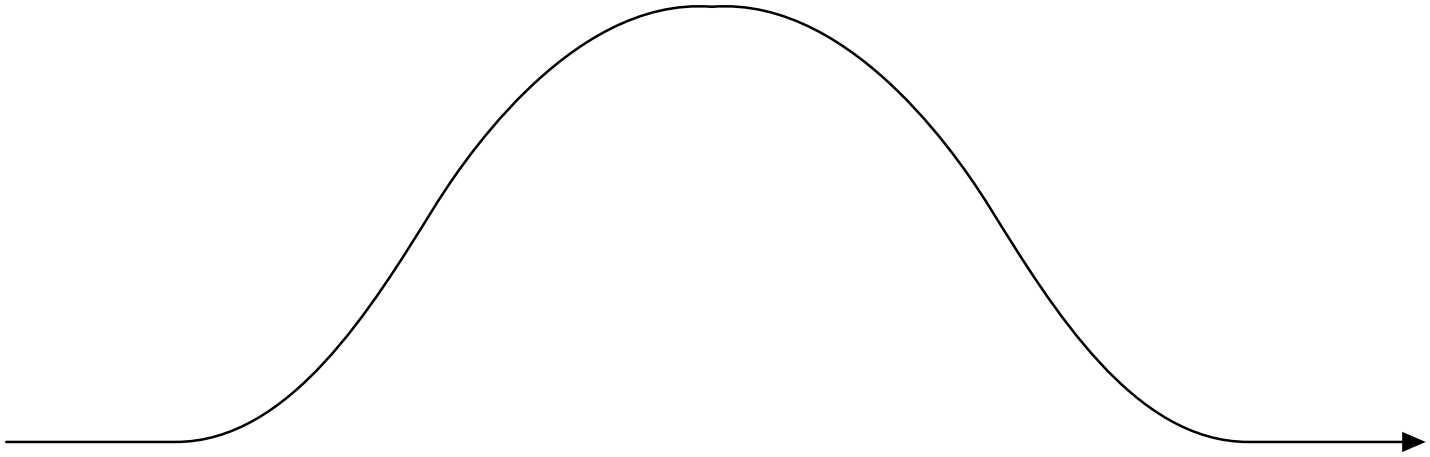
Problem T1. Zero gravity *(10 points)*

Part A. Zero-g flight *(3 points)*

i. (0.5 pts) Mark on the figure, where the zero-g flight starts, and where it ends



ii. (0.5 pts) Direction and magnitude of the acceleration (expression and value)

iii. (0.5 pts) The speed of the airplane at the highest point of its trajectory (expression and value)

iv. (0.5 pts) Time taken for the airplane to reach the highest point in its trajectory (expression and value)

v. (0.5 pts) Altitude of the airplane at the highest point of its trajectory from the sea level (expression and value)

vi. (0.5 pts) Maximal total duration of a zero-g flight segment (expression and value)

Part B. Glass of water in weightlessness *(3 points)*

i. (1 pt) Sketch of the new equilibrium shape of the water surface at the axial cross-section of the glass

ii. (1 pt) Minimal distance between the water surface and the bottom of the glass at the new equilibrium state (expression and value)

iii. (1 pt) Maximal volume of water which can be held in this glass in weightlessness (expression and value) and a corresponding sketch of the shape of the water surface at the axial cross-section of the glass

Part C. Sharpshooter on geostationary orbit *(4 points)*

i. (0.7 pts) Radius of the geostationary orbit (expression and value)

ii. (1.8 pts) Aiming angle of the rifle with respect to the vector pointing towards the centre of the Earth (expression and value)

iii. (1.5 pts) Bullet's smallest possible travel time until hitting the spaceship

Problem T2. Controlled fusion *(11 points)*

Part A. General considerations *(0.5 points)*

i. (0.5 pts) fusion temperature T_0 in Kelvins

Part B. Tokamak *(2.5 points)*

i. (0.5 pts) Sketch of the magnetic field lines of an infinitely long straight current

ii. (0.5 pts) Sketch of the magnetic field lines of a circular current loop

iii. (0.75 pts) Sketch of the magnetic field lines of an infinitely long straight current passing coaxially through a circular current loop which starts from a small distance from the circular current

iv. (0.75 pts) Sketch of the magnetic field lines of an infinitely long straight current passing coaxially through a circular current loop which starts from a small distance from the straight current

Part C. Cold fusion *(3.5 points)*

i. (1 pt) Expression of p in terms of R and other natural constants (expression)

ii. (1 pt) Estimate of the radius R of the ground state (expression and value for both the electron and the muon)

iii. (1 pt) Equilibrium distance between the two nuclei (expression and value for both the electron and the muon)

iv. (0.5 pts) Number of times by which the distance between the deuterium and tritium atoms reduced when orbital electrons are substituted by muons

Part D. Inertial confinement fusion *(4.5 points)*

i. (0.5 pts) Mass of the small piece of shell of surface area ΔA (expression)

ii. (1 pt) Initial acceleration of a small piece of the shell (expression)

iii. (1.5 pts) Minimal radius of the shell r_m and the maximal temperature T_m (expressions)

iv. (1.5 pts) Estimate of the pressure p_e in terms of P, r and u

Problem T3. RayleighTaylor instability *(9 points)*

Part A. Instability growth rate *(4 points)*

i. (1 pt) Potential energy of the system (expression)

ii. (1 pt) Kinetic energy of the system in terms of v and other previously defined quantities

iii. (1 pt) Proof that the displacement x grows exponentially in time and an expression for the corresponding instability growth rate γ

iv. (1 pt) Instability growth rate γ for the spherical shell (expression)

Part B. Stabilization due to surface tension *(3 points)*

i. (1 pt) A sketch of the new shape of the interface in $x-y$-intersection when $d = d_0$ and when it has become noticeably deformed due to the Rayleigh-Taylor instability

ii. (1 pt) A sketch of the shape of the interface when $d = d_1$ and it has become noticeably deformed due to the Rayleigh-Taylor instability, in two $x - y$-intersections: one at the distance $l/4$ from one end of the slit, and the other — at the distance $l/4$ from the other end of the slit

iii. (1 pt) An expression for d_1 in terms of ρ_1, ρ_2, σ, and g

Part C. Gravity surface waves *(2 points)*

i. (2 pts) Speed of the boat (expression and value)