So, these base units need to have an agreed upon standard value themselves or else this whole standardization thing goes right out the door. **Figure 1.7.2** provides the standards upon which the base units themselves are measured.

Figure 1.7.2

Base Units Definitions

Note that these definitions are all complex, so you don't need to memorize each definition. Since about 1960, scientists have increasingly defined measurement units based on constants—never-changing relationships between matter—and that has then changed the standards we use to define the unit. For example, in the late 1700s, an actual metal bar was made that for about 100 years served as the definition for how long a meter was. That bar was changed in 1889 to a different physical bar, then in1960 the meter's length was changed to be defined by the wavelength of radiation emitted by krypton-86. Even though 1 meter is an actual physical distance, the meter's standard is no longer an actual, physical length of metal, but a value defined by natural constants. A similar process occurred with the kilogram, where for more than a hundred years, 1 kilogram of mass was defined by a physical chunk of metal that contained 1 kg of matter. However, since 2019, the amount of 1 kg of matter is provided by several constants (Planck's constant, the speed of light in a vacuum, and the cesium frequency).

Base Unit (name)	Definition
ampere (current)	1 A = the flow of $1.602176634 \times 10^{-19}$ elemental charges per second.
candela (light intensity)	The luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 5.4×10^{14} hertz with a radiant intensity in that direction of 1/683 watt per steradian.
kelvin (thermodynamic temperature)	1 K = change in temperature that results in a change of thermal energy by 1.380649×10^{-23} J.
kilogram (mass)	Until May 20, 2019, the kilogram was officially defined as the mass of a 47 cubic centimeter cylinder of platinum-iridium alloy kept in the Pavillon de Breteuil, France. However, 1 kg is now calculated based upon the Planck constant, so that $1\ \text{kg} = 1.475521399270 \times 10^{40} \frac{h\,\Delta\nu_{Cs}}{c^2}$, where h = Planck constant, ΔVCs = the definition of 1 second, c = the speed of light.
meter (length)	Since 2019, the definition of the length of a meter became dependent upon the definition of a second (which itself is dependent upon another constant, as noted below); however, in effect, 1 meter is equal to the distance light travels in a vacuum in 1/299,752,458 second.
mole (amount of a substance)	The amount of substance of a system which contains $6.02214076 \times 10^{23}$ units.
second (time)	The duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium-133 atom.

1.8 INTERNATIONAL SYSTEM OF UNITS—DERIVED UNITS

Not all units are directly measurable units, though. **Derived units** cannot be directly measured. Instead, they are calculated from two or more base units or other derived units, using division and multiplication. The important derived units in physics are listed in **Figure 1.8.1.**

- The SI base units are time, length, mass, electric current, amount of substance, luminous intensity and the thermodynamic temperature.
- The SI derived units are calculated by combining base units and/or other derived units.
- The SI system is a base 10 system, which makes it very easy to work with.
- Scientific notation is utilized frequently in all sciences, including physics, and serves as a quick method of abbreviation.
- SI prefixes can be very helpful in writing very large or very small numbers and are placed before the base or derived units to indicate specific value.
- Accuracy is the ability of a measuring device to obtain the correct value and precision is the ability of a measuring device to obtain the same value with repeated measurements.

1.15 DEFINITIONS

Accuracy
The ability of a measuring device to obtain the correct value.

Base units
Units of the International System of Units that are directly measurable.

Calibrate
The process of ensuring that your measuring device is accurate.

Control group
The group that is not exposed to the variable in a control study.

Controlled experiment
An experimental design where a hypothesis is tested by changing one variable and comparing the outcome of that variable to the control group.

Derived units
Units of the International System of Units that are calculated; units that are made up of the product or quotient of base units and/or other derived units.

Experimental group
The group in a controlled experiment that is exposed to the variable.

Experimentation
The process of testing how well a hypothesis can explain current, and predict future, observations/scientific data.

Factor
Anything in an experiment that may change the outcome.

Hypothesis
An educated statement that explains observations to a certain degree and is then tested by formal experimentation.

Imperial units
The official measurement units of Great Britain.

International System of Units
The official measurement units of a large majority of the world as well as the scientific community.

Kelvin
The base unit of temperature; 1 K = the change in temperature that results in a change of thermal energy by 1.380649×10^{-23} J

Kilogram
The base unit of mass; the amount of matter defined by a relationship to Planck's constant. (Note: this amount of matter corresponds to the mass of a 47 cm^3 cylinder of platinum-iridium alloy).

Law
A theory that has been proven true over and over.

Matter
Anything that has mass and takes up space.

Measurement
The assignment of a number to a characteristic of an object or event, which can be compared with other objects or events; a type of experimental observation.

Meter
The base unit of measurement defined as the length of the path that light travels in a vacuum in 1/299,752,458 second.

Metric system
The previous base 10 measurement system that was subsequently converted into the International System of Units.

Mole
The base unit of amount of a substance; the amount of substance of a system which contains $6.02214076 \times 10^{23}$ units.

Observation
The part of the scientific method in which data are collected.

Observation experiment
A way to test a hypothesis in which data are collected through the five senses.

Physics
The study of energy, its motion through, and in, space and how it interacts with matter.

Physicist
A scientist who studies physics.

Precision
The ability of a measuring device to obtain the same result when measuring the same value repeatedly.

Qualitative data
Data that have no numbers or values; subjective information.

Quantitative data
Data that have numbers or values; objective information.

Second
The base unit of time; technically, it is the duration of 9,192,631,770 periods the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium–133 atom.

Scientific method
The standardized, rigorous way that scientists go about collecting and assessing data.

Scientific notation
A way to write numbers that consists of a decimal piece and an exponent piece, taking the form of "decimal piece x 10^x" or "decimal piece x exponential piece".

SI prefixes
An International Standards of Measurement that precedes a base unit or derived unit that indicates to multiply the unit times the corresponding factor of 10.

Standardized
To do something the same way wherever that thing is done.

10. In question 9, what is the variable?

11. What is measurement?

12. True or False: qualitative data are the preferred data to be collected for scientific experiments.

13. True or False: when qualitative data has been acquired during an experiment, that means that objective data has been acquired.

14. True or False: the "metric system" uses the exact same measurements as the SI system.

15. What are the two types of units in the SI system?

16. What are the seven SI base units? Please also list each one's symbol.

17. What base unit is defined as, "the change in temperature that results in a change of thermal energy by 1.380649×10^{-23} J".

18. True or False: derived units are directly measured values and base units are calculated values.

19. True or False: one of the reasons the SI system is so easy to work with is that it is a base 10 system, regardless of what unit is being measured or calculated.

20. What derived unit is defined as kg/ms^2 and what does it measure?

21. True or False: $1m^3$ would be said, "one cubic meter."

22. What is the format of "decimal piece x exponential piece" called?

23. Put the following numbers in proper scientific notation.
    a. 1101258.3
    b. 000.0015687
    c. 98300.2
    d. 0.0000000037
    e. 5980000000000000
    f. 267.15300009

24. Write out the following numbers in their correct numerical form, as well as spell out what the unit is before you converted it. For example, 5.0 fC would be 0.000000000000005 C and the "fC" stands for "femtocoulomb" (note that the scientific notation conversions do not require you to spell out what the unit was before you converted it since there is no unit provided).
    a. 1.56 pm
    b. 27 kA
    c. 206 EJ
    d. 7.56×10^8
    e. 12 ns
    f. 0.767×10^{-7}