

The Gravitational Constant

Pounds, Tons & Miles / Two Unit Systems, One Law

The numerical value of G must match the units used for *both* masses, the force, and the separation. Here, a “ton” means a U.S. short ton; force is explicitly measured in short ton-force, not ton-mass.^{[2][3]}

$$F = \frac{GMm}{r^2}$$

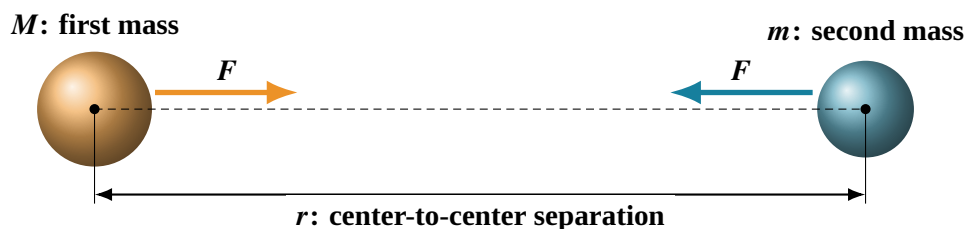


Figure 1. Each body attracts the other with an equal, oppositely directed force. The arrows act on different bodies; the diagram is not to scale.^[5]

CASE A / Mass in Pounds Force in Tons Distance in Miles

Enter M and m in pound-mass, F in short ton-force, and r in miles.

$$G \approx 5.95968 \times 10^{-22} \frac{\text{ton}_f \text{ mi}^2}{\text{lb}_m^2}$$

CASE B / Mass in Tons Force in Tons Distance in Miles

Enter M and m in short ton-mass, F in short ton-force, and r in miles.

$$G \approx 2.38387 \times 10^{-15} \frac{\text{ton}_f \text{ mi}^2}{\text{ton}_m^2}$$

lb_m = pound-mass; ton_m = short ton-mass; ton_f = short ton-force. These explicit labels are used throughout this lesson to prevent mass and force from being confused.

Both results are derived from the same recommended SI value, $G = 6.67430 \times 10^{-11} \text{ N m}^2/\text{kg}^2$. They are not two different physical constants.^[1] These forms apply to point masses or non-overlapping spherically symmetric bodies, with $r > 0$.^[5] Inside: unit definitions (p. 2); full derivations (pp. 3–5); worked checks (pp. 6–7); illustrated article (pp. 8–10); other kinds of tons and a reference guide (pp. 11–12).

First, Name the Kind of Quantity

Mass, Force & Distance Are Different Measurements

A pound-mass describes an amount of mass. A pound-force describes a force. A short ton-mass is 2,000 pound-mass; a short ton-force is 2,000 pound-force. Similar unit names do not make mass and force interchangeable.^{[2][3]}

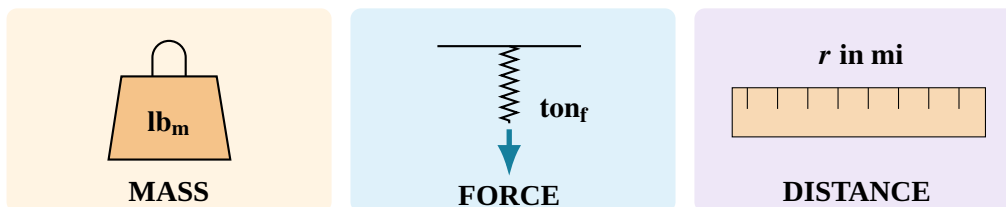


Figure 2. A mass, a force sensor, and a ruler answer three different questions. The force-unit definition does not depend on the gravity at the place of measurement.

Exact Conversions Used in Every Calculation

Unit or reference	Exact relation
Pound-mass	$1 \text{ lb}_m = 0.45359237 \text{ kg}$
Short ton-mass	$1 \text{ ton}_m = 2,000 \text{ lb}_m = 907.18474 \text{ kg}$
International mile	$1 \text{ mi} = 1,609.344 \text{ m}$
Standard gravity	$g_n = 9.80665 \text{ m/s}^2$
Pound-force	$1 \text{ lb}_f = 4.4482216152605 \text{ N}$
Short ton-force	$1 \text{ ton}_f = 2,000 \text{ lb}_f = 8,896.443230521 \text{ N}$
Newton	$1 \text{ N} = 1 \text{ kg m/s}^2$

Unit definitions: NIST conversion tables and exact-factor footnotes; standard gravity: NIST.^{[2][3][4]}

Where the Force Conversion Comes From

$$(0.45359237 \text{ kg})(9.80665 \text{ m/s}^2) = 4.4482216152605 \text{ N} = 1 \text{ lb}_f.$$

Multiplying by 2,000 gives one short ton-force. The standard acceleration g_n is a defined reference, not a claim that actual local gravity is exactly that value everywhere.^{[4][6]}

A 1 ton_m object has a gravitational weight of 1 ton_f when its local gravitational acceleration equals g_n . Moving the object to a different gravitational field changes its weight, not its mass. The unit ton_f itself does not change.

The mile here is the international land mile, not the nautical mile or the historical U.S. survey mile. Long tons and metric tonnes are treated separately on page 11.

Build the Conversion Once

Then Apply It to Either Mass Unit

Start by rearranging the gravitational law. Since the numerator contains *two masses*, the units of G contain the square of the mass unit in the denominator:

$$G = \frac{Fr^2}{Mm}, \quad [G] = \frac{\text{force} \times \text{length}^2}{\text{mass}^2}.$$

Square brackets mean “units of.” In SI, $[G] = \text{N m}^2/\text{kg}^2 = \text{m}^3/(\text{kg s}^2)$.^{[1][5]}

Define Three Numerical Conversion Factors

Let one chosen mass unit equal a kilograms, one chosen force unit equal b newtons, and one chosen distance unit equal c meters. Here a , b , and c are numerical conversion factors, not new physical constants.

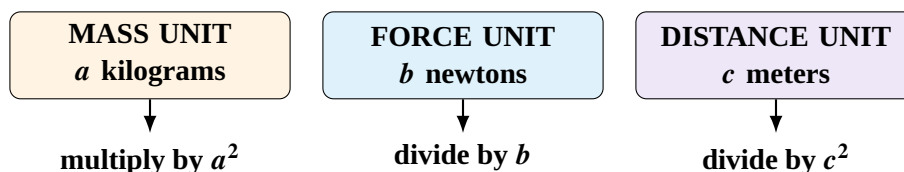


Figure 3. Two mass factors, one force factor, and two distance factors control the converted coefficient.

Substitute the New Numerical Inputs Into SI

Let M_u, m_u, r_u, F_u be the numerical readings in the chosen units. Then

$$M_{\text{kg}} = aM_u, \quad m_{\text{kg}} = am_u, \quad r_{\text{m}} = cr_u, \quad F_{\text{N}} = bF_u.$$

Use these in the SI numerical equation:

$$bF_u = G_{\text{SI,num}} \frac{(aM_u)(am_u)}{(cr_u)^2} \implies F_u = \left(G_{\text{SI,num}} \frac{a^2}{bc^2} \right) \frac{M_u m_u}{r_u^2}.$$

The Numerical Conversion Rule

$$G_{\text{new,num}} = G_{\text{SI,num}} \frac{a^2}{bc^2}$$

Attach the matching unit force unit $\times$ distance unit²/mass unit² to the resulting number. A bare decimal is not a complete value of G .

Predict the Direction Before Computing

A larger mass unit increases a and therefore increases this coefficient when force and distance units stay fixed. A larger force unit or distance unit decreases the coefficient. These are statements about *numerical representations*, not changes in physical attraction.

Do not multiply by 1,609.344² when converting the SI coefficient into mile-based force units. A numerical separation of one mile already represents 1,609.344 meters, so that squared factor belongs in the divisor.

The conversion rule is an algebraic derivation from $F = GMm/r^2$. It assumes both masses use the same chosen unit. For different mass units, replace a^2 by $a_1 a_2$.

FREE MATH TUTOR / MEASURE · CONVERT · EXPLAIN

Case A: Pounds, Tons & Miles

Mass: lb_m Force: ton_f Distance: mi

Step 1 / Write the starting value with its full units.^[1]

$$G = 6.67430 \times 10^{-11} \frac{\text{N m}^2}{\text{kg}^2}.$$

Step 2 / Multiply by conversion factors equal to one. Place the units so that newtons, meters squared, and kilograms squared all cancel:

$$G = \left(6.67430 \times 10^{-11} \frac{\text{N m}^2}{\text{kg}^2} \right) \left(\frac{1 \text{ ton}_f}{8,896.443230521 \text{ N}} \right) \times \left(\frac{1 \text{ mi}}{1,609.344 \text{ m}} \right)^2 \left(\frac{0.45359237 \text{ kg}}{1 \text{ lb}_m} \right)^2.$$

Step 3 / Check the units before evaluating the numbers.

$$\frac{\text{N m}^2}{\text{kg}^2} \cdot \frac{\text{ton}_f}{\text{N}} \cdot \frac{\text{mi}^2}{\text{m}^2} \cdot \frac{\text{kg}^2}{\text{lb}_m^2} = \frac{\text{ton}_f \text{ mi}^2}{\text{lb}_m^2}.$$

Step 4 / Square both conversion factors that are squared.

$$(0.45359237)^2 = 0.2057460381222169,$$

$$(1,609.344)^2 = 2,589,988.110336.$$

Step 5 / Evaluate the converted coefficient.

$$\begin{aligned} G_{A,\text{num}} &= \frac{(6.67430 \times 10^{-11})(0.45359237)^2}{(8,896.443230521)(1,609.344)^2} \\ &= \frac{(6.67430 \times 10^{-11})(0.2057460381222169)}{(8,896.443230521)(2,589,988.110336)} \\ &= 5.959681115452 \dots \times 10^{-22}. \end{aligned}$$

Final Value / Case A

$$G \approx 5.95968 \times 10^{-22} \frac{\text{ton}_f \text{ mi}^2}{\text{lb}_m^2}$$

$$F_{\text{ton}_f} = (5.95968 \times 10^{-22}) \frac{M_{\text{lb}_m} m_{\text{lb}_m}}{(r_{\text{mi}})^2}$$

The subscripts in the last equation identify *numerical readings*: masses in lb_m , distance in mi , and the resulting force in ton_f .

Sources: SI starting value [1]; exact conversion definitions [2–4]. All arithmetic is derived here. The small value reflects both the small masses and the selected large distance and force units.

Case B: Tons, Tons & Miles

Mass: ton_m Force: ton_f Distance: mi

Step 1 / Change the mass conversion. Each mass is now entered in short tons:

$$1 \text{ ton}_m = 907.18474 \text{ kg}.$$

The force and distance conversions are *unchanged*.^{[2][3]} Step 2 / Write the complete dimensional conversion.

$$G = \left(6.67430 \times 10^{-11} \frac{\text{N m}^2}{\text{kg}^2} \right) \left(\frac{1 \text{ ton}_f}{8,896.443230521 \text{ N}} \right) \times \left(\frac{1 \text{ mi}}{1,609.344 \text{ m}} \right)^2 \left(\frac{907.18474 \text{ kg}}{1 \text{ ton}_m} \right)^2.$$

The surviving unit is $\text{ton}_f \text{ mi}^2 / \text{ton}_m^2$. Do not cancel ton_f against ton_m : one is a force unit and the other is a mass unit.
Step 3 / Square the new mass conversion and compute.

$$(907.18474)^2 = 822,984.1524888676,$$

$$\begin{aligned} G_{B,\text{num}} &= \frac{(6.67430 \times 10^{-11})(907.18474)^2}{(8,896.443230521)(1,609.344)^2} \\ &= 2.383872446180 \dots \times 10^{-15}. \end{aligned}$$

Final Value / Case B

$$G \approx 2.38387 \times 10^{-15} \frac{\text{ton}_f \text{ mi}^2}{\text{ton}_m^2}$$

$$F_{\text{ton}_f} = (2.38387 \times 10^{-15}) \frac{M_{\text{ton}_m} m_{\text{ton}_m}}{(r_{\text{mi}})^2}$$

Another Method / Convert Directly From Case A

$$\boxed{M : \times 2,000} \times \boxed{m : \times 2,000} \rightarrow \frac{2,000^2}{= 4,000,000}$$

Figure 4. Each of the two mass factors changes by 2,000 when a one-unit short-ton input is compared with a one-unit pound input.

$$G_{B,\text{num}} = G_{A,\text{num}}(2,000)^2 = (5.959681115452 \dots \times 10^{-22})(4 \times 10^6).$$

The coefficient becomes four million times larger, but for the *same physical bodies* the two numerical mass inputs each become 2,000 times smaller. Their effects cancel exactly.

A one-ton mass is not the same physical mass as a one-pound mass. Changing the physical masses changes the force; relabeling unchanged masses in different units does not.

The Same Bodies Must Give the Same Force

A Three-Way Check: Pounds, Tons & SI

Take two non-overlapping spherical bodies with masses 2 ton_m and 3 ton_m , separated by 1 mi between centers. Treat the stated inputs as exact classroom values and retain guard digits during arithmetic.

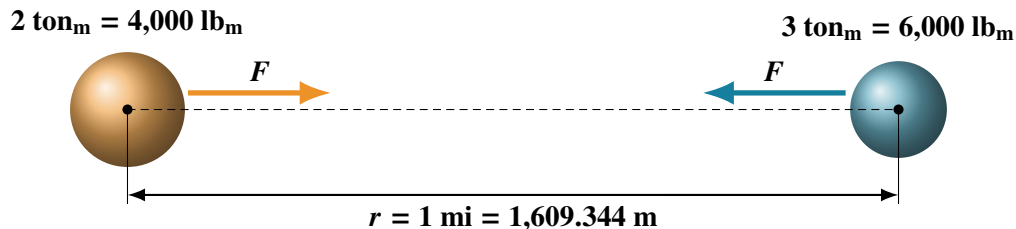


Figure 5. The diagram describes one physical arrangement. Both unit choices must predict the same attraction. Sizes and arrow lengths are schematic.

Route A / Pound-Mass Inputs

$$M = 4,000, \quad m = 6,000, \quad r = 1.$$

$$F = (5.959681115 \dots \times 10^{-22})$$

$$\times \frac{(4,000)(6,000)}{1^2}$$

$$F \approx 1.43032 \times 10^{-14} \text{ ton}_f$$

Route B / Ton-Mass Inputs

$$M = 2, \quad m = 3, \quad r = 1.$$

$$F = (2.383872446 \dots \times 10^{-15})$$

$$\times \frac{(2)(3)}{1^2}$$

$$F \approx 1.43032 \times 10^{-14} \text{ ton}_f$$

Route C / Start Over in SI

Convert each mass and the distance directly:

$$M = 2(907.18474) = 1,814.36948 \text{ kg},$$

$$m = 3(907.18474) = 2,721.55422 \text{ kg}, \quad r = 1,609.344 \text{ m}.$$

$$F = \frac{(6.67430 \times 10^{-11})(1,814.36948)(2,721.55422)}{(1,609.344)^2} \text{ N} \approx 1.27248 \times 10^{-10} \text{ N}.$$

Now convert that force to short ton-force:

$$F = \frac{1.272479153 \dots \times 10^{-10}}{8,896.443230521} \text{ ton}_f \approx 1.43032 \times 10^{-14} \text{ ton}_f.$$

Why the check matters: the mass inputs changed from 4,000, 6,000 to 2, 3; the coefficient changed in the opposite direction by 4,000,000. The physical force did not change. A mismatch would reveal a conversion, exponent, or unit-label error.

This is the mutual force between the two bodies, not the force of Earth on either body. Source model: Newtonian attraction between non-overlapping spherical bodies [5].

A Shorter Distance, a Different Force

A Second Worked Example With Pound-Mass Inputs

Two idealized spherical objects have masses 150 lb_m and 200 lb_m . Their center-to-center distance is 0.01 mi . The aim is to calculate their mutual attraction, not their Earth weights.

Identify the Inputs Before Squaring

$$M = 150, \quad m = 200, \quad r = 0.01, \quad r^2 = 0.0001.$$

$$F = (5.959681115452 \dots \times 10^{-22}) \frac{(150)(200)}{(0.01)^2}$$

$$= (5.959681115452 \dots \times 10^{-22})(300,000,000)$$

$$F \approx 1.78790 \times 10^{-13} \text{ ton}_f$$

Check the Same Result in Other Units

$$F \approx (1.7879043346 \dots \times 10^{-13})(2,000) = 3.57581 \times 10^{-10} \text{ lb}_f,$$

$$F \approx (1.7879043346 \dots \times 10^{-13})(8,896.443230521) = 1.59060 \times 10^{-9} \text{ N}.$$

The equivalent ton-mass inputs are $150/2,000 = 0.075$ and $200/2,000 = 0.1$. Using Case B gives the same force:

$$(2.38387244618 \dots \times 10^{-15}) \frac{(0.075)(0.1)}{(0.01)^2} = 1.7879043346 \dots \times 10^{-13}.$$

Do Not Replace Center Distance With Surface Height

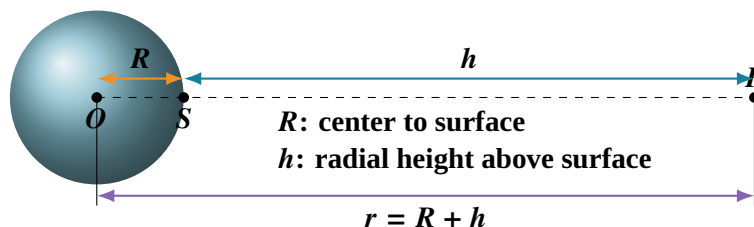


Figure 6. The unit changes, but the endpoints do not. If $R = 4,000 \text{ mi}$ and $h = 250 \text{ mi}$ in an invented spherical model, use $r = 4,250 \text{ mi}$, not 250 mi .^[6]

Calculator entry for Case A: $5.95968\text{E-}22 * M * m / (r*r)$

Calculator entry for Case B: $2.38387\text{E-}15 * M * m / (r*r)$

In both entries, r must be in miles, and the output is in short ton-force. Match the mass unit to the chosen entry.

A small positive distance is still squared. At fixed masses, doubling r makes the force one fourth as large; changing units alone never creates that physical change.

The Constant Behind Every Calculation

An Article on G / Part I: One Law, Many Numerical Languages



Figure 7. Different masses and locations produce different forces; the gravitational constant is the same in the standard theory. Sizes and distances are not to scale.^{[5][9]}

The Factor That Sets the Scale

In Newton's model, the attraction between two point masses is proportional to the product of their masses and inversely proportional to their squared separation. A proportionality tells us a pattern: double one mass and the force doubles; double the separation and the force becomes one fourth. The constant G converts that pattern into an actual force.^[5] Imagine a set of experiments in which the masses and their separation change. The forces would change, too. In the ideal Newtonian model, however, the combination $Fr^2/(Mm)$ would stay equal to G . That is the mathematical meaning of the constant in this relationship. It is not the force itself and does not have force units by itself.

Big G Is Not Little g

The lowercase g describes gravitational acceleration at a particular location. Outside an ideal spherical source,

$$g(r) = \frac{GM}{r^2}.$$

A different source mass or a different location changes g even while G stays the same. At a body's surface $r = R$; above it, $r = R + h$. The Sun, Earth, and Moon therefore do not need different universal constants to have different gravitational fields.^[6] The exact number 9.80665 m/s^2 is a third idea: standard gravity, g_n . It defines a reference acceleration used in conventional force units. It is neither the universal constant nor a measurement of every place on Earth.^[4]

Why Units Change the Number

A distance of one mile and a distance of 1,609.344 meters can describe the same physical separation. The number changed because the size of the measuring unit changed. The same logic applies to a constant with compound units, but every exponent must be carried through the conversion. Here, each of the two mass inputs contributes one conversion factor. The distance contributes a squared factor, and the output force contributes one factor. That is why our derived numerical rule is $G_{\text{new,num}} = G_{\text{SI,num}} a^2 / (bc^2)$, rather than a single pounds-to-kilograms multiplier. The two answers on page 1 are thus two labels for one quantity. Comparing their bare decimal values as though one described "stronger gravity" would compare numbers stripped of the very units that give them meaning.

A Small Number Needs Context

With two one-kilogram point masses one meter apart, the ideal force is 6.67430×10^{-11} newtons. That is a small laboratory force, obtained directly by substituting those inputs. Large astronomical masses lead to very different forces through the same equation. The coefficient's small decimal alone is not a unit-independent measure of weakness: changing units changes that decimal. To understand a prediction, specify the masses, the distance, the model, and the resulting force unit. The complete calculation tells the physical story; the isolated exponent does not.

Measuring an Almost Invisible Attraction

An Article on G / Part II: From a Twisting Fiber to a Number

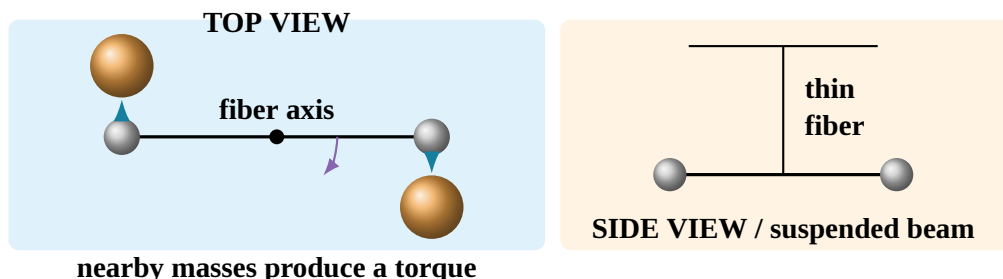


Figure 8. A torsion balance converts a very small gravitational attraction into a measurable twist. This simplified conceptual diagram omits enclosures, readout optics, and the full force geometry.^[7]

A Laboratory Question

Knowing the inverse-square pattern is not enough to establish its coefficient. To determine G , an experiment needs measured information about the source masses, their positions, and the resulting interaction. In the simplest idealized picture, one infers

$$G = \frac{Fr^2}{Mm}.$$

A real experiment does not simply read an isolated force off a drawing. It must account for the arrangement and dimensions of the masses and for the instrument's response. Position and geometry matter because they are part of the gravitational prediction.

Why a Torsion Balance Helps

A sensitive torsion balance suspends a beam or other structure from a thin fiber. Nearby source masses create a tiny twisting effect. The fiber resists the twist. Measuring its angular response and calibrating the apparatus lets researchers infer the gravitational interaction.^[7] Henry Cavendish's 1798 experiment is a landmark in this story. Using a suspended beam with small masses and nearby larger masses, he measured an attraction far weaker than the obvious downward pull of Earth. Modern instruments retain the central idea but use much more elaborate control and measurement systems.^[7] The laboratory lesson is subtle: a weak signal can still be measurable when the apparatus is designed to respond sensitively to it. Large everyday forces are not the only forces that scientific instruments can detect.

A Model Must Match the Apparatus

For a simple rotational model, a fiber with torsional stiffness κ produces a restoring torque of magnitude $\kappa\theta$ at a small twist angle θ . A force also produces torque through its lever arm. Relating those ideas can turn an angular measurement into an estimate of force. But a complete balance includes several interacting masses, not just one nearest pair. Their gravitational contributions, lever arms, and separations must be modeled together. An elegant equation is useful only when its variables describe the actual experiment.

What Can Disturb the Result?

Experimentalists must distinguish the gravitational signal from effects of temperature, pressure, alignment, and instrument calibration. A 2026 NIST report describes a re-determination using a BIPM torsion balance, including measurements by both mechanical twisting and electrostatic balancing. The new result did not remove the disagreement among precision measurements.^[8] That disagreement does not automatically mean gravity changes when the equipment changes. It calls for careful comparisons of uncertainty and possible systematic effects. A result may be extremely repeatable while still carrying a shared offset caused by the apparatus or its model.

Changing Units Is Not Measuring G

Our pounds–tons–miles calculations use an already measured reference value. Exact unit conversions rewrite that value; they do not supply new experimental evidence. A correctly converted answer must inherit the original uncertainty rather than acquire extra certainty from a long calculator display.

Precision, Planets & Einstein

An Article on G / Part III: What the Constant Can Tell Us

A Measured Value, Not an Exact Definition

$$G = (6.67430 \pm 0.00015) \times 10^{-11} \text{ N m}^2/\text{kg}^2.$$

The $\pm$ value is the standard uncertainty. The relative uncertainty is approximately 2.2×10^{-5} , or about 22 parts per million, in the 2022 CODATA recommendation.^[1]

Exact Conversions Preserve Uncertainty

The pound-to-kilogram and mile-to-meter factors used here are exact definitions. Multiplying a measured quantity by an exact conversion factor changes its value and its absolute uncertainty by the same scale factor. The relative uncertainty therefore stays unchanged. For the two answers in this lesson, the converted standard uncertainties are approximately

$$u(G_A) \approx 1.34 \times 10^{-26} \frac{\text{ton}_f \text{ mi}^2}{\text{lb}_m^2},$$

$$u(G_B) \approx 5.36 \times 10^{-20} \frac{\text{ton}_f \text{ mi}^2}{\text{ton}_m^2}.$$

These numbers are calculated from the SI uncertainty, not independently measured. Guard digits in the arithmetic prevent avoidable rounding error; they do not make the underlying experiment more accurate.

A Recommendation Is Not Every Result

The calculations in this lesson consistently use the CODATA 2022 recommended value displayed by NIST. New measurements can appear before a new international adjustment is completed. NIST's 2026 work is important experimental evidence, but a single new result should not be silently substituted into one calculation while a different reference value remains in another.^{[8][11]} The useful habit is to identify the adopted reference, its date or adjustment, and its uncertainty. That makes later comparisons possible and prevents an apparent unit-conversion discrepancy from actually being a change of input data.

Why Astronomers Often Use GM

A body's gravitational parameter is $\mu = GM$. In a spherical model, orbital acceleration depends directly on this product. JPL tabulates gravitational parameters for solar-system bodies.^[10] For example, the same product appears in $g =$

μ/r^2 and in the circular-orbit relation $v^2 = \mu/r$ for a small satellite. Those formulas explain why orbital observations naturally constrain GM . Separating the product into a mass in kilograms requires an adopted G :

$$M = \frac{\mu}{G}.$$

This distinction is not wordplay. Measuring a product well does not necessarily measure each factor equally well. It also shows why one must read the units of a tabulated astronomical parameter rather than assume it is a mass.

Einstein Keeps G but Extends the Model

General relativity describes gravity through spacetime geometry. The gravitational constant remains part of the relationship between matter and energy and that geometry. In this sense, G connects the Newtonian description to the broader relativistic theory.^[9] Writing G in customary units does not turn Newton's inverse-square formula into a complete relativistic calculation. Strong gravitational fields, light propagation, and precision clock comparisons may require a more detailed spacetime model. The units must still be consistent, but consistency alone does not prove that the chosen physical model is adequate.

The Last Check Is Physical Meaning

A result should say which masses interact, where the separation begins and ends, and which force unit is reported. The formula used here gives a magnitude for a suitable Newtonian pair model; direction and additional bodies require further information. One physical constant can have many numerical expressions. Good measurement, clear units, and an appropriate model work together; none can replace the others.

Keep the distinction: G is universal in the standard theory; g is location-dependent; g_n is a defined reference; GM is a body's gravitational parameter. None of these symbols is interchangeable with the others.

Article sources: recommended value and uncertainty [1]; exact conversions [2–4]; current reference context [8,11]; gravitational parameters [10]; relativity [9]. Uncertainty conversions are derived here.

Which Ton? What About Seconds?

Useful Boundaries for Reusing the Answers

Three Different Meanings of “Ton”

The main answers use U.S. short tons. A long ton is 2,240 pounds-mass, while a metric tonne is 1,000 kilograms. Each corresponding force unit below is defined using standard gravity.^{[2][3][4]}

1 long ton-mass = 1,016.0469088 kg; 1 tonne = 1,000 kg. Multiply either mass unit by g_n to define its corresponding ton-force or tonne-force unit.

Converted G for Each Explicit Convention

In the next table, T_m and T_f mean the selected row's mass and force units. Distance is always the international mile.

Convention	Both masses in lb_m : G in $T_f \text{ mi}^2/\text{lb}_m^2$	Both masses in T_m : G in $T_f \text{ mi}^2/T_m^2$
U.S. short ton	5.95968×10^{-22}	2.38387×10^{-15}
Imperial long ton	5.32114×10^{-22}	2.66994×10^{-15}
Metric tonne	5.40653×10^{-22}	2.62777×10^{-15}

Calculated using $G_{\text{new,num}} = G_{\text{SI,num}} a^2/(bc^2)$. These are alternatives, not replacements for the short-ton assumptions used on pages 1–10.

Force Units Are Not Automatically Mass $\times$ Miles/ s^2

A short ton-force is *not* defined as the force that accelerates one short ton-mass at one mile per second squared. Therefore, dividing a numerical force in ton_f by a numerical mass in ton_m does not directly give acceleration in mi/s^2 .

$$\frac{1 \text{ ton}_f}{1 \text{ ton}_m} = 9.80665 \text{ m/s}^2 = 0.006093569802 \dots \text{ mi/s}^2.$$

Consequently, for these specific numerical readings,

$$a_{\text{mi/s}^2} = 0.006093569802 \dots \frac{F_{\text{ton}_f}}{m_{\text{ton}_m}}.$$

A Separate, Coherent Distance–Mass–Time Form

When using miles, short ton-mass, and seconds in an acceleration or orbital equation, convert the SI form $\text{m}^3/(\text{kg s}^2)$ instead:

$$G_{\text{coh,num}} = (6.67430 \times 10^{-11}) \frac{907.18474}{(1,609.344)^3},$$

$$G \approx 1.45263 \times 10^{-17} \frac{\text{mi}^3}{\text{ton}_m \text{ s}^2}.$$

Use this last form directly in $g = GM/r^2$ to obtain g in miles per second squared. Do not substitute its numerical value into a force formula expecting a short-ton-force output without converting the force unit as well.

The force-based answers already include the necessary force conversion. Do not divide them by an additional 32.174... factor; that would apply an unrelated feet-based conversion a second time.

Keep This Reference

Equations, Unit Checks & Linked Scientific Sources

The Two Requested Forms / U.S. Short Tons

$$F_{\text{ton}_f} = (5.95968 \times 10^{-22}) \frac{M_{\text{lb}_m} m_{\text{lb}_m}}{(r_{\text{mi}})^2}, \quad F_{\text{ton}_f} = (2.38387 \times 10^{-15}) \frac{M_{\text{ton}_m} m_{\text{ton}_m}}{(r_{\text{mi}})^2}.$$

Use the matching mass inputs. Both equations return short ton-force; both use center-to-center distance in miles.

Check	What to confirm
Kind of quantity	Mass is not force: $\text{lb}_m \neq \text{lb}_f$ and $\text{ton}_m \neq \text{ton}_f$.
Meaning of ton	Short ton, long ton, or metric tonne is explicitly stated.
Powers	Convert both mass factors and square the entire distance.
Geometry	Use center separation; outside a sphere, $r = R + h$.
Model and precision	Use an appropriate Newtonian model and round only after calculation.

Sources & Further Reading

Each title below is a clickable source link. The numbered references beside the text point to this list. Numerical conversions, examples, diagrams, and the article are prepared for this lesson; cited references provide the underlying definitions and scientific context.

- [1] NIST. Fundamental Physical Constants—Extensive Listing, 2022 CODATA adjustment, p. 1. Recommended G and standard uncertainty.
- [2] NIST SP 811. Appendix B.9: Conversion factors by quantity. Pounds, miles, short tons, long tons, tonnes, and force units.
- [3] NIST SP 811. Footnotes 22–23. Exact avoirdupois pound and pound-force conversion factors.
- [4] NIST. Standard acceleration of gravity. The exact conventional value $g_n = 9.80665 \text{ m/s}^2$.
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- [6] OpenStax. University Physics, Volume 1, Section 13.2: Gravitation Near Earth's Surface. Local g , altitude, and spherical models.
- [7] NIST. How Do You Measure the Strength of Gravity? February 24, 2025. Torsion-balance explanation and Cavendish context.
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One closing idea: a unit conversion changes the *number and unit together*. It does not change the physical force between unchanged bodies. The pair of results on page 1 passes that test in the worked verification on page 6.