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**Calculating a Hohmann Transfer Orbit with Units and Error Terms**

Please study equations 1 through 6. Notice that error terms have been added. You are to follow the pattern shown in those equations in the equations that follow. Quality is more important than speed.

1. First step has no equations
2. Earth’s distance from sun:

R1(Earth) =149600000 ± 5e4 km

Mars distance from sun:

R2(Mars) = 227920000 ± 5e3 km

1. Gravitational parameter:

GM = 1.327e11 ± 5e7 km3/s2

1. Orbital Periods in seconds:

P1(Earth) = 31558149.504 ± 5e-4 s

P2(Mars) = 59329255.68 ± 5e-3 s

1. Compute the Semi-major Axis of the Transfer Orbit:

a(Hohman transfer) = (R1(Earth) km + R2(Mars) km) / 2

a(Hohman transfer) = (149600000 ± 5e4 km + 227920000 ± 5e3 km) / 2

a(Hohman transfer) = ((149600000 + 227920000) ± (5e4 + 5e3) km) / 2

a(Hohman transfer) = (377520000 ± 5.5e4 km) / 2

a(Hohman transfer) = 188760000 ± 5e4 km

1. Find the period of the Hohmann Transfer Orbit:

P(Hohman transfer) = √(4𝜋2 × a3 km3/ GM km3/s2)

P(Hohman transfer) = √(4 × (3.141592653589793 ± 5e-16)2 ×

(188760000 ± 5e4)3 km3 / 1.327e11 ± 5e7 km3/s2)

P(Hohman transfer) = √(4 × (3.141592653589793 ± 5e-16)2 ×

(188760000 ± 5e4)3 km3 / 1.327e11 ± 5e7 km3/s2)

(3.141592653589793 ± 5e-16)2 ⇒ 9.869604401089359 ±

9.869604401089359 × 2 × 5e-16 ÷ 3.141592653589793

(3.141592653589793 ± 5e-16)2 ⇒ 9.869604401089359 ±

19.739208802178717 × 5e-16 ÷ 3.141592653589793

(3.141592653589793 ± 5e-16)2 ⇒ 9.869604401089359 ±

9.8696044010893585e-15 ÷ 3.141592653589793

(3.141592653589793 ± 5e-16)2 ⇒ 9.869604401089359 ± 3e-15

P(Hohman transfer) = √(4 × 9.869604401089359 ± 3e-15 ×

(188760000 ± 5e4)3 km3 / 1.327e11 ± 5e7 km3/s2)

4 × 9.869604401089359 ± 3e-15 ⇒ (4 × 9.869604401089359) ± (4 × 3e-15)

⇒ 39.4784176044 ± 4 × 3e-15

⇒ 39.4784176044 ± 12e-15

⇒ 39.4784176044 ± 2e-14

P(Hohman transfer) = √(39.4784176044 ± 2e-14 ×

(188760000 ± 5e4)3 km3 / 1.327e11 ± 5e7 km3/s2)

(188760000 ± 5e4)3 km3

⇒ 1887600003 ± (3 × 5e4 ÷ 188760000 × 1887600003)

⇒ 6.725582525376001e24 ± (3 × 5e4 ÷ 188760000 × 6.725582525376001e24)

⇒ 6.725582525376001e24 ± (1.5e5 ÷ 188760000 × 6.725582525376001e24)

⇒ 6.725582525376001e24 ± (0.00079465988 × 6.725582525376001e24)

⇒ 6.725582525376001e24 ± 5.3445506e21

⇒ 6.725582525376001e24 ± 5e21

⇒ 6.726e24 ± 5e21

P(Hohman transfer) = √(39.4784176044 ± 2e-14 ×

6.726e24 ± 5e21 km3 / 1.327e11 ± 5e7 km3/s2)

39.4784176044 ± 2e-14 × 6.726e24 ± 5e21 km3

⇒ 2.6553184e26 ± (2e-14 ÷ 39.4784176044 + 5e21 ÷ 6.726e24) × 2.6553184e26 km3

⇒ 2.6553184e26 ± (5.0660592e-16 + 5e21 ÷ 6.725e24) × 2.6553184e26 km3

⇒ 2.6553184e26 ± 0.00074349442 × 2.6553184e26 km3

⇒ 2.6553184e26 ± 1.9742144e23 km3

⇒ 2.6553184e26 ± 2e23 km3

⇒ 2.655e26 ± 2e23 km3

P(Hohman transfer) = √(2.655e26 ± 2e23 km3 / 1.327e11 ± 5e7 km3/s2)

2.655e26 ± 2e23 km3 / 1.327e11 ± 5e7 km3/s2

⇒ 2.0007536e15 ± (2e23 ÷ 2.655e26 + 5e7 ÷ 1.327e11) × 2.0007536e15 s2

⇒ 2.0007536e15 ± (0.00075329566 + 0.00037678975) × 2.0007536e15 s2

⇒ 2.0007536e15 ± 2.2610225e12 s2

⇒ 2.0007536e15 ± 3e12 s2

⇒ 2.001e15 ± 3e12 s2

P(Hohman transfer) = √(2.001e15 ± 3e12 s2)

√(2.001e15 ± 3e12 s2)

⇒ √(2.001e15) ± (0.5 × 3e12 ÷ 2.001e15 × 44732538.4927) s

⇒ 44732538.4927 ± (0.5 × 3e12 ÷ 2.001e15 × 44732538.4927) s

⇒ 44732538.4927 ± (1.53e12 ÷ 2.001e15 × 44732538.4927) s

⇒ 44732538.4927 ± 34203.2902501 s

⇒ 44732538.4927 ± 3.42032902501e4 s

⇒ 44740000. ± 4e4 s

P(Hohman transfer) = 44740000. ± 4e4 s

1. Find the Velocity of Earth’s Orbit:

V1(Earth) = (2𝜋 × R1(Earth) km) / P1(Earth) s

V1(Earth) = (2 × 3.14159265358979323 × 149600000 ± 5e4 km) / 31558149.504 ± 5e-4 s

V1(Earth) = (6.283185307179586 × 149600000 ± 5e4km) / 31558149.504 ± 5e-4 s

V1(Earth) = 939964521.954066134416 ± 5e4 km / 31558149.504 ± 5e-4 s

V1(Earth) = 29.785159672778833 ± 0.00159 km/s

1. Find the velocity of Mar’s Orbit:

V2(Mars) = (2𝜋 × R2(Mars) km) / P2(Mars) s

V2(Mars) = (6.283185307179586 × 227920000 ± 5e3 km) / 59329255.68 ± 5e-3 s

V2(Mars) = 1432063595.21237124112 ± 5e3 km / 59329255.68 ± 5e-3 s

V2(Mars) = 24.137562131849271 ± 0.000084 km/s

1. Find the Velocity of the Hohmann Transfer Orbit at its Perihelion (Earth)

V(Hohmann perihelion) = (2𝜋 × a(Hohmann transfer) km / P(Hohmann transfer) s) ×

√((2 × a(Hohmann transfer) km / R1(Earth) km) -1)

V(Hohmann perihelion) = (6.283185307179586 × 188760000 ± 5e4 km / 44731077.518050780798587 ± 4e4 s) ×

√((2 × 188760000 ± 5e4 km/149600000 ± 5e4 km) -1)

V(Hohmann perihelion) = (1186014058.58321865336 ± 5e4 km / 44731077.518050780798587 ± 4e4 s) ×

√((2 × 188760000 ± 5e4 km/149600000 ± 5e4 km) -1)

V(Hohmann perihelion) = (1186014058.58321865336 ± 5e4 km / 44731077.518050780798587 ± 4e4 s) ×

√((377520000 ± 5e4 km/149600000 ± 5e4 km) -1)

V(Hohmann perihelion) = (1186014058.58321865336 ± 5e4 km / 44731077.518050780798587 ± 4e4 s) ×

√((2.523529411764706 ± 0.0018) -1)

V(Hohmann perihelion) = 26.514319001249511 ± 0.02483 km/s × √((2.523529411764706 ± 0.0018) -1)

V(Hohmann perihelion) = 26.514319001249511 ± 0.02483 km/s × √(1.523529411764706 ± 0.0018)

V(Hohmann perihelion) = 26.514319001249511 ± 0.02483 km/s × 1.234313336136617 ± 0.00078)

V(Hohmann perihelion) = 32.726977541822779 ± 0.05133 km/s

1. Find ∆V1(Earth) (the change in Velocity required to enter the Hohmann Transfer orbit at perihelion)

∆V1(Earth) = V(Hohmann perihelion) km/s – V1(Earth) km/s

∆V1(Earth) = 32.726977541822779 ± 0.05133 km/s – 29.785159672778833 ± 0.00159 km/s

∆V1(Earth) = 2.941817869043946 ± 0.05292 km/s

1. Find the Velocity of the Hohmann Transfer Orbit at its Aphelion (Mars)

V(Hohmann aphelion)  = (2 × a(Hohmann transfer) km / P(Hohmann transfer) s) ×

√((2×a(Hohmann transfer) km/R2 km)-1)

V(Hohmann aphelion)  = (6.283185307179586 × 188760000 km / 44731077.518050780798587 s) ×

√((2×188760000 km/227920000 km)-1)

V(Hohmann aphelion)  = (1186014058.58321865336 km / 44731077.518050780798587 s) ×

√((2×188760000 km/227920000 km)-1)

V(Hohmann aphelion)  = (1186014058.58321865336 km / 44731077.518050780798587 s) ×

√((377520000 km/227920000 km)-1)

V(Hohmann aphelion) = (1186014058.58321865336 km / 44731077.518050780798587 s) ×

√((1.656370656370656)-1)

V(Hohmann aphelion) = (1186014058.58321865336 km / 44731077.518050780798587 s) ×

√(0.656370656370656)

V(Hohmann aphelion) = 26.514319001249511 km/s × √(0.656370656370656)

V(Hohmann aphelion) = 26.514319001249511 km/s × 0.810167054607046

V(Hohmann aphelion) = 21.481027730153946 km/s

1. Find ∆V2(Mars) (the change in Velocity required to enter Mars orbit and Hohmann Transfer orbit aphelion)

∆V2(Mars) = V2(Mars) km/s - V(Hohmann aphelion) km/s

∆V2(Mars) = 24.137562131849271 km/s – 21.481027730153946 km/s

∆V2(Mars) = 2.656534401695325 km/s

1. Find the Time of Flight from Earth to Mars (Hohmann Transfer orbit: Perihelion to Aphelion) in seconds

TOF(seconds) = ½ × P(Hohmann transfer) s

TOF(seconds) = ½ × 4.4731077518050780798587e07 s

TOF(seconds) = 2.236553875902539039929e07 s

1. Find the Time of Flight from Earth to Mars (Hohmann Transfer orbit: Perihelion to Aphelion) in days

TOF(days) = TOF(seconds) s / 86400 s/day

TOF(days) = 2.236553875902539039929e07 s / 86400 s/day

TOF(days) = 258.860402303534611 day