STUDENT No

ANSWER SHEET

PROBLEM 1

GPhO Riyadh 2017

## Problem T1. Main sequence stars *(11 points)*

### Part A. Lifetime of Sun *(3 points)*

**i. (0.7 pts)** The total radiation power of the Sun (expression and value in watts)

**ii. (0.5 pts)** Proof that the energy released by such a fusion of four protons is $W_0 = 24\,\text{MeV}$

**iii. (0.5 pts)** Energy carried away from Sun by photons and neutrinos per each fusion of four protons (expression and value

**iv. (1.3 pts)** An estimate for the total lifetime of the Sun (expression and value)

### Part B. Mass-luminosity relationship of stars *(4.5 points)*

**i. (0.4 pts)** Free fall acceleration at point $Q$ (expression)

**ii. (0.4 pts)** Free fall acceleration at point $Q$ (expression)

**iii. (0.4 pts)** Gravity force acting on a piece of the spherical layer (expression)

**iv. (0.4 pts)** Core pressure $p_c$ (expression)

**v. (1 pt)** $p_c$ expressed in terms of $R_0$, $M$, and $T_c$:

**vi. (0.4 pts)** $R_0$ expressed in terms of $M$ and $T_c$:

**vii. (1.5 pts)** Assuming $P \propto M^{\gamma}$, expression for the exponent $\gamma =$

## Part C. Proton-proton fusion chain *(3.5 points)*

**i. (1.5 pts)** Expression in terms of fundamental constants and value for the dimensionless combination $\alpha^{-1}$

**ii. (1 pt)** Estimate for the fusion temperature $T'$ based on classical thermodynamics (expression and value)

**iii. (1 pt)** The tunnelling probability for the proton-proton fusion reaction (expression)

## Problem T2. Water tube *(8 points)*

**i. (0.5 pts)** Expression and value for $p_P - p_Q$

**ii. (1.5 pts)** Sketch of the tube with all the forces; expressions and magnitudes for these forces

**iii. (1.2 pts)** Expressions and values of the pressures $p_P$ and $p_Q$

**iv. (0.8 pts)** Expression and value of the tension force $T$ in the steel bar

**v. (1 pt)** Why does the tube jump: a qualitative explanation

**vi. (3 pts)** The duration $\tau$ (expression and value) during which the tube remains standing

## Problem T3. Accelerating shock wave *(11 points)*

**i. (1 pt)** The velocity components $v'_x$, $v'_y$, $v'_z$ of the electron after being hit by the shock wave

**ii. (1 pt)** A qualitative sketch of the trajectory drawn by the electron (at least $t = \frac{\pi m}{Be}$)

**iii. (0.5 pts)** The curvature radius of the electron's trajectory immediately after its first collision with the shock wave

**iv. (1 pt)** An equation for determining the time the second impact $t_2$, and a numerically obtained expression for $t_2$

**v. (0.5 pts)** An expression for the average $x$-directional velocity $v_x$ of the electron

**vi. (1.5 pts)** Proof that $v_y + kx = \text{const}$, and an expression for $k$

**vii. (1 pt)** An expression for the average $y$-directional acceleration $a_y$ of the electron

**viii. (1 pt)** A sketch for the electron's *phase trajectory*

**ix. (1.5 pts)** An expression for the total kinetic energy $W_f$ of the electron when it falls behind the shock wave

**x. (2 pts)** By which relativistic energies of the electron will it fall behind the shock wave