

SFCalcSheet formula collection

Preface

This is an index of formulas used internally by [SFCalcSheet](#), the science fiction calculation spreadsheet. Hopefully, and independent of whether you are a user of the spreadsheet, these formulas can help you with various worldbuilding and astronomy related tasks.

If you find a mistake in this document, don't hesitate and [file an issue](#) on GitHub. You can also contact the author on [Reddit](#), [Twitter](#) or on his [Discord server](#). Ideas, constructive feedback and praise are always appreciated.

Star formulas

Luminosity from absolute magnitude

$$\sqrt[5]{100}^{M_{Sun}-M}$$

L = luminosity (Suns), M = absolute magnitude

Absolute magnitude from luminosity

$$M = M_{Sun} - 2.5 \cdot \log_{10}(L)$$

M = absolute magnitude, L = luminosity (Suns)

Visible magnitude from absolute magnitude and distance

$$m = M - 5 + 5 \cdot \log_{10}(d)$$

m = visible magnitude, M = absolute magnitude, d = distance (pc)

Luminosity difference from absolute magnitudes

$$\Delta L = \sqrt[5]{100}^{(M_{Big}-M_{Small})}$$

L = luminosity, M = absolute magnitude

Luminosity from mass

$$L = m^{3.5}$$

L = luminosity (Suns), m = mass (Suns)

Radius from mass (stars less massive than the Sun)

$$r = m^{0.8}$$

r = radius (Suns), m = mass (Suns)

Radius from mass (stars as massive or more massive than the Sun)

$$r = m^{0.57}$$

r = radius (Suns), m = mass (Suns)

Surface temperature from mass

$$T_s = 5778 \cdot m^{0.54}$$

T_s = surface temperature (K), m = mass (Suns)

5778 is the Sun's surface temperature in Kelvin.

Inner rim of habitable zone

$$r_{inner} = \sqrt{\frac{L}{1.1}}$$

r_{inner} = inner rim (AU), L = luminosity (Suns). This is a conservative formula resulting in a narrow HZ. Use the "habitable zone limits" formula for more flexibility.

Outer rim of habitable zone

$$r_{h_{outer}} = \sqrt{\frac{L}{0.53}}$$

$r_{h_{outer}}$ = outer rim (AU), L = luminosity (Suns). This is a conservative formula resulting in a narrow HZ. Use the “habitable zone limits” formula for more flexibility.

Main sequence life span from mass

$$l = 10^{10} \cdot \left(\frac{1}{m}\right)^{2.5}$$

l = life span (years), m = mass (Suns)

Luminosity relative to ZAMS (zero age main sequence)

$$L = 1 + 10^{-10} \cdot m^{2.5} \cdot t$$

L = relative luminosity (ZAMS = 1), m = mass (Suns), t = age of star (years)

Orbital period of binary orbit from distance and mass

$$T = 2\pi \cdot \sqrt{\frac{d^3}{G \cdot (m_1 + m_2)}}$$

T = orbital period (s), d = separation of bodies' centers/sum of semi-major axes (m), G = gravitational constant, m_1 and m_2 = masses of orbiting bodies (kg)

Barycenter of binary orbit

$$d_b = \frac{d}{1 + \frac{m_1}{m_2}}$$

d_b = distance of barycenter to center of first body (m), d = distance between bodies' centers (m), m_1 and m_2 = masses of orbiting bodies (kg)

Planet formulas

Radius from mass and density

$$r = \sqrt[3]{\frac{3m}{4\pi \cdot \rho}}$$

r = radius (m), m = mass (kg), ρ = density (kg/m³)

Gravitational acceleration from mass and radius

$$g = \frac{G \cdot m}{r^2}$$

g = gravitational acceleration (m/s²), G = gravitational constant, m = body mass (kg), r = body radius (m)

Escape velocity from mass and radius

$$v_e = \sqrt{\frac{2m \cdot G}{r}}$$

v_e = escape velocity (m/s), G = gravitational constant, m = mass (kg), r = radius (m)

Roche limit (rigid bodies) from densities

$$d = r_p \cdot 1.26 \cdot \sqrt[3]{\frac{\rho_p}{\rho_s}}$$

d = Roche limit (m), r_p = planet radius (m), ρ_p = density of planet (kg/m³), ρ_s = density of satellite (kg/m³)

Roche limit (fluid/loose bodies) from densities

$$d = r_p \cdot 2.44 \cdot \sqrt[3]{\frac{\rho_p}{\rho_s}}$$

d = Roche limit (m), r_p = planet radius (m), ρ_p = density of planet (kg/m³), ρ_s = density of satellite (kg/m³)

Orbital period from distance and mass

$$T = \sqrt{\frac{4\pi^2 \cdot d^3}{G \cdot m}}$$

T = orbital period (s), d = semi-major axis (m), G = gravitational constant, m = mass of orbited body (kg)

Hill sphere

$$r_h = d \cdot \sqrt[3]{\frac{m}{3m_o}}$$

r_h = radius of Hill sphere (m), d = distance to orbited body (m), m = mass of body (kg), m_o = mass of orbited body (kg)

Tidal force

$$F_t = G \cdot m \cdot \frac{2r}{d^3}$$

F_t = tidal force (m/s²), G = gravitational constant, m = mass of causing body (kg), r = radius of affected body (m), d = distance between bodies (m)

Habitable zone limits

$$d = \sqrt{\frac{L}{S_e}}$$

d = distance of HZ limit to the star (AU), L = luminosity (Suns), S_e = normalized stellar flux (runaway greenhouse = 1.41; moist greenhouse = 1.107; 1st condensation = 0.53; maximum greenhouse = 0.356)

Solar irradiance

$$R = L \cdot G_{SC} \cdot \left(\frac{1}{d}\right)^2$$

R = irradiance (W/m²), L = luminosity of star (Suns), G_{SC} = solar constant (1,361 W/m²), d = distance of planet to star (AU)

Effective temperature

$$T_e = \sqrt[4]{\frac{(1-A) \cdot L}{16\pi \cdot d^2 \cdot \sigma}}$$

T_e = effective temperature (K), A = bond albedo of planet, L = luminosity of star (W), d = distance to star (m), σ = Stefan-Boltzmann constant

Surface temperature

$$T_s = T_e \cdot \sqrt[4]{\frac{1}{1-\varepsilon}}$$

T_s = surface temperature (K), T_e = effective temperature (K), ε = atmospheric absorption (0-1)

Land area

$$A_l = 4\pi \cdot r^2 \cdot A_{l_p}$$

A_l = land area (km²), r = planet radius (km), A_{l_p} = land percentage (0-1)

Satellite formulas

Visual diameter

$$d_v = 2 \cdot \arcsin\left(\frac{r}{d}\right)$$

d_v = visual diameter (rad), r = radius of satellite (km), d = distance to satellite (km)

Visual area from visual diameter

$$A_v = \pi \cdot \left(\frac{d_v}{2}\right)^2$$

A_v = visual area (rad²), d_v = visual diameter (rad)

Illuminance

$$E_v = \frac{A_v \cdot \left(\frac{A_b}{0.12}\right)}{48900}$$

E_v = illuminance (full moons; ≈ 0.25 lux), A_v = visual area (rad²), A_b = bond albedo (0-1)

48900 is a shorthand for 1 divided by half the Moon's angular diameter (in radians) squared. 0.12 is the Moon's bond albedo.

Compact object formulas

Schwarzschild radius

$$r_s = \frac{2G \cdot m}{c^2}$$

r_s = Schwarzschild radius (m), G = gravitational constant, m = mass (kg), c = speed of light (m/s)

Black hole lifetime

$$t_l = m^3 \cdot \frac{5120 \cdot \pi \cdot G^2}{\hbar \cdot c^4}$$

t_l = lifetime (s), m = mass (kg), G = gravitational constant, \hbar = Dirac constant, c = speed of light (m/s)

Disaster formulas

Impactor mass

$$m = \frac{4}{3} \cdot \pi \cdot \rho \cdot r^3$$

m = impactor mass (kg), ρ = impactor density (kg/m³), r = impactor radius (m)

Impactor kinetic energy

$$K = \frac{1}{2} \cdot m \cdot v^2$$

K = impactor kinetic energy (J), m = impactor mass (kg), v = impactor velocity (m/s)

Impact crater approximate size

$$d_c = \left(\frac{K}{4.184 \cdot 10^{12}} \right)^{0.3} \cdot 46$$

d_c = approximate crater diameter (m), K = impactor kinetic energy (J)

$4.184 \cdot 10^{12}$ is the explosion energy of 1 kt TNT in joules. 46 is the diameter of the crater left by the explosion of 1 kt TNT (in meters).

Impact crater size lower bound

$$d_{crlower} = \frac{d_c}{3.48}$$

$d_{crlower}$ = crater diameter lower bound, d_c = approximate crater diameter

Impact crater size upper bound

$$d_{cruupper} = d_c \cdot 3.48$$

$d_{cruupper}$ = crater diameter upper bound, d_c = approximate crater diameter

Energy of matter/antimatter annihilation

$$E = mc^2$$

E = released energy (J), m = total reaction mass (kg), c = speed of light (m/s)

Bomb blast maximum fireball radius

$$r_{max} = E^{0.4} \cdot 39$$

r_{max} = maximum fireball radius (m), E = bomb yield (kt TNT)

This is an intermediate formula between the approximate fireball radii of aerial and ground-based detonations. Use a multiplier of 33.5 for aerial and 44 for ground-based detonations.

Bomb blast fireball duration

$$t = E^{0.45} \cdot 0.2$$

t = fireball duration (s), E = bomb yield (kt TNT)

Bomb blast crater diameter

$$d = E^{0.3} \cdot 46$$

d = crater diameter (m), E = bomb yield (kt TNT)

Bomb blast shockwave radius

$$r = E^{\frac{1}{5}} \cdot \Delta t^{\frac{2}{5}} \cdot \rho^{-\frac{1}{5}}$$

r = shockwave radius (m), E = explosion energy (J), Δt = time since detonation (s), ρ = mass density of medium (kg/m³)

Earthquake energy

$$E = 10^{4.4+1.5M}$$

E = released energy (J), M = earthquake magnitude

Travel formulas

Time dilation (outside observer) / relativistic mass

$$\Delta t = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

t = time, v = velocity (m/s), c = speed of light (m/s)

Uniform acceleration time

$$t_a = \frac{v_f - v_i}{a}$$

t_a = acceleration time (s), v_f = final velocity (m/s), v_i = initial velocity (m/s), a = acceleration (m/s²)

Uniform acceleration distance

$$d = \frac{(v_i + v_f) \cdot t_a}{2}$$

d = distance (m), v_i = initial velocity (m/s), v_f = final velocity (m/s), t_a = acceleration time (s)