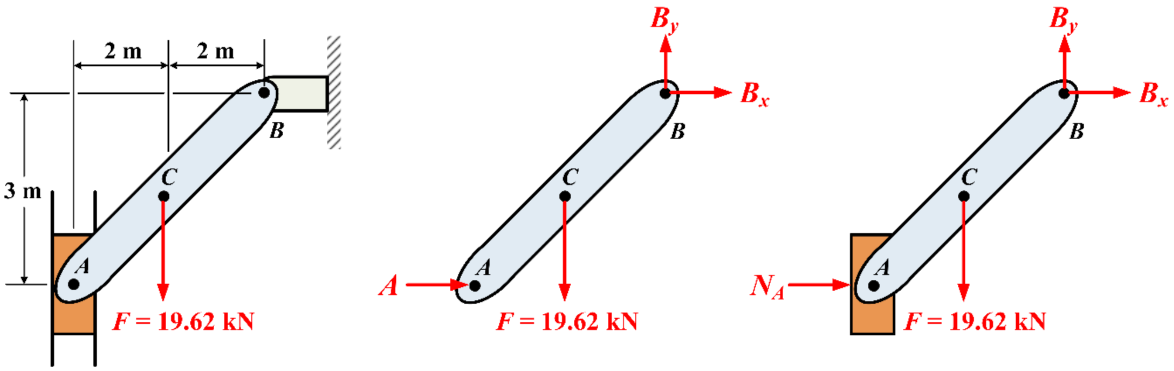
Meriam and Kraige's FBDs for this problem are shown in Figure 1(b). Note that the 1000-lb force is the tension in the cable *AD*. In Figure 1(c), which includes a better FBD, the pulley *A*, the cable and the load are all considered to be one subsystem, and the 1000-lb force acts at the center of gravity of the suspended mass. By analyzing each subsystem in 1(c), we find that the solution to this example is $T = 250$ lb.

Potential pitfall in Dynamics: The issues that arise with a FBD similar to the one in Figure 1(b) can perhaps be best demonstrated if we look at a different tension value than the one found in the static case. For example, if we pick $T = 500\text{ lb}$ and assume that the mass of the pulleys remains negligible, we find that $T_{AD} = 2000\text{ lb}$, which is obviously not the same as the 1000-lb weight, meaning the system accelerates, that is, $T_1 + T_2 - 1000\text{ lb} = ma$. This exercise hopefully demonstrates that the physical and logical consistency of the properly drawn FBD in 1(c) in both static and dynamic applications better serves students compared to the oversimplification of the FBD in 1(b) for a purely static analysis.

Prevalence in textbooks: Every one of the engineering mechanics textbooks that we reviewed includes at least one example of a FBD in which the tension in a rope is assumed to be equal to the weight rather than including the weight as part of the system. However, all three of the introductory-level Physics texts that were reviewed treated the weight properly.

Poor practice #2: Normal force reaction acting directly on a pin rather than on the original support: Another common poor habit in drawing FBDs that we have seen in different textbooks, both Statics and Dynamics books, has to do with oversimplifying reactions due to supports, particularly the normal force. In this practice, supports such as the collar on a frictionless rod, the slider in a frictionless slot, or rollers or rockers are ignored. For these problems, the reaction force is drawn directly on the pinned end without the support. The reaction experienced by the slider in Figure 2(a) for example, is due to the net normal force exerted directly by the wall on the slider, not on the pin that connects the slider and the bar. Similar to *Poor practice #1*, for a massless collar/slider/roller/rocker in a static setting, placing the reaction force directly at the pin would still yield the correct result, but if the collar/slider/roller/rocker has mass and is accelerating, this practice would result in an incorrect solution. An example of this poor habit is demonstrated for a setup supported by a frictionless slider in a slot in Figure 2 (modified version of Example 5.4 from Bedford and Fowler [12]).

> *Example*: Bar *AB* in Figure 2(a) supports a 2 Mg mass. The structure is attached to a slider in a vertical slot at *A* and has a pin support at *B*. What is the reaction at *A*?



(a) **(b)** **(c)**

Figure 2. (a) Problem statement figure, (b) Bedford and Fowler's FBD, (c) Better FBD

Bedford and Fowler's FBD for this problem is shown in Figure 2(b). Note that the reaction force due to the slider is drawn directly at the pin *A* without the slider. A better FBD is shown in Figure 2(c) where the slider is included as part of the system, and the reaction experienced by the slider is explicitly denoted as N_A to indicate that it is a normal force. The reaction force at *A* is found in this case to be $\vec{A} = \vec{N}_A = 13.1\text{ kN} \leftarrow$.

Potential pitfall in Dynamics: The problem with the FBD depicted in Figure 2(b) can be seen when there is motion with this setup. If we neglect gravity and assume that the slider has a mass and accelerates downwards (*A* could accelerate if the support at *B* is replaced by a linkage), the force in the pin will have a vertical and a horizontal component, whereas the force between the slider and the wall will still be horizontal. Therefore, in a dynamic setting, the assumption that the normal force acting on the slider is equal to the force acting on the pin is simply not correct.

Prevalence in textbooks: Unfortunately, every one of the Statics and Engineering Mechanics textbooks that we reviewed incorporated this poor FBD habit to some extent, particularly when dealing with problems involving rollers. The topic of reaction forces due to supports and rigid-body equilibrium in general is too advanced for an introductory-level Physics course, and so this scenario was not addressed at all in any of those texts.

Poor practice #3: Putting all forces at a point: Perhaps the most significant of the poor FBD habits that we have observed at the beginner level is the inclination to shrink the object of interest to a single point and draw *all* of the forces acting on the object through that point. While this is fine when dealing with particles, we find it to be an oversimplification of how forces interact with the object (surface vs. body forces) and believe that this method of introducing students to the FBD (which is primarily done in Physics) could lead to more misconceptions instead of being a stepping stone to understanding rigid-body equilibrium. An example of this poor habit is demonstrated for a two-block setup connected by an inextensible cable (modified Sample Problem 5.03 from Halliday and Resnick [20]).

Example: Determine the largest mass *m* where block *A* would remain stationary if $M = 10$ kg, $\mu_s = 0.20$ and $\mu_k = 0.15$.

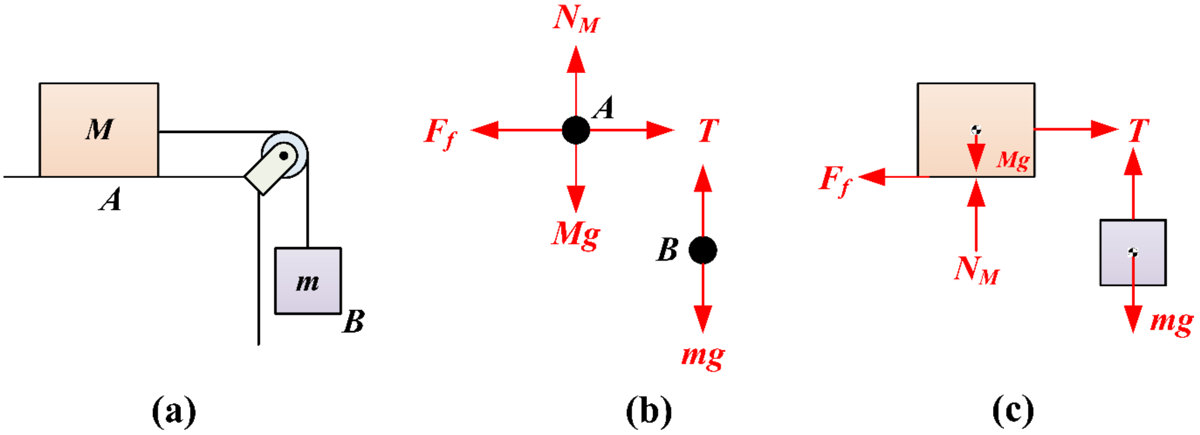


Figure 3. (a) Problem statement figure, (b) Halliday and Resnick's FBDs, (c) Better FBDs

Halliday and Resnick's FBDs for this problem are shown in Figure 3(b). Note that all of the forces on each block are concentrated at points *A* and *B*, respectively. The better FBDs in Figure 3(c) show the two bodies with the respective forces acting at the proper locations. By analyzing each subsystem in 3(c), we find that the solution to this example is $m = 0.2$ kg.

Potential pitfall in Statics: The limitations of the FBDs in Figure 3(b) are exposed if we are looking at any type of rigid-body analysis. For example, we can check for whether block *A* will slip or tip first. Assuming that block *A* is a rectangle with a height of 2 meters and a width of 3 meters, and that the cable acts at the middle of one side, the mass *m* required to cause block *A* to tip clockwise is $m = 30$ kg. It is important to note that the resultant normal force acts at the bottom right corner of the block in the case of tipping as seen in Figure 4.

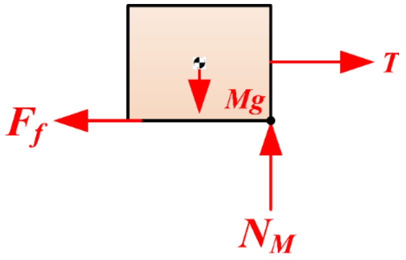


Figure 4. Free-body diagram when the block it about to tip clockwise

Since $m = 0.2$ kg is a much smaller mass, block *A* will slip before it tips. This analysis would not be possible from the FBD in Figure 3(b).

Potential pitfall in Dynamics: Very similar to the pitfall mentioned from a static analysis perspective, we can look at the case when both blocks are moving to determine the maximum mass of block *B* before block *A* starts to tip. This analysis is impossible had we treated the system like particles.

Prevalence in textbooks: Interestingly, the only textbooks where we observed FBDs similar to the ones in Figure 3(b) were the three introductory-level Physics texts. Even though every Statics textbook discusses equilibrium of particles and rigid bodies separately, none of the books encourage students to concentrate all of the forces acting on the body onto a single point. From our discussions with Physics faculty, the breadth of material that must be covered in introductory college Physics precludes any discussion of rigid-body motion and limits the focus to mechanics of particles only. Since most students are required to take Physics as a pre- or co-requisite with their first Engineering Mechanics course, we believe that the focus on drawing FBDs as points in Physics could lead to misconceptions in Statics, Dynamics and later courses that might be difficult to correct.

Summary: In Table 1, we summarize our observations from 11 Statics and Physics textbooks with regards to the three poor practices in drawing FBDs that we have highlighted here. It is important to note that every Statics textbook included the first two types of errors. The Physics books we examined did not, but they did not not have examples where this type of error might be made.

Table 1. Summary of poor practice observations from Engineering Mechanics and Physics textbooks

	Poor Practices		
	T replaces *W*	Normal reaction forces	All forces at a point
Beer and Johnston [10]	Yes	Yes	No
Hibbeler [11]	Yes	Yes	No
Bedford and Fowler [12]	Yes	Yes	No
Sheppard and Tongue [13]	Yes	Yes	No
Meriam and Kraige [14]	Yes	Yes	No
Costanzo and Plesha [15]	Yes	Yes	No
Riley and Sturges [16]	Yes	Yes	No
Pytel and Kiusalaas [17]	Yes	Yes	No
Giancoli [18]	No	Not Applicable	Yes
Young and Freedman [19]	No	Not Applicable	Yes
Halliday and Resnick [20]	No	Not Applicable	Yes

Mnemonics for drawing FBDs

Although there may be more, the authors are aware of two mnemonics to help students draw complete FBDs. One is called "The ABC's of FBD's" [21]. The first four letters of the alphabet identify items that must be included in FBDs:

A – All reactions and applied loads
B – Body
C – Coordinate System
D – Dimensions

It is then stressed that the equilibrium equations or "E" comes after you've established "ABCD."

The second mnemonic is called BREAD, which was developed at the United States Air Force Academy several years ago. These letters stand for:

B – Body
R – Reactions
E – External Forces
A – Axis
D – Dimensions

Prior to the adoption of BREAD, they used the mnemonic BARFD (Body, Axis, Reactions, Forces, Dimensions). They switched to BREAD since the order of the elements indicated by the letters is more representative of the actual order of the steps taken to draw a FBD.

<u>Another strategy (a short description of the exploded view approach)</u> [22]

Finally, we will discuss one additional proposed strategy for drawing FBDs called the "exploded view approach." This approach is not a completely new concept; it is merely an extension of the general methodology used to evaluate trusses, frames and machines to virtually every mechanical system. This approach incorporates Newton's 3rd law of motion to express the forces and moments internal to a system as external forces and moments acting on components of that system. The steps in the exploded view approach involve:

1. *<u>External forces/moments</u>*: Define a coordinate system and draw every external force and moment acting on the <u>entire</u> mechanical system.
2. *<u>Separate everything</u>!* This is somewhat an exaggeration, but this step involves separating all of the particles and bodies present in the system from one another, the ground or any other support and drawing the forces and moments acting on each of the individual entities present in the system.
3. *<u>Identify the knowns and the unknowns</u>*: All of the knowns and unknowns (including the magnitude and direction of all of the forces/moments present in the problem) should be clearly identified.

4. *Choose the correct free-body diagram*: As a check, "add" all of the separated particles/bodies with their forces/moments and the result should be identical to the original figure of the system in Step 1. Identify the proper FBD using two simple rules of thumb:
   - Neglect the ground and supports.
   - Start with the FBD with the least number of unknowns.

An example of the exploded view approach applied to a mechanical system and the resulting subsystems is shown in Figure 5. Using this approach, subsystems 5 and 2 will be the chosen FBDs that will be analyzed for this system.

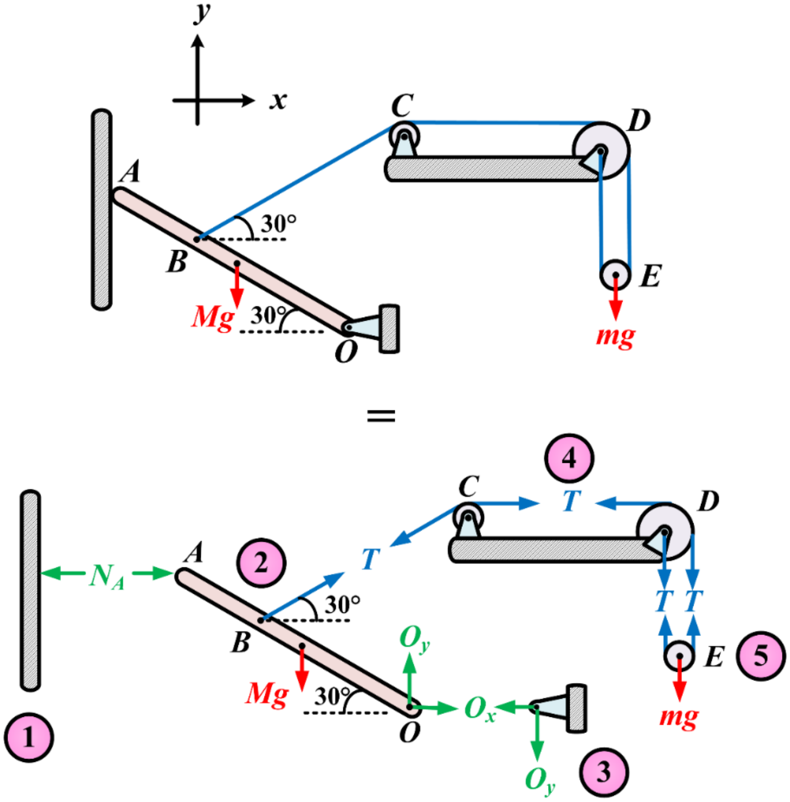


Figure 5. Example of the exploded view approach to drawing FBDs [22]

Survey results

A survey was developed to get feedback on elements of free-body diagrams (FBDs) and mnemonics for drawing FBDs (see Appendix B). Respondents were asked about the importance of including the five elements identified from Statics books earlier in this paper. We sent the survey to faculty members in the ME, CE, and BE departments at our university who teach courses that use free-body diagrams, and we received surveys from 21 faculty members. Table 2 shows the results from this survey as to the importance of each item.

Table 2. Survey results on the importance of FBD elements.

FBD Element	Not important	Somewhat important	Neutral	Important	Very important
Define the body, that is, what are you isolating for analysis.	0	4.8%	0%	4.8%	90.4%
Draw a diagram that represents the system's complete external boundary.	4.8%	4.8%	19.0%	19.0%	52.4%
Represent all external forces and moments on the free-body diagram as vectors with arrows.	0%	4.8%	0%	4.8%	90.4%
Include appropriate dimensions.	14.3%	14.3%	23.8%	28.6%	19.0%
Show the choice of coordinates.	4.8%	0%	23.8%	14.3%	57.1%

From Table 2 it is clear that there was no consensus on the need to include dimensions on a free-body diagram, and roughly a third did not think including a coordinate system was important. We were surprised by the ratings of the second element and believe that there may have been some confusion as to what we meant by the second element. Based on this survey we believe most Mechanics faculty members generally acknowledge the importance of these five elements, except perhaps the importance of including dimensions. Clearly there were differences of opinion, however, and we believe encouraging faculty members to teach a more consistent approach would be of benefit to students. For example, a clear choice of the body (or system) when drawing a FBD is expected to reduce the problem of students treating an internal force inside the system as an external force applied to the system.

In the survey we also presented the respondents with a very brief description of each mnemonic, that is "The ABC's of FBD's" and "BREAD," and we asked, based on the brief descriptions (see Appendix B), which they preferred. The results are shown in Figure 6. From this figure it is clear that there were faculty members that liked both mnemonics, but faculty members preferred BREAD by an over 2 to 1 margin. The most common reasons faculty members gave for choosing BREAD were that "it is a more natural order of tasks" and "it seemed more complete." Several commented that choosing the body is often the most important step, so putting it first is good. The most common reason for choosing "The ABC's of FBD's" was that it was "simpler with fewer steps." One faculty member preferred it because it sounded "catchy." We recognize that this survey is simply based on first impressions, and that faculty members would need to use these in their classes to actually determine whether or not they improve the quality of FBDs.

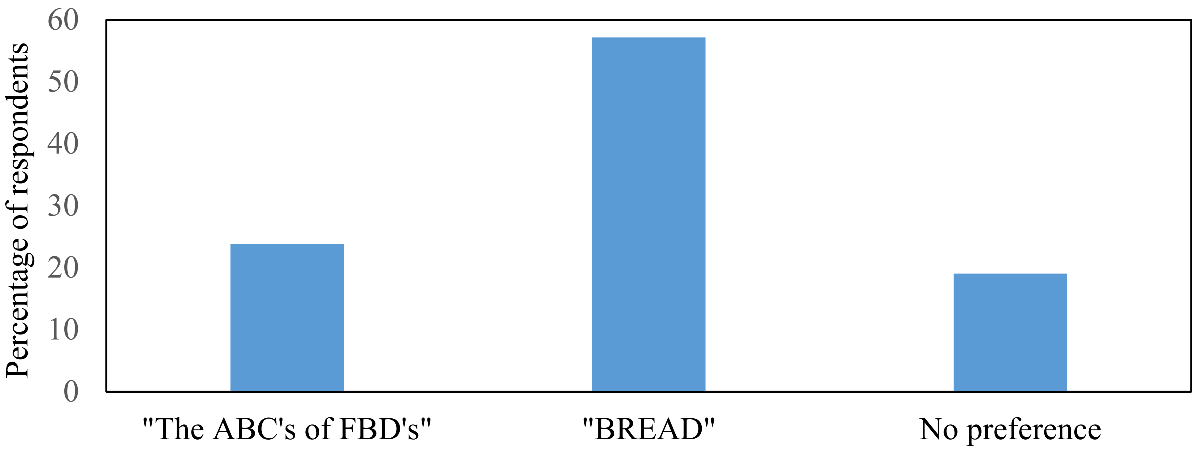


Figure 6. Results from asking faculty members which mnemonic, if any, they prefer for drawing FBDs.

Only one faculty member was aware of any additional mnemonics for free-body diagrams, and it was “FBD: F – forces, B – body, D – directions.”

Conclusions and recommendations

In this study we summarized recommended procedures for drawing FBDs found in Statics books. In spite of the fact that every Statics book presents a step-by-step procedure for drawing free-body diagrams, every Statics book we examined included what the authors consider to be poor practices that can lead to misconceptions and difficulties when students take Dynamics. We argue that a consistent application of the procedures advocated in this paper would avoid those problems. Our survey of experienced instructors in Statics and Dynamics indicated that, in general, faculty members agreed on most of the elements found in these books, although there was no consensus on the importance of including dimensions on a FBD. Of the two mnemonics for drawing FBDs: “The ABC’s of FBD’s” and “BREAD,” we found a slight preference for “BREAD,” but faculty members noted advantages and disadvantages for each of them.

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Appendix A – Summary of procedures found in Statics textbooks

Beer and Johnston [9]: This book does not give a bulleted procedure for particles, but does for a rigid body FBD. A summary is shown below.

Particles

- Shows the particle and all the forces acting on it.
- Include in the free-body diagram the magnitudes of known forces, as well as any angle or dimensions that define the direction of the force.
- Any unknown magnitude or angle should be denoted by an appropriate symbol.

Rigid Bodies

1. Start with a clear decision regarding the choice of the free body to be analyzed. Mentally, you need to detach this body from the ground and separate it from all other bodies. Then you can sketch the contour of this isolated body.
2. Indicate all external forces on the free-body diagram. These forces represent the actions exerted on the free body by the ground and by the bodies that have been detached. In the diagram, apply these forces at the various points where the free body was supported by the ground or was connected to the other bodies. Generally, you should include the weight of the free body among the external forces. You should draw the weight so it acts at the center of gravity of the body. If the free body is made of several parts, do not include the forces the various parts exert on each other among the external forces. These forces are internal forces as far as the free body is concerned.
3. Clearly mark the magnitudes and directions of the known external forces on the free-body diagram. Recall that when indicating the directions of these forces, the forces are those exerted on, and not by, the free body. Known external forces generally include the weight of the free body and forces applied for a given purpose.
4. Unknown external forces usually consist of the reactions through which the ground and other bodies oppose a possible motion of the free body. The reactions constrain the free body to remain in the same position; for that reason, they are sometimes called constraining forces. Reactions are exerted at the points where the free body is supported by or connected to other bodies; you should clearly indicate these points.
5. The free-body diagram should also include dimensions, since these may be needed for computing moments of forces. Any other detail, however, should be omitted.

Hibbeler [10]. Hibbeler provides two different procedures for FBDs for particles and rigid bodies. All the details in the textbook are not included below, but the section headings are:

Particles:

1. Draw outlined shape
2. Show all forces
3. Identify each force

Rigid Bodies

1. Draw outlined shape
2. Show all forces and couple moments
3. Identify each loading and give dimensions

Sheppard and Tongue [12]. Sheppard and Tongue include an entire chapter on how to draw a FBD. A summary of how they recommend drawing a free-body diagram is shown below:

1. Study the physical system. Classify the system as planar or non-planar.
2. Define (either by imaging or actually drawing) a boundary that isolates the system from the surroundings, then **draw the system,** that is, within the boundary. **Establish a coordinate system**.
3. Identify cross-boundary forces (e.g. **gravity**) acting on the system and draw them at appropriate centers of gravity.
4. Identify **known loads** acting at the boundary and add these to the drawing, placing each known load at its point (or surface area) of application: identify each load on the drawing with a variable label and magnitude.
5. Identify the loads associated with each **support**, both those loads that act at discrete points and those that consist of distributed forces.

Meriam and Kraige [13]

1. Decide which system to isolate.
2. Next isolate the chosen system by drawing a diagram which represents its complete external boundary.
3. Identify all forces which act on the isolated system as applied by the removed contacting and attracting bodies, and represent them in their proper positions on the diagram of the isolated system.
4. Show the choice of coordinate axis directly on the diagram. Pertinent dimensions may also be represented for convenience.

Riley and Sturges [15]

<u>Particles</u>

1. Make a decision regarding what body is to be isolated and analyzed. Prepare a sketch of the external boundary of the body selected.
2. Represent all forces, known and unknown, that are applied by other bodies to the isolated body with vectors in their correct positions.

<u>Rigid Bodies</u>

1. Decide which body or combination of bodies is to be shown on the free-body diagram.
2. Prepare a drawing or sketch of the outline of this isolated or free body.
3. Carefully trace around the boundary of the free body and identify all forces and moments exerted by contacting or interacting bodies that were removed during the isolation.
4. Choose the set of coordinates to be used in solving the problem and indicate these directions on the free-body diagram.

Appendix B

Survey on drawing FBDs

The purpose of this survey is to get feedback on elements of free-body diagrams (FBDs) and mnemonics for drawing FBDs. All responses are anonymous, and you do not need to complete this survey, but we would appreciate it if you would. A summary of the key elements for drawing a free-body diagram as found in five Statics textbooks are shown below. For each element please indicate how important you believe this step is from "very important" to "not important."

1. How important is it to define the body, that is, define what are you isolating for analysis? This is sometimes called the system, or the free-body.

1	2	3	4	5
Not important	Somewhat important	Neutral	Important	Very important

2. How important is it to draw a diagram that represents the system's complete external boundary?

1	2	3	4	5
Not important	Sort of important	Neutral	Important	Very important

3. How important is it to represent all external forces and moments as vectors with arrows on the free-body diagram? These include body and surface forces as well as known and unknown forces. The forces should be drawn where they act.

1	2	3	4	5
Not important	Sort of important	Neutral	Important	Very important

4. How important is it to include appropriate dimensions on the FBD?

1	2	3	4	5
Not important	Sort of important	Neutral	Important	Very important

5. How important is it to show the choice of coordinates on the FBD?

1	2	3	4	5
Not important	Sort of important	Neutral	Important	Very important

Do you believe anything is missing from these steps? If so, please discuss below.

Two mnemonics and one expanded FBD approach have been identified as possible approaches to helping students draw complete and correct FBDs.

Mnemonic 1: "**The ABC's of FBD's**" The first four letters of the alphabet identify items that must be included in FBDs.

A – All reactions and applied loads
B – Body
C – Coordinate System
D – Dimensions

It is then stressed that the equilibrium equations or "E" come **after** you've established "ABCD."

Mnemonic 2: BREAD. This mnemonic was developed at the United States Air Force Academy and these letters stand for:

B – Body
R – Reactions
E – External Forces
A – Axis
D – Dimensions

We recognize that you have probably not used either one of these mnemonics, but based on the very brief descriptions above, which one of the two approaches do you prefer? (circle one)

- Mnemonic 1: "The ABC's of FBD's"
- Mnemonic 2: BREAD
- No preference

Why do you prefer the one you chose?

Are you aware of any other mnemonic for helping students draw FBDs? If so, please describe it.