Important Preliminary Design Formulas PDF

Formulas
Examples
with Units

List of 27
Important Preliminary Design Formulas

1) Crew Weight given Fuel and Empty Weight Fraction Formula

Evaluate Formula

Formula

$$W_c = DTW \cdot \left(1 - E_f - F_f\right) - PYL$$

Example with Units

$$12600\,\text{kg} = 250000\,\text{kg} \cdot \left(1 - 0.5 - 0.4\right) - 12400\,\text{kg}$$

2) Crew Weight given Takeoff Weight Formula

Evaluate Formula

Formula

$$W_c = DTW - PYL - FW - OEW$$

Example with Units

$$12600\,\text{kg} = 250000\,\text{kg} - 12400\,\text{kg} - 100000\,\text{kg} - 125000\,\text{kg}$$

3) Design Range given Range Increment Formula

Evaluate Formula

Formula

$$R_D = R_H - \Delta R$$

Example with Units

$$52\,\text{km} = 123\,\text{km} - 71\,\text{km}$$

4) Empty Weight Fraction Formula

Evaluate Formula

Formula

$$E_f = \frac{OEW}{DTW}$$

Example with Units

$$0.5 = \frac{125000\,\text{kg}}{250000\,\text{kg}}$$

5) Empty Weight Fraction given Takeoff Weight and Fuel Fraction Formula

Evaluate Formula

Formula

$$E_f = 1 - F_f - \frac{PYL + W_c}{DTW}$$

Example with Units

$$0.5 = 1 - 0.4 - \frac{12400\,\text{kg} + 12600\,\text{kg}}{250000\,\text{kg}}$$

6) Empty Weight given Empty Weight Fraction Formula

Evaluate Formula

Formula

$$OEW = E_f \cdot DTW$$

Example with Units

$$125000\,\text{kg} = 0.5 \cdot 250000\,\text{kg}$$

7) Empty Weight given Takeoff Weight Formula

Evaluate Formula

Formula

$$OEW = DTW - FW - PYL - W_c$$

Example with Units

$$125000\,\text{kg} = 250000\,\text{kg} - 100000\,\text{kg} - 12400\,\text{kg} - 12600\,\text{kg}$$

8) Fuel Fraction Formula

Evaluate Formula

Formula

$$F_f = \frac{FW}{DTW}$$

Example with Units

$$0.4 = \frac{100000\,\text{kg}}{250000\,\text{kg}}$$

9) Fuel Fraction given Takeoff Weight and Empty Weight Fraction Formula

Evaluate Formula

Formula

$$F_f = 1 - E_f - \frac{PYL + W_c}{DTW}$$

Example with Units

$$0.4 = 1 - 0.5 - \frac{12400\,\text{kg} + 12600\,\text{kg}}{250000\,\text{kg}}$$

10) Fuel Weight given Fuel Fraction Formula

Evaluate Formula

Formula

$$FW = F_f \cdot DTW$$

Example with Units

$$100000\,\text{kg} = 0.4 \cdot 250000\,\text{kg}$$

11) Fuel Weight given Takeoff Weight Formula

Evaluate Formula

Formula

$$FW = DTW - OEW - PYL - W_c$$

Example with Units

$$100000\,\text{kg} = 250000\,\text{kg} - 125000\,\text{kg} - 12400\,\text{kg} - 12600\,\text{kg}$$

12) Harmonic Range given Range Increment Formula

Evaluate Formula

Formula

$$R_H = \Delta R + R_D$$

Example with Units

$$123\,\text{km} = 71\,\text{km} + 52\,\text{km}$$

13) Helicopter Flying Range Formula

Evaluate Formula

Formula

$$R = 270 \cdot \frac{G_T}{W_a} \cdot \frac{C_L}{C_D} \cdot \eta_r \cdot \frac{\xi}{c}$$

Example with Units

$$1002.5517\,\text{km} = 270 \cdot \frac{37.5\,\text{kg}}{1001\,\text{N}} \cdot \frac{1.1}{0.51} \cdot 3.33 \cdot \frac{2.3}{0.6\,\text{kg/h/W}}$$

14) Maximum Lift over Drag Formula

Evaluate Formula

Formula

$$LDmax_{ratio} = K_{LD} \cdot \left(\frac{AR}{\frac{S_{wet}}{S}} \right)^{0.5}$$

Example with Units

$$19.799 = 14 \cdot \left(\frac{4}{\frac{10.16\,m^2}{5.08\,m^2}} \right)^{0.5}$$

15) Optimum Range for Jet Aircraft in Cruising Phase Formula

Evaluate Formula

Formula

$$R = \frac{V_{L/D(max)} \cdot LDmax_{ratio}}{c} \cdot \ln\left(\frac{W_i}{W_f} \right)$$

Example with Units

$$1002.4725\,km = \frac{42.9\,kn \cdot 19.7}{0.6\,kg/h/W} \cdot \ln\left(\frac{514\,kg}{350\,kg} \right)$$

16) Optimum Range for Prop-Driven Aircraft in Cruising Phase Formula

Evaluate Formula

Formula

$$R_{opt} = \frac{\eta \cdot LDmax_{ratio}}{c} \cdot \ln\left(\frac{W_i}{W_f} \right)$$

Example with Units

$$42.2435\,km = \frac{0.93 \cdot 19.7}{0.6\,kg/h/W} \cdot \ln\left(\frac{514\,kg}{350\,kg} \right)$$

17) Payload Weight given Fuel and Empty Weight Fractions Formula

Evaluate Formula

Formula

$$PYL = DTW \cdot \left(1 - E_f - F_f \right) - W_c$$

Example with Units

$$12400\,kg = 250000\,kg \cdot \left(1 - 0.5 - 0.4 \right) - 12600\,kg$$

18) Payload Weight given Takeoff Weight Formula

Evaluate Formula

Formula

$$PYL = DTW - OEW - W_c - FW$$

Example with Units

$$12400\,kg = 250000\,kg - 125000\,kg - 12600\,kg - 100000\,kg$$

19) Preliminary Endurance for Jet Aircraft Formula

Evaluate Formula

Formula

$$P_E = \frac{LDmax_{ratio} \cdot \ln\left(\frac{W_i}{W_f} \right)}{c}$$

Example with Units

$$45423.0911\,s = \frac{19.7 \cdot \ln\left(\frac{514\,kg}{350\,kg} \right)}{0.6\,kg/h/W}$$

20) Preliminary Endurance for Prop-Driven Aircraft Formula

Evaluate Formula

Formula

$$E = \frac{LDEmax_{ratio} \cdot \eta \cdot \ln\left(\frac{W_{L(beg)}}{W_{L,end}}\right)}{c \cdot V_{(Emax)}}$$

Example with Units

$$2028.2518\,s = \frac{26 \cdot 0.93 \cdot \ln\left(\frac{400\,kg}{300\,kg}\right)}{0.6\,kg/h/W \cdot 40\,kn}$$

21) Preliminary Take Off Weight Built-up for Manned Aircraft Formula

Evaluate Formula

Formula

$$DTW = PYL + OEW + FW + W_c$$

Example with Units

$$250000\,kg = 12400\,kg + 125000\,kg + 100000\,kg + 12600\,kg$$

22) Preliminary Take off Weight Built-Up for Manned Aircraft given Fuel and Empty Weight Fraction Formula

Evaluate Formula

Formula

$$DTW = \frac{PYL + W_c}{1 - F_f - E_f}$$

Example with Units

$$250000\,kg = \frac{12400\,kg + 12600\,kg}{1 - 0.4 - 0.5}$$

23) Takeoff Weight given Empty Weight Fraction Formula

Evaluate Formula

Formula

$$DTW = \frac{OEW}{E_f}$$

Example with Units

$$250000\,kg = \frac{125000\,kg}{0.5}$$

24) Takeoff Weight given Fuel Fraction Formula

Evaluate Formula

Formula

$$DTW = \frac{FW}{F_f}$$

Example with Units

$$250000\,kg = \frac{100000\,kg}{0.4}$$

25) Velocity at Maximum Endurance given Preliminary Endurance for Prop-Driven Aircraft Formula

Evaluate Formula

Formula

$$V_{(Emax)} = \frac{LDEmax_{ratio} \cdot \eta \cdot \ln\left(\frac{W_{L(beg)}}{W_{L,end}}\right)}{c \cdot E}$$

Example with Units

$$40.005\,kn = \frac{26 \cdot 0.93 \cdot \ln\left(\frac{400\,kg}{300\,kg}\right)}{0.6\,kg/h/W \cdot 2028\,s}$$

26) Velocity for Maximizing Range given Range for Jet Aircraft Formula

Evaluate Formula

Formula

$$V_{L/D(max)} = \frac{R \cdot c}{LDmax_{ratio} \cdot \ln\left(\frac{W_i}{W_f}\right)}$$

Example with Units

$$42.7942\,\text{kn} = \frac{1000\,\text{km} \cdot 0.6\,\text{kg/h/W}}{19.7 \cdot \ln\left(\frac{514\,\text{kg}}{350\,\text{kg}}\right)}$$

27) Winglet Friction Coefficient Formula

Evaluate Formula

Formula

$$\mu_{friction} = \frac{4.55}{\log10\left(Re_{wl}^{2.58}\right)}$$

Example

$$0.4768 = \frac{4.55}{\log10\left(5000^{2.58}\right)}$$

Variables used in list of Preliminary Design Formulas above

- **AR** Aspect Ratio of a Wing
- **c** Power Specific Fuel Consumption *(Kilogram per Hour per Watt)*
- C_D Drag Coefficient
- C_L Lift Coefficient
- **DTW** Desired Takeoff Weight *(Kilogram)*
- **E** Endurance of Aircraft *(Second)*
- E_f Empty Weight Fraction
- F_f Fuel Fraction
- **FW** Fuel Weight to be Carried *(Kilogram)*
- G_T Weight of Fuel *(Kilogram)*
- K_{LD} Landing Mass Fraction
- $LDEmax_{ratio}$ Lift to Drag Ratio at Maximum Endurance
- $LDmax_{ratio}$ Maximum Lift-to-Drag Ratio of Aircraft
- **OEW** Operating Empty Weight *(Kilogram)*
- P_E Preliminary Endurance of Aircraft *(Second)*
- **PYL** Payload Carried *(Kilogram)*
- **R** Range of Aircraft *(Kilometer)*
- R_D Design Range *(Kilometer)*
- R_H Harmonic Range *(Kilometer)*
- R_{opt} Optimum Range of Aircraft *(Kilometer)*
- Re_{wl} Winglet Reynolds Number
- **S** Reference Area *(Square Meter)*
- S_{wet} Aircraft Wetted Area *(Square Meter)*
- $V_{(Emax)}$ Velocity for Maximum Endurance *(Knot)*
- $V_{L/D(max)}$ Velocity at Maximum Lift to Drag Ratio *(Knot)*
- W_a Aircraft Weight *(Newton)*
- W_c Crew Weight *(Kilogram)*
- W_f Weight of Aircraft at End of Cruise Phase *(Kilogram)*

Constants, Functions, Measurements used in list of Preliminary Design Formulas above

- Functions: **ln**, ln(Number)
  The natural logarithm, also known as the logarithm to the base e, is the inverse function of the natural exponential function.
- Functions: **log10**, log10(Number)
  The common logarithm, also known as the base-10 logarithm or the decimal logarithm, is a mathematical function that is the inverse of the exponential function.
- Measurement: **Length** in Kilometer (km)
  Length Unit Conversion
- Measurement: **Weight** in Kilogram (kg)
  Weight Unit Conversion
- Measurement: **Time** in Second (s)
  Time Unit Conversion
- Measurement: **Area** in Square Meter (m²)
  Area Unit Conversion
- Measurement: **Speed** in Knot (kn)
  Speed Unit Conversion
- Measurement: **Force** in Newton (N)
  Force Unit Conversion
- Measurement: **Specific Fuel Consumption** in Kilogram per Hour per Watt (kg/h/W)
  Specific Fuel Consumption Unit Conversion

- W_i Weight of Aircraft at Beginning of Cruise Phase *(Kilogram)*
- $W_{L(beg)}$ Weight of Aircraft at Beginning of Loiter Phase *(Kilogram)*
- $W_{L,end}$ Weight of Aircraft at End of Loiter Phase *(Kilogram)*
- ΔR Range Increment of Aircraft *(Kilometer)*
- η Propeller Efficiency
- η_r Rotor Efficiency
- $\mu_{friction}$ Coefficient of Friction
- ξ Coefficient of Power loss

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