graphs.sign Sign convention

1 The sign (positive or negative) of a variable is used to represent an orientation of its physical quantity. For instance, −3 m/s could mean 3 m/s to the right or left. No one can say which is better (right is better). Deciding how the physical quantity corresponds to the sign of the variable is called sign assignment. When we use a sign convention, we make the assignment in a conventional manner. For instance, the sign convention for normal stress is that compression is negative and tension is positive.

sign

sign assignment

sign convention

2 Why use a sign convention? If we follow a convention when constructing a problem, we can use the convention's interpretation of the result. For complicated systems, this helps us keep things straight. Furthermore, if someone else attempts to understand our work, it is much easier to simply say "using the standard sign convention, …" than explaining our own snowflake sign assignment. However, it is nonetheless true that we can assign signs arbitrarily.

sign interpretation

3 Arbitrary? Vive la révolution! But wait. If a source is present, we must observe some caution. A source typically comes with its own convention. For instance, if we hook up a power supply to the circuit with the + and − leads a certain way, unless we want to get very confused, we should probably accommodate that sign.

Vive la révolution!

4 A sign convention for each of the energy domains we've considered follows.

Electronic systems

5 We use the passive sign convention of electrical engineering, defined below.

passive sign convention

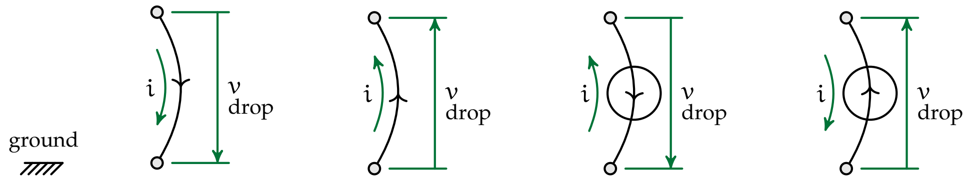


Figure sign.1: passive sign convention for electronic systems in terms of voltage v and current i. Passive elements are on the left, active on the right.

Definition graphs.1: passive sign convention

Power flowing in to a component is considered to be positive and power flowing out of a component is considered negative.

6 Because power $\mathcal{P} = vi$, this implies the current and voltage signs are prescribed by the convention. For passive elements, the electrical potential must drop in the direction of positive current flow. This means the assumed direction of voltage drop across a passive element must be the same as that of the current flow. For active elements, which supply power to the circuit, the converse is true: the voltage drop and current flow must be in opposite directions. Figure sign.1 illustrates the possible configurations.

passive element

active element

7 When drawing a linear graph of a circuit, for each passive element's edge, draw the arrow beside it pointing in the direction of assumed current flow and voltage drop.

8 The purpose of a sign convention is to help us interpret the signs of our results. For instance, if, at a given instant, a capacitor has voltage $v_C = 3$ V and current $i_C = -2$ A, we compute $\mathcal{P}_C = -6$ W and we know 6 W of power is flowing from the capacitor into the circuit.

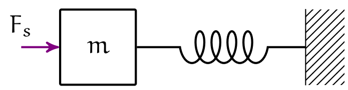
interpretation

9 For passive elements, there is no preferred direction of "assumed" voltage drop and current flow. If a voltage or current value discovered by performing a circuit analysis is positive, this means the "assumed" and "actual" directions are the same. For a negative value, the directions are opposite.

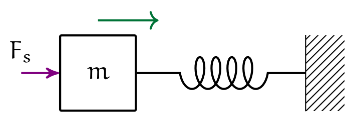
10 For active elements, choose the sign in accordance with the physical situation. For instance, if a positive terminal of a battery is connected to a certain terminal in a circuit, it ill behooves one to simply say "but Darling, I'm going to call that negative." It's positive whether you like it or not, Nancy.

Translational mechanical systems

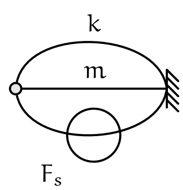
11 The following steps can be applied to any translational mechanical system. We introduce the convention with an inline example. Consider the simple mechanical system shown at right.



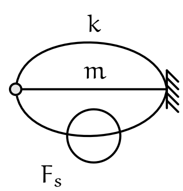
12 **coordinate arrow** Assign the sign by drawing a coordinate arrow, as shown at right. The direction of the arrow is arbitrary, however, if possible, assign the positive direction to match the sources. If the problem allows, it is best practice to have all sources and the coordinate arrow in the same direction.



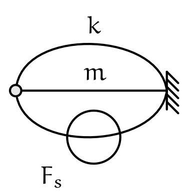
draw linear graph without arrows There are two nodes with distinct velocities: ground and the mass, as shown at right. The mass node is always drawn to ground. The spring connects between the mass and ground. Finally, the force source connects to the mass, where it is applied, and also connects to ground, which is impervious to it.



13 **assign spring and damper directions** On each spring and damper element, define the positive velocity drop and edge arrow to be in the direction of the coordinate arrow.



14 **assign mass directions** On each mass element, define the positive velocity drop and edge arrow to be toward ground. Sometimes we dash the latter half of the mass edge in to signify that it is "virtually" connected to ground.



15 **assign force source directions** On each force source element, define the positive

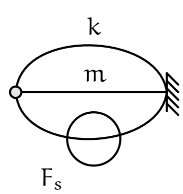
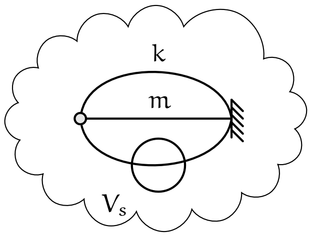


Table sign.1: interpretation of the translational mechanical system sign convention.

	force f		velocity v	
	positive +	negative −	positive +	negative −
m	force in direction of the coordinate arrow	force opposite the direction of the coordinate arrow	velocity in the coordinate arrow direction	velocity opposite the coordinate arrow direction
k	compressive force	tensile force	velocity drops in the coordinate arrow direction	velocity drops opposite the coordinate arrow direction
B	compressive force	tensile force	velocity drops in the coordinate arrow direction	velocity drops opposite the coordinate arrow direction

direction as follows.
(ideal) If the force source has the same definition of positive as your coordinate arrows, draw it toward the node of application.
(if needed) If the force source has the opposite definition of positive as your coordinate arrow, draw it away from the node of application.

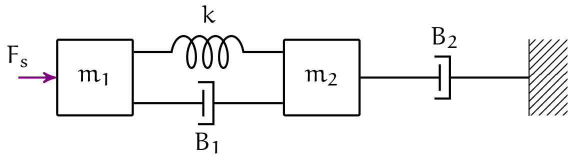
16 **assign velocity source directions** On each velocity source element, define the positive direction as follows.
(ideal) If the velocity source has the same definition of positive as your coordinate arrows, draw it away from the node of application.
(if needed) If the velocity source has the opposite definition of positive as your coordinate arrow, draw it toward the node of application.



17 This convention yields the interpretations of Table sign.1.

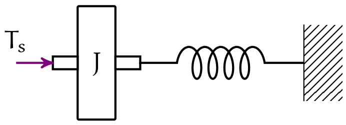
Example graphs.sign−1 **re: translational mechanical sign convention**

For the system shown, draw a linear graph and assign signs according to the sign convention.

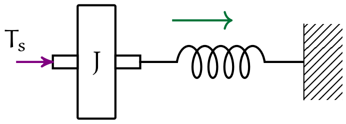


Rotational mechanical systems

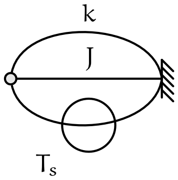
18 The following steps can be applied to any rotational mechanical system. We introduce the convention with an inline example. Consider the simple system shown at right.



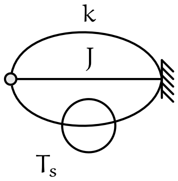
19 **coordinate arrow** Assign the sign by drawing a coordinate arrow, as shown at right. The direction of the arrow is arbitrary, however, if possible, assign the positive direction to match the sources. If the problem allows, it is best practice to have all sources and the coordinate arrow in the same direction. The right-hand rule is always implied.



20 **draw linear graph without arrows** There are two nodes with distinct velocities: ground and the inertia, as shown at right. The inertia node is always drawn to ground. The spring connects between the inertia and ground. Finally, the torque source connects to the mass, where it is applied, and also connects to ground, which is impervious to it.

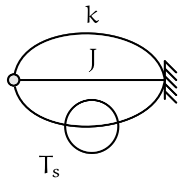


21 **assign spring and damper directions** On each inline spring and damper element, define the positive velocity drop and edge arrow to be in the direction of the coordinate arrow. Springs and dampers that aren't inline

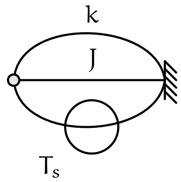


typically connect to ground, toward which edge arrows should point.

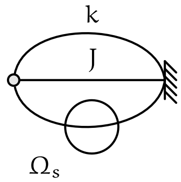
22 **assign inertia directions** On each inertia element, define the positive angular velocity drop and edge arrow to be toward ground. Sometimes we dash the latter half of the inertia edge to signify that it is "virtually" connected to ground.



23 **assign torque source directions** On each torque source element, define the positive direction as follows.
(ideal) If the torque source has the same definition of positive as your coordinate arrows, draw it toward the node of application.
(if needed) If the torque source has the opposite definition of positive as your coordinate arrow, draw it away from the node of application.



24 **assign angular velocity source directions** On each angular velocity source element, define the positive direction as follows.
(ideal) If the source has the same definition of positive as your coordinate arrows, draw it away from the node of application.
(if needed) If the source has the opposite definition of positive as your coordinate arrow, draw it toward the node of application.



25 This convention yields the interpretations of Table sign.2.

Example graphs.sign–2 **re: rotational mechanical sign convention**

For the system shown, draw a linear graph and assign signs according to the sign convention.

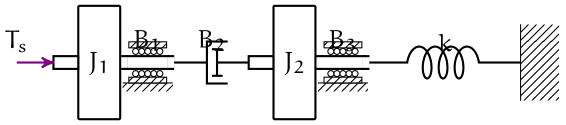
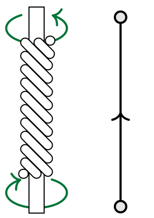
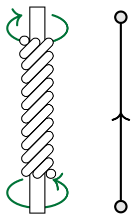
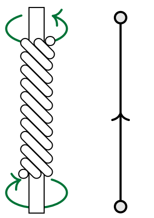
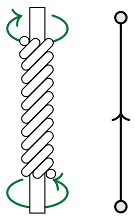


Table sign.2: interpretation of the mechanical system sign convention.

	torque T		angular velocity Ω	
	positive +	negative −	positive +	negative −
J	torque in direction of the coordinate arrow	torque opposite the direction of the coordinate arrow	velocity in the coordinate arrow direction	velocity opposite the coordinate arrow direction
k	wring! 	wrong! 	velocity drops in the coordinate arrow direction	velocity drops opposite the coordinate arrow direction
B	wring! 	wrong! 	velocity drops in the coordinate arrow direction	velocity drops opposite the coordinate arrow direction