EXERCISE SOLAR IMPULSE - SOLUTION

a)
Using the course formulas on solar irradation, we have, for July 1st (Day J = 182) at 25°N:
- $(r\_avg/r)^2$ = 0.967 and for the
- declination δ on J = 182 => 23.12°, or 0.4035 rad
- from δ we then obtain $\sin\delta$ = 0.39266 and $\tan\delta$ = 0.42695
- from the latitude ϕ = 25° we obtain $\sin\phi$ = 0.4226 and $\tan\phi$ = 0.4663
- for the hour angle $H_{D/2}$ we get 101.5° (1.7715 rad) or 6.766 h for the length of half a day of sunshine, thus 13.53 h for the length of daylight on July 1st at 25°N. ($\tan H_{D/2}$ = -4.915)
=> daytime 13.5; nighttime 10.5 h.
Finally, we compute the solar irradiance input per square meter of horizontal plane on July 1st to :
10.45 kWh*0.9(albedo)*0.967*0.39266*0.4226*(1.7715 + 4.915) =
10.45 kWh*0.9*0.967*0.166*(6.6865) = 10.45 kWh*0.9*0.967*1.11 = **10.09 kWh/m²**

At best, the solar input on July 1st at 25°N = 10.09 kWh/m² for 275 m² PV panels = **2776 kWh**. With 20% PV efficiency, this amounts to 2775 x 0.2 = **555 kWhe** electricity, and with the PV-to-engine efficiency (77%), see (b), this is 555 x 0.77 = 427.3 kWhe.

b)
Peak input of 1367 W/m² * 0.9 (albedo 10% at 10 km height) = 1230 W/m²
=> for 275 m²: 338.33 kWp solar input
PV efficiency 20% => 67.67 kWp electrical
Propulsion train efficiency: 4 engines of 13 kWe = 52 kWe max obtained from 67.7 kWp PV production
=> efficiency = 52/67.67 **= 77%.**

c) and d)
7000 km distance to cover at 80 km/h at day (13.5 h), at 60 km/h at night (10.5 h), for 5 days and nights.

Battery : 650 kg * 0.25 kWh/kg = 162.5 kWhe; depth of discharge 95% => 154.4 kWhe available.
Nighttime : 154.4 kWhe battery power => 77% propulsion efficiency gives 119 kWhe to the engines; 60 km/h for 10.5 h = 628 km => max consumption **246 Whe/km** (battery energy based), and average engine power 119 kWhe/10.5h = **11.3 kWe**

Daytime : 555 kWhe PV max produced, out of which 162.5 kWeh/90% (charging efficiency) = 180.56 kWhe are consumed to fully charge the batteries for the night flight. I.e. 374.69 kWhe are left, supplied to the engine with 77% efficiency, hence 287.9 kWhe. 80 km/h for 13.5 h = 1082 km => max consumption **346 Whe/km** (battery energy based), and average engine power 288.3 kWhe/13.5h = **21.3 kWe**