The Abdus Salam
International Centre for Theoretical Physics

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Meeting of Modern Science and School Physics: College for School Teachers of Physics in ICTP

27 April - 3 May, 2011

Physics of flight (aerodynamics)

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Physics of Flight

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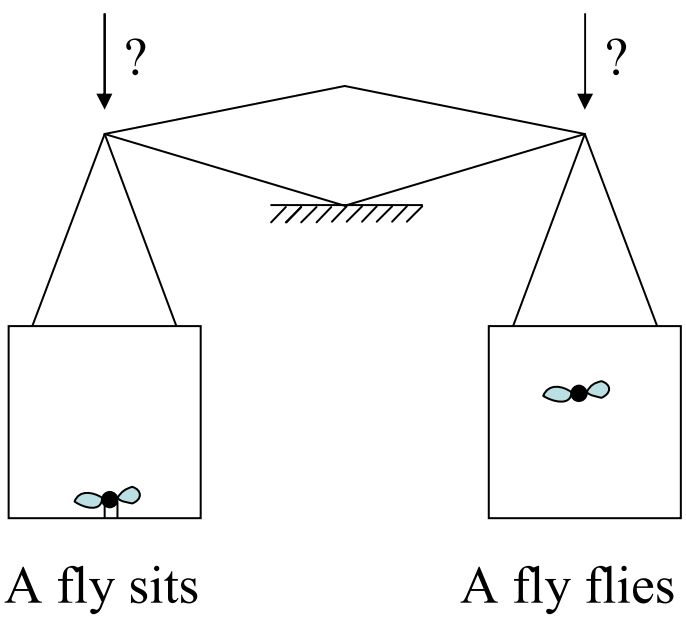
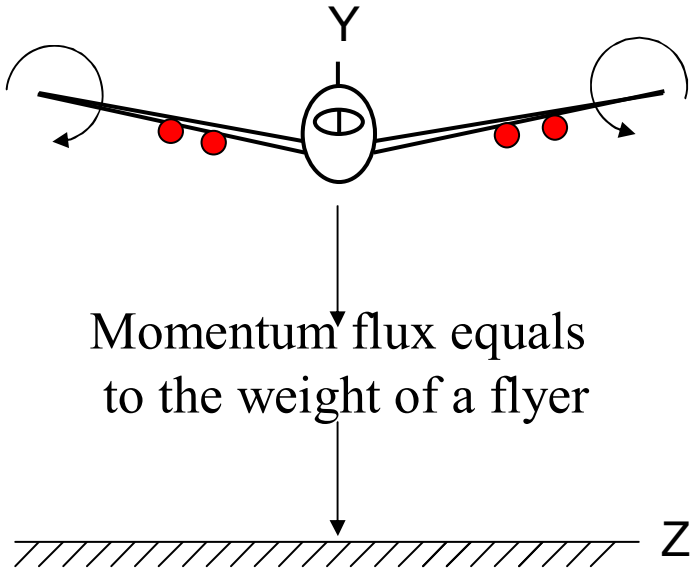
AND FLIGHT ENGINEERING

Principal topics

1. General aerodynamic force
2. Parachute area
3. An aircraft leans against the earth surface
4. Those dangerous vortices (animations)
5. An Eagle and a Sparrow
6. Reactive movement
7. Flight and potential energy
8. That huge ORION Project
9. Does the “cosmic cold” exit?
10. Reentry corridor
11. Vehicle heat-proof

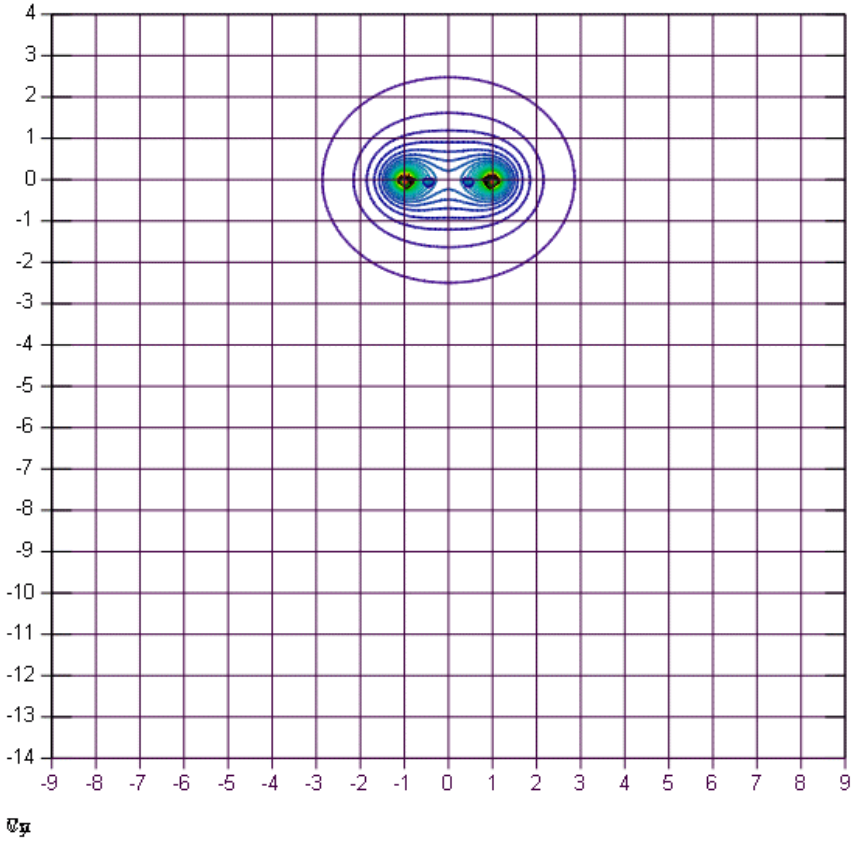
A flyer presses upon the earth surface





Descending aircraft vortices in the calm atmosphere

Aircraft position y = 0, -1 < z < 1



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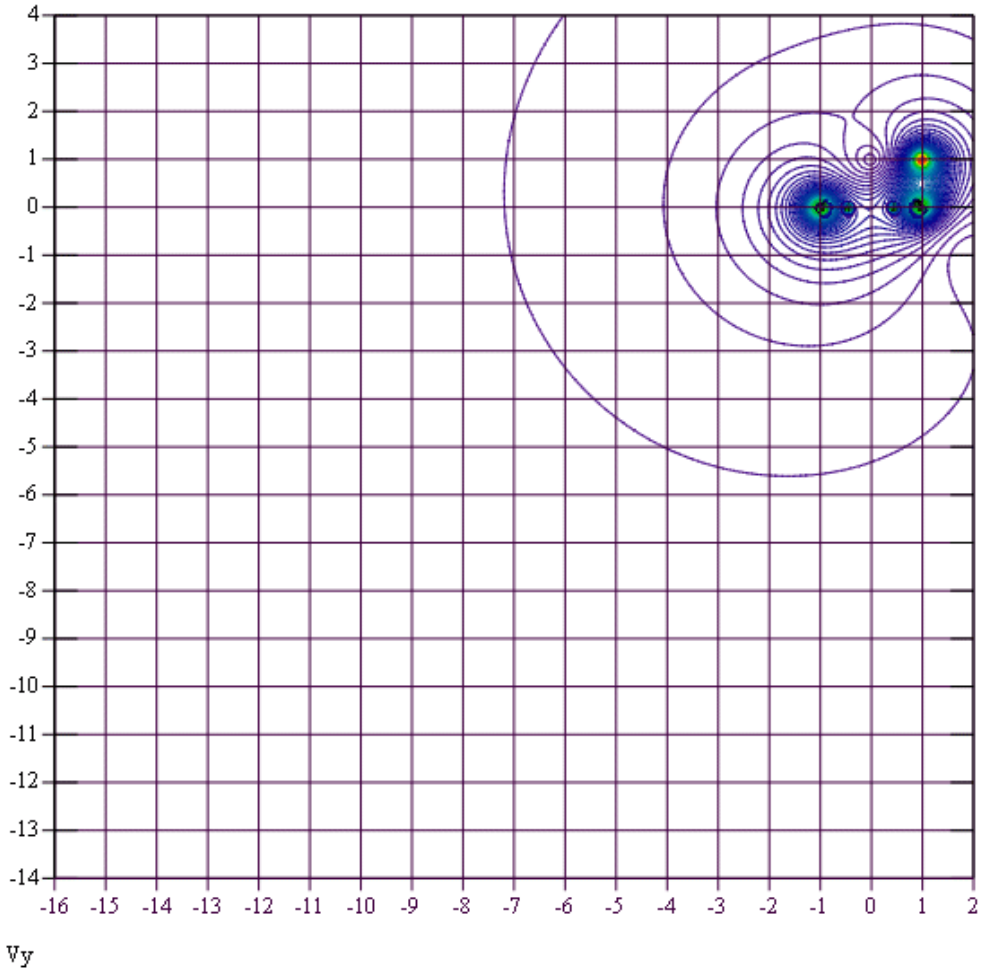
Aircraft meets an alien vortex (see up and right)



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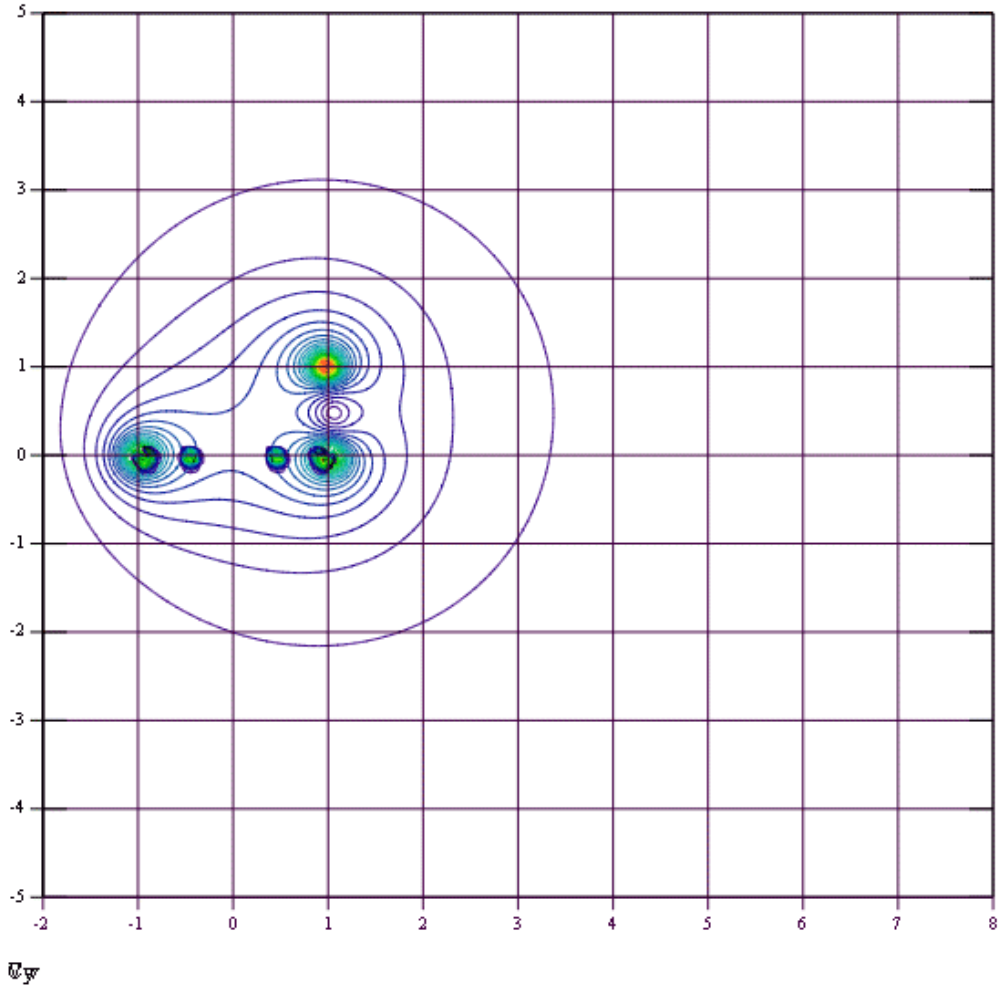
The same, an alien vortex of the opposite size



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PRINCIPAL AERODYNAMIC FORCE

DEPENDS ON ρ V L

$\frac{\mathrm{kg}}{\mathrm{m}^3}$ $\frac{\mathrm{m}}{\mathrm{s}}$ m

$$F \sim \rho V^2 L^2, \quad \mathrm{N} = \frac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}$$

or $F \sim \rho V L \Gamma$ (Kutta – Zhukovsky)

$\Gamma \sim VL$ – circulation, $\frac{\mathrm{m}^2}{\mathrm{s}}$

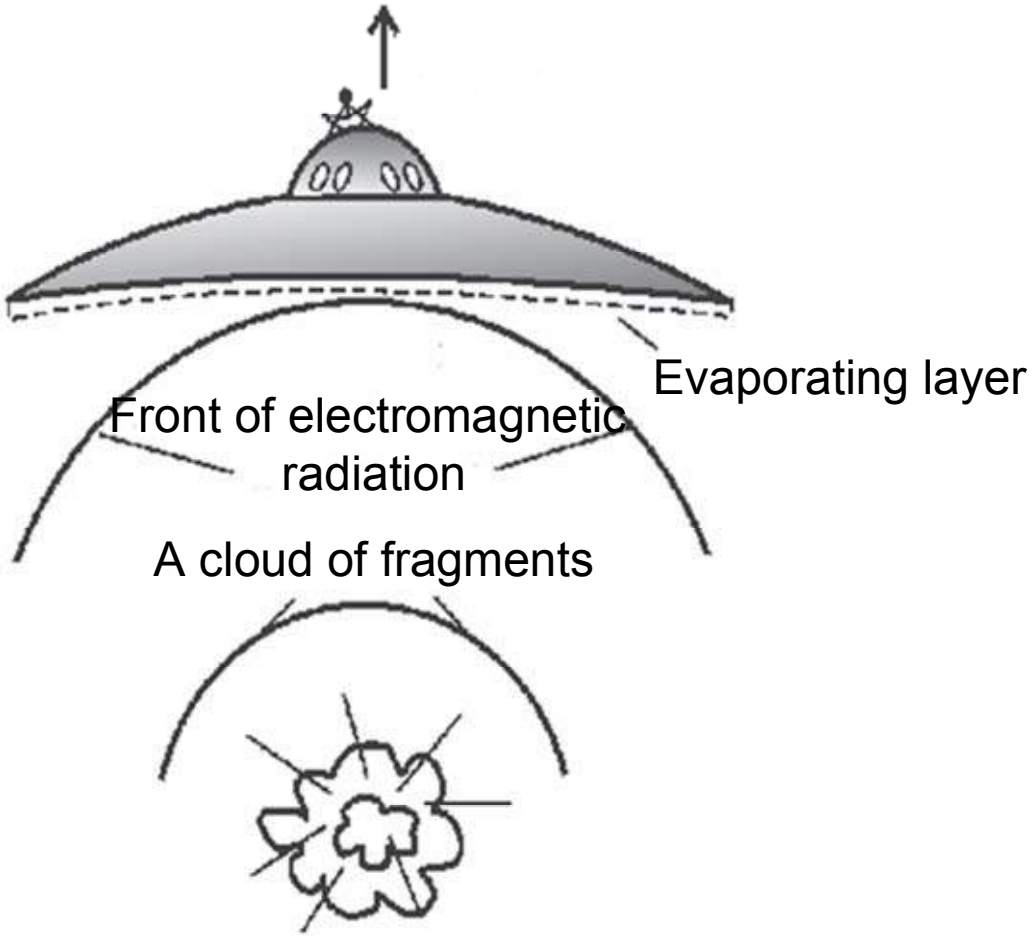
What parachute area needed?

$$m\,g \approx \rho V^2 S_\perp,$$

$$S_\perp \sim \frac{mg}{\rho V^2} \approx \frac{10^2\,\mathrm{kg}\cdot 10\,\frac{\mathrm{m}}{\mathrm{s}^2}}{1\,\frac{\mathrm{kg}}{\mathrm{m}^3}\cdot 25\,\frac{\mathrm{m}^2}{\mathrm{s}^2}} \approx 40\,\mathrm{m}^2$$

$$V \le 5\,\frac{\mathrm{m}}{\mathrm{s}}$$

The huge ORION Project



The step-by-step acceleration of the vehicle
is provided with the explosions of atom bombs

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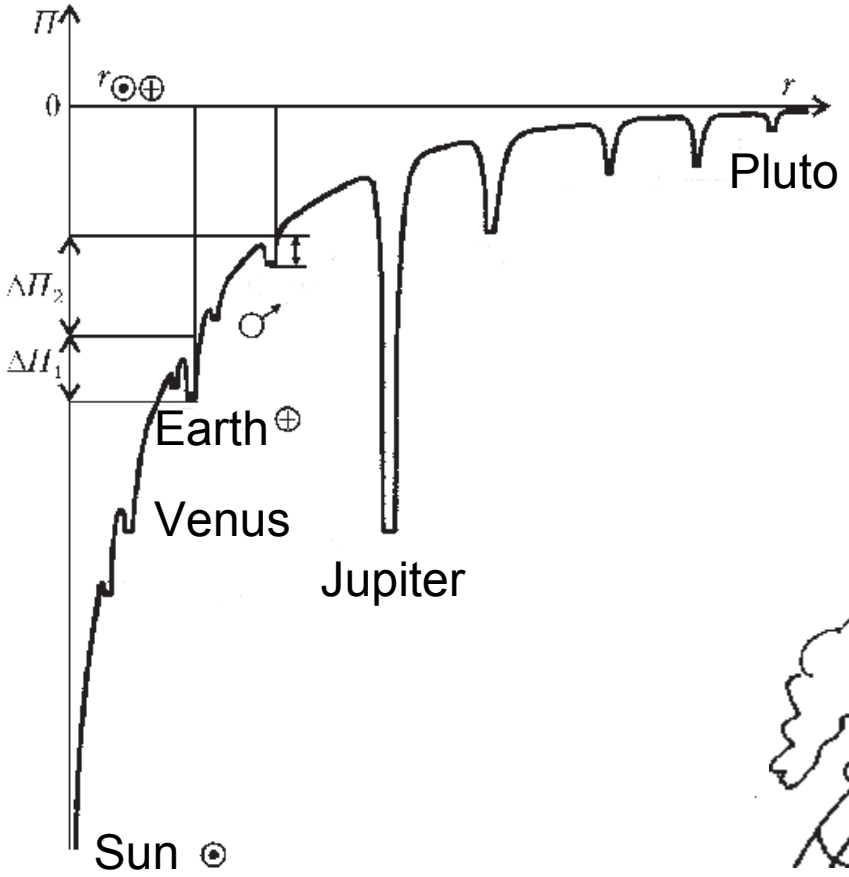
Interplanetary mission
from the point of view of potential energy



Potential energy of a body in dependence on its distance from the Sun center
(the case of “parade of planet”)

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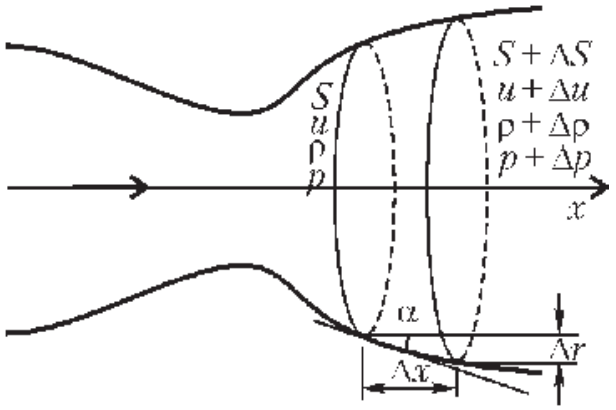
Reactive Movement

E.K. Tsiolkovsky formula

$$\frac{u}{u_{exit}} = \ln\frac{m}{m_0}$$



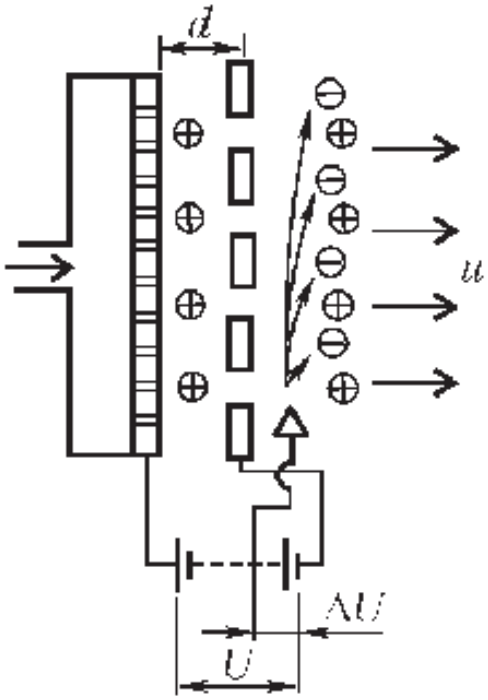
$$\rho u S = \text{const}$$

$$p = \rho\frac{RT}{M}$$

$$\frac{u^2}{2} + \frac{5}{2}\frac{RT}{M} = const$$

$$\rho u \Delta u = -\Delta p$$

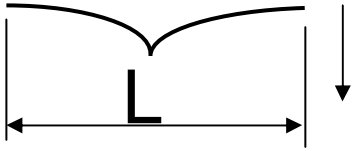
de Laval nozzle which allows to accelerate the gas over sound velocity



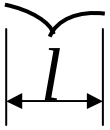
Scheme of the ion thruster

An eagle and a sparrow

Eagle, $M \sim L^3$ Sparrow, $m \sim l^3$



$V \sim \Omega L$



$v \sim \omega l$

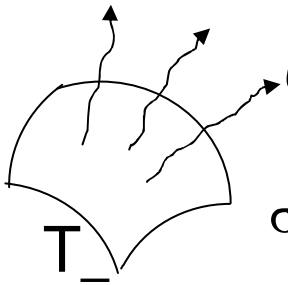
$$Mg \sim \rho V^2 L^2 \sim \rho \Omega^2 L^4 \sim L^3 g$$

$$Mg \sim \rho v^2 l^2 \sim \rho \omega^2 l^4 \sim l^3 g$$

$$\omega^2 l \approx \Omega^2 L \qquad \frac{\omega}{\Omega} = \sqrt{\frac{L}{l}}$$

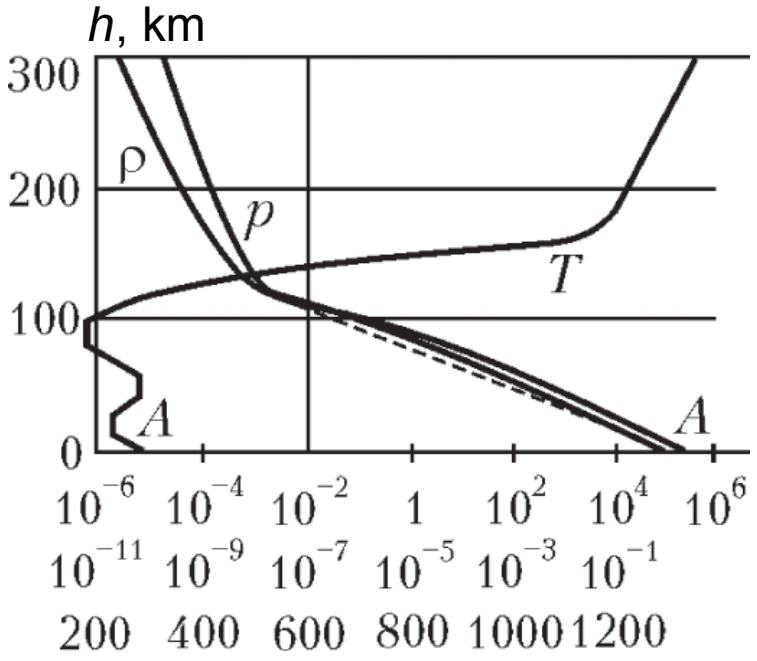
Is there cold in Space?

Heat Radiation

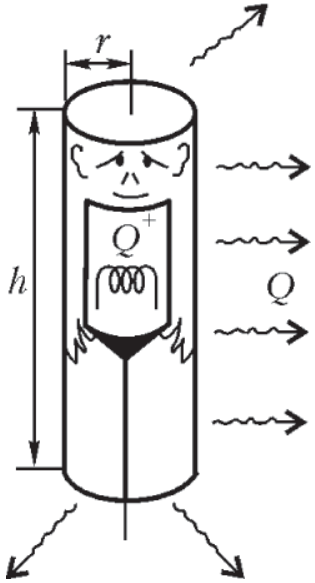


$$q = \sigma T^4 \qquad \frac{\mathrm{W}}{\mathrm{m}^2}$$

$$\sigma = 5.7 \cdot 10^{-8} \frac{\mathrm{W}}{\mathrm{m}^2 \mathrm{K}^4}$$



A simple model of human being



$$q_o = 1400 \frac{\mathrm{W}}{\mathrm{m}^2}$$

Heat balance

$$Q_o + q_o S_\perp = \sigma T_h^4 S$$

$T_h \sim 350$ K $\rightarrow$ $T_h \sim 80^o$ C !!!

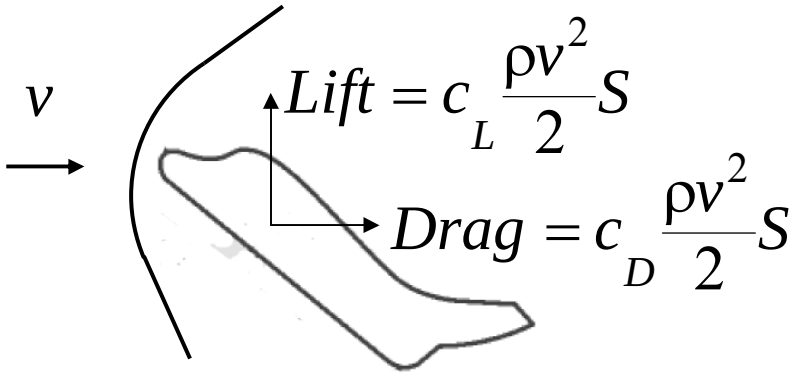
REENTRY CORRIDOR

Severe Restriction

AB: $v \le v_1 = \sqrt{gR_E}$

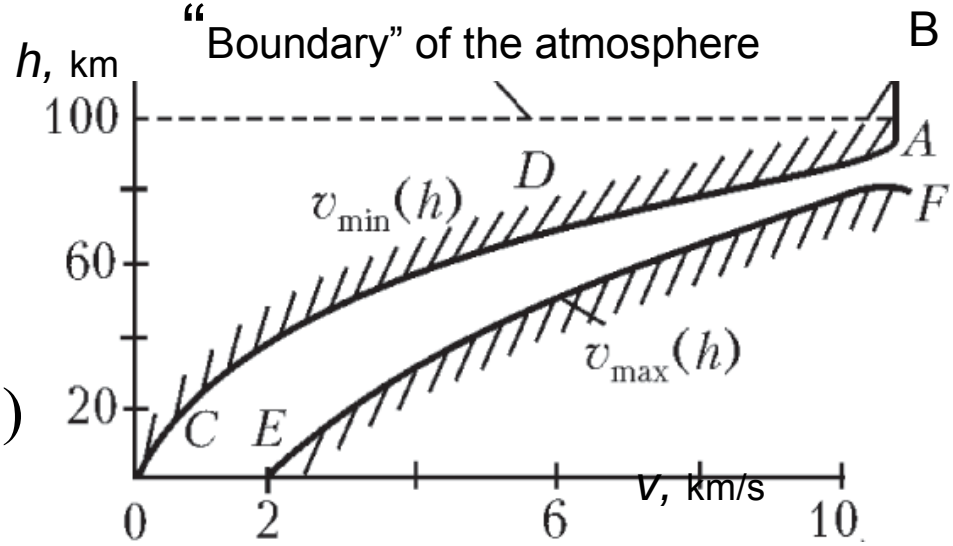
CD: $c_L \rho v^2 S \ge m(g - \frac{v^2}{R_E})$

EF: $\frac{v}{2}\rho v \le \sigma T_m^4$

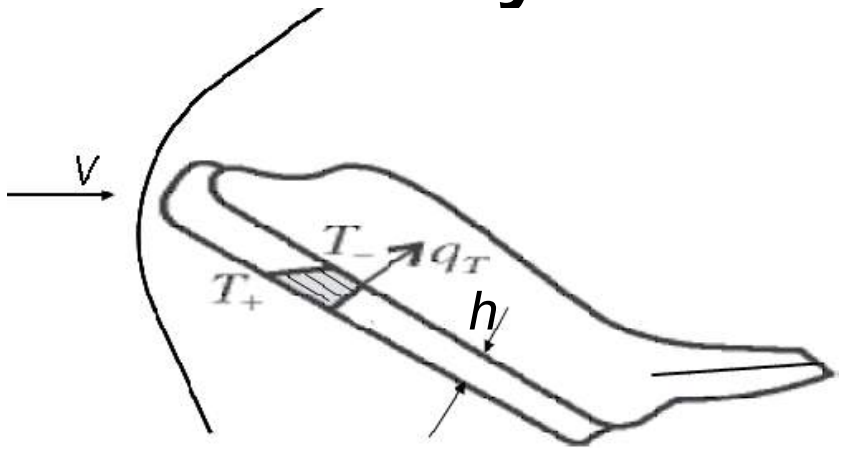


Heat to the flyer

$$Q = c_D S \rho v^3 = \frac{c_D m}{c_L R_E} v(v_1^2 - v^2)$$



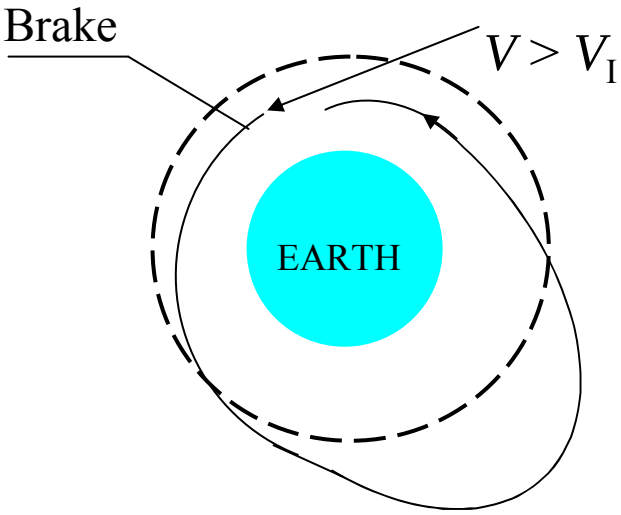
Reentry Vehicle Heat-Proof



$$q = \lambda \frac{T_+ - T_-}{h}, \frac{\mathrm{J}}{\mathrm{m}^2\mathrm{s}}; \quad \tau \sim \frac{\rho_m c h^2}{\lambda} \sim$$

$$\sim \frac{10^2 \frac{\mathrm{kg}}{\mathrm{m}^3} \cdot 10^3 \frac{\mathrm{J}}{\mathrm{kg}\cdot\mathrm{K}} \cdot (10^{-1}\mathrm{m})^2}{10^2 \frac{\mathrm{J}}{\mathrm{m}\cdot\mathrm{s}\cdot\mathrm{K}}} \sim 10^5 \mathrm{s}$$

entrance



Thank you very much
for your attention !

It was nice to see you…