EJERCICIO: Utilización del programa CEA para el cálculo de las actuaciones de un motor cohete

a) Resolución analítica

$$AH_2 + BO_2 \longrightarrow CH_2 + DO_2 + EH_2O$$

Reacción química equilibrada: $\frac{1}{2}O_2 + H_2 \rightarrow H_2O$ => $\frac{1}{2}x16x2 + 2x1 = 18$ => Relación en peso oxidante /reductor en reacción equilibrada = 16/2=8 > 3.4 => Exceso de combustible (H_2) => D=0

H: $2A = 2C + 2E$

O: $2B = E$

- ⇨ $E = 2B$; $C = A - 2B$
- ⇨ $\frac{32xB}{2xA} = 3.4 = \frac{17}{5}$ => $80B = 17A$; => A = 80; B = 17; E = 34; C = 46

Reacción del problema (no equilibrada): $17O_2 + 80H_2 \rightarrow 34H_2O + 46H_2$

$\bar{\mathcal{M}} = \frac{C\mathcal{M}_{H_2} + D\mathcal{M}_{O_2} + E\mathcal{M}_{H_2O}}{C+D+E} = \frac{46 \cdot 2 + 34 \cdot 18}{46+34} = 8.8$

$R = \frac{R_U}{\bar{\mathcal{M}}} = \frac{8341}{8.8} = 944.77 \frac{J}{kgK}$

$\gamma = 1.28$ => $\Gamma(\gamma) = \sqrt{\gamma}\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{2(\gamma-1)}} = 0.6636$

$P_c = 1000\ psia = 6894760\ Pa$

$\varepsilon = \frac{A_s}{A_g} = \frac{\Gamma(\gamma)}{\left(\frac{P_S}{P_c}\right)^{1/\gamma}\sqrt{\frac{2\gamma}{\gamma-1}\left[1-\left(\frac{P_S}{P_c}\right)^{\frac{\gamma-1}{\gamma}}\right]}} = 7$ => Iteración => $\frac{P_S}{P_c} = 0.0166$

$P_s = 114697.5\ Pa$

$C_{Eadap} = \Gamma(\gamma)\sqrt{\frac{2\gamma}{\gamma-1}\left[1-\left(\frac{P_S}{P_c}\right)^{\frac{\gamma-1}{\gamma}}\right]} = 1.5436$

$C_{Evac} = \Gamma(\gamma)\sqrt{\frac{2\gamma}{\gamma-1}\left[1-\left(\frac{P_S}{P_c}\right)^{\frac{\gamma-1}{\gamma}}\right]} + \varepsilon\frac{P_S}{P_c} = 1.66$

$c^* = \frac{\sqrt{RT_c}}{\Gamma(\gamma)} = 2519.93\ m/s$

$I_{SPadap} = C_{Eadap} \cdot c^* = 3889.96\ m/s$

$I_{SPvac} = C_{Evac} \cdot c^* = 4183.40\ m/s$

$I_{SPadap}(s) = \frac{I_{SPadap}\left(\frac{m}{s}\right)}{9.81} = 396.53\ s$

$I_{SPvac}(s) = \frac{I_{SPvac}\left(\frac{m}{s}\right)}{9.81} = 426.44\ s$

Productos: Fracción molar del H_2O: $x_{H_2O}(\%) = \frac{34}{34+46} = 0.425$

Fracción molar del H_2: $x_{H_2}(\%) = \frac{46}{34+46} = 0.575$

b) Resolución CEA

	CHAMBER	THROAT	EXIT
Pinf/P	1.0000	1.7762	55.940
P, BAR	68.947	38.818	1.2325
T, K	2960.00	2700.19	1375.72
RHO, KG/CU M	2.4650 0	1.5272 0	9.5576-2
H, KJ/KG	438.60	-1094.31	-7549.24
U, KJ/KG	-2358.48	-3636.05	-8838.83
G, KJ/KG	-69720.7	-65095.6	-40157.3
S, KJ/(KG)(K)	23.7025	23.7025	23.7025
M, (1/n)	8.799	8.833	8.870
(dLV/dLP)t	-1.00403	-1.00209	-1.00000
(dLV/dLT)p	1.0791	1.0446	1.0000
Cp, KJ/(KG)(K)	6.6043	5.9363	4.2668
GAMMAs	1.1942	1.2062	1.2816
SON VEL,M/SEC	1827.6	1750.9	1285.6
MACH NUMBER	0.000	1.000	3.109

Ae/At	1.0000	7.0000
CSTAR, M/SEC	2578.4	2578.4
CF	0.6791	1.5502
Ivac, M/SEC	3202.6	4319.6
Isp, M/SEC	1750.9	3997.0

MOLE FRACTIONS			
*H	0.01261	0.00688	0.00000
*H2	0.56244	0.56652	0.57161
H2O	0.42159	0.42514	0.42839
*O	0.00004	0.00001	0.00000
*OH	0.00330	0.00145	0.00000
*O2	0.00001	0.00000	0.00000

c) Comparativa

	Analítico	**CEA**
Pc/Ps	60.11	55.94
Ps (Pa)	114698	123250
γ	1.28	1.2816
c* (m/s)	2519.9	2578.4
C_{Eadap}	1.5437	1.5502
I_{SPvac} (m/s)	4183.4	4319.6
I_{SPadap} (m/s)	3890.0	3997.0
x_{H_2O}	0.425	0.42839
x_{H_2}	0.575	0.57161