# Calculating Muzzle Energy – The Quest for the Magic Number

## System of Units

The system of measurement units commonly used in the United States is the US Customary System, which is based on units derived from the English system.

The English Engineering system (EE) uses four primary units:

- Force (pound-force, $lb_f$)
- Mass (pound-mass, $lb_m$)
- Length (feet, ft)
- Time (seconds, s)

Other units in the EE system are derived from its primary units, for example:

- Velocity (ft/s)
- Energy (foot-pound, ft-$lb_f$)

In the EE system a force of one pound ($lb_f$) accelerates a mass of one pound ($lb_m$) at a rate equal to the standard acceleration of gravity (32.174 ft/$s^2$).

$$1\ lb_f = 1\ lb_m * 32.174\ ft/s^2$$

The **constant** (32.174 ft/$s^2$) was conveniently chosen so that at standard gravity ($g_n$) the weight of one pound-mass is exactly one pound-force, allowing mass and weight to be used interchangeably simply as pounds!

| $g_n = 32.174\ ft/s^2$ | $1\ lb_f = 1\ lb_m * g_n \rightarrow 1\ lb_m = 1\ lb_f / g_n$ |
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**Question:** What happens when local gravity is not equal to standard gravity?

**Answer:**

- From Newton's second law of motion we know that: Force (F) = mass (m) * acceleration (a)
  So it follows that: Weight (W) = mass (m) * acceleration of local gravity (g)
- Since mass is an intrinsic property of an object (i.e., the mass of an object is the same on Earth or on the Moon), the weight of one pound-mass at local gravity will vary as follows:

  $W = m * g$

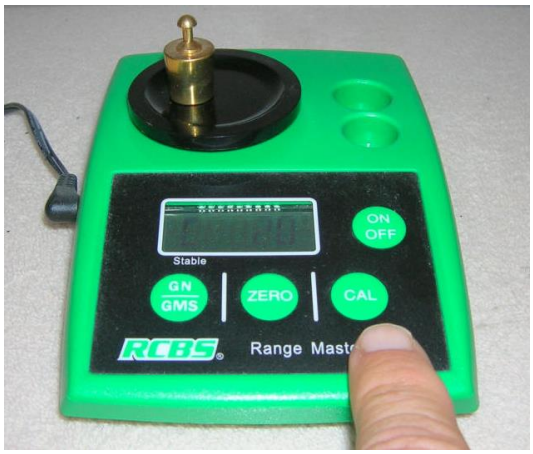
  For ($m = 1\ lb_m$), we can substitute: $m = (1\ lb_f / g_n)$

  $W = 1\ lb_f * (g / g_n)$

So while the mass of an object remains constant, its weight varies by the ratio of local gravity and standard gravity ($g / g_n$).

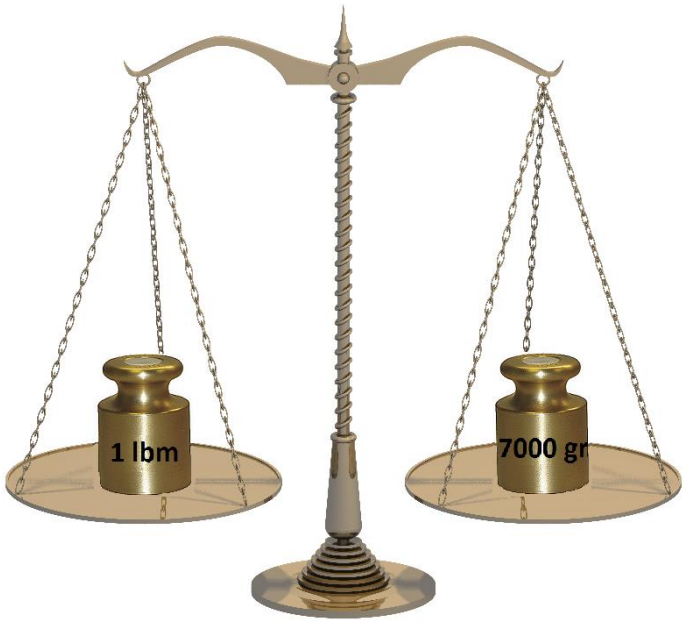
**Problem:** When we weigh pellets on a scale we are trying to measure their **mass** (in grains or grams), but the scale is actually measuring **weight** (force); and as previously discussed, weight may vary with local gravity!

**Solution:** To compensate for local gravity and variances in the scale's measuring mechanism, the scale needs to be calibrated using objects of known mass, referred to as "Calibration weights".




## Mass Conversion Factor

In the EE system, a unit of mass (1 $lb_m$) is defined to be equal to 7000 grains.




1 $lb_m$ = 7000 grain

# Kinetic Energy (KE)

$$KE = \tfrac{1}{2}\, m * v^2$$

The unit of energy in the English system is defined as the **foot-pound** ($ft\text{-}lb_f$). It is the energy transferred by applying a force of one pound-force ($lb_f$) through a displacement of one foot.

Given mass (M) in grains, and muzzle velocity (V) in (ft/s), we can calculate Muzzle Energy in ($ft\text{-}lb_f$) by substituting as follows:

$$KE = \tfrac{1}{2} * (M\ grain) * (1\ lb_m / 7000\ grain) * [\ 1\ lb_f\ / (1\ lb_m * 32.174\ ft/s^2)\ ] * (V^2\ ft^2/s^2)$$

Units cancel to give us:

$$KE = \tfrac{1}{2} * (M) * (1 / 7000) * [\ 1\ lb_f\ / (32.174)\ ] * (V^2\ ft)$$

$$KE = (M) * (V^2)\ ft * lb_f / (2 * 7000 * 32.174)$$

$$KE = (M) * (V^2)\ ft * lb_f / (450436)$$

| |
|---|
| **Muzzle Energy** ($ft\text{-}lb_f$) = $\dfrac{Mass\ (grain) * [\ Muzzle\ Velocity\ (ft/s)\ ]^2}{(450436)}$ |
| **Magic Number** = 450436 |

**MYTH BUSTERS:**

- The ($32.174\ ft/s^2$) above is not a substitution for gravity, but rather a substitution based on the chosen **constant** in the English system, where by definition: $1\ lb_f = 1\ lb_m * 32.174\ ft/s^2$.
- As mentioned previously, **mass** does not vary with gravity, so it follows that **Kinetic Energy** as a function of mass does not vary with gravity!