MŰEGYETEM 1782

# FLUID MECHANICS

## TESTS

Attention: there might be more correct answers to the questions.

## **Chapter 12**: Compressible flows, gas dynamics, basics of acoustics

**T.12.1.1** An airplane travels below the speed of sound of the respective ambient temperature. Assume isentropic conditions. On the nose there is a stagnation point, where temperature is $T_s$, pressure is $p_s$. Ambient temperature, density, and pressure are $T$, $\rho$, and $p$, respectively. $R$ is the gas constant, $c_p$ is specific heat. Choose the correct equations!

*a,* $T_t = \frac{\rho}{2} v^2$

*b,* $T_t = T + \frac{v^2}{2c_p}$

*c,* $T_t = T + \frac{v^2}{2}$

*d,* $p_t = p + \frac{\rho}{2} v^2$

*e,* $T_t = T - \frac{v^2}{2R}$

The answer is:

**T.12.1.2** In case of an inviscid steady flow without heat conduction the energy equation has the following form: $\underline{v}\text{grad}\left(\frac{v^2}{2} + c_p T\right) = 0$, where $v$ is velocity, $T$ is temperature and $c_p$ is specific heat. Using the above form, the following equation can be obtained: $\left(\frac{v^2}{2} + c_p T\right) = const$, for which the following statements can be made:

*a, only valid if* $\text{grad}\left(\frac{v^2}{2} + c_p T\right) = 0$

*b, valid because the velocity field has no vortices*

*c, only valid in case of laminar flows*

*d, valid for points on one streamline*

*e, only valid for 1D flows in pipes with constant cross-section*

The answer is:

**T.12.2.1**Speed of sound is calculated as:

*a,* $\sqrt{\kappa R T}$

*b,* $\sqrt{\frac{\mathrm{d}p}{\mathrm{d}\rho}}$

*c,* $\sqrt{\frac{\mathrm{d}\rho}{\mathrm{d}p}}$

*d,* $\sqrt{\frac{R T}{\kappa}}$

*e,* $\sqrt{\frac{p}{R T}}$

The answer is:

**T.12.2.2** The isentropic change of state is

*a, frictional and isolated*

*b, frictionless and isothermal*

*c, frictionless and isolated*

*d, frictionless and irreversible*

*e, None of the above are correct.*

The answer is:

**T.12.3.1** In case of a frictionless flow of an incompressible fluid

*a, velocity always decreases along a pipe with increasing cross-section*

*b, flow velocity in the smallest cross-section always equals to the speed of sound*

*c, supersonic flow occurs in pipes with decreasing cross-section*

*d, in a supersonic flow increasing velocity means increasing cross-section*

*e, flow velocity in the smallest cross-section cannot be over the speed of sound*

The answer is:

**T.12.3.2** Choose the correct statements regarding a Laval nozzle ($p_{outer}/p_{reservoir}$=0.4 and $\kappa$=1.4)

*a, In the smallest cross-section the local Mach number is one.*

*b, Downstream of the smallest cross-section the local Mach number increases if the cross-section increases.*

*c, Velocity increases until the smallest cross-section point, afterwards it decreases.*

*d, Local speed of sound decreases along the whole length of the Laval nozzle.*

*e, The greatest Mach number is found at the outlet cross-section of the Laval nozzle.*

The answer is:

**T.12.3.3**Gas flows out from a reservoir ($p_r$,$T_r$, $\rho_r$) through a Laval nozzle. Choose the correct statements assuming isentropic outflow into the environment. (Ambient parameters are $p_0$, $T_0$, while in the outlet cross-section of the Laval nozzle $p_{out}$, $T_{out}$, $\rho_{out}$).

$$a, \rho_{out} = \rho_r \left(\frac{p_0}{p_r}\right)^{\frac{\kappa-1}{\kappa}}$$

$$b, T_{out} = T_r \frac{2}{\kappa+1}$$

$$c, T_{out} = T_0$$

$$d, T_{out} = T_r \left(\frac{p_0}{p_r}\right)^{\frac{\kappa-1}{\kappa}}$$

$$e, \rho_{out} = \rho_0$$

The answer is:

**T.12.3.4** A compressible fluid flows out from a reservoir through a Laval nozzle. Reservoir temperature ($T_r$) and pressure ($p_r$) are assumed constant while the ambient pressure ($p_a$) is changed in order to ensure that $p_a$/ $p_t$<0.53 in all cases. $q_m$ is the outflow mass flow rate.

*a, The outlet cross-section with a given $q_m$ is defined by $p_a$ only for a given gas.*

*b, The value of $q_m$ is determined by $p_a$ and the outlet cross-section.*

*c, If $p_a$ is zero, then the outlet cross-section of the Laval nozzle should be infinity.*

*d, The size of the smallest cross-section can be determined in the knowledge of $q_m$.*

*e, For all $p_a$, removing the expanding part of the nozzle does not influence $q_m$.*

The answer is:

**T.12.3.5** The outflow velocity from a reservoir through a nozzle of decreasing cross-section can be determined using the following expression(s) (reservoir conditions $p_r$, $T_r$, $\rho_r$, ambient conditions $p_a$, $T_a$, $\rho_a$,$p_a/p_r$<0.53 and $\kappa$=1.4):

$$a, v = \sqrt{\frac{2\kappa}{\kappa-1} R\, T_r \left[1 - \left(\frac{p_a}{p_r}\right)^{\frac{\kappa-1}{\kappa}}\right]}$$

$$b, v = \sqrt{\kappa\, R\, T_r}$$

$$c, v = \sqrt{\frac{2}{\rho_r}(p_r - p_a)}$$

$$d, v = \sqrt{\frac{2\kappa}{\kappa-1}\frac{p_r}{\rho_r}\left[1 - \frac{2}{\kappa-1}\right]}$$

$$e, v = \sqrt{\kappa\, R\, T_r \frac{2}{\kappa-1}}$$

The answer is:

**T.12.4.1** Sound intensity is

*a, the temporal mean of the instantaneous pressure squared*

*b, sound power travelling through unit surface area*

*c,* $\frac{p_{eff}}{\rho\, a}$*(where* $p_{eff}$ *is the effective sound pressure)*

*d,* $\frac{\hat{p}^2}{2\rho a}$ *(where* $\hat{p}$ *is the pressure amplitude)*

The answer is:

**T.12.4.2** The expression for mean sound power level *P* is (denoting intensity *I*, effective pressure $p_{eff}$, and particle velocity *v'*):

$a, P = v' p_{eff}\, A$

$b, P = \frac{p_{eff}^2}{\rho a}$

$c, P = \frac{p_{eff}}{\rho a}$

$d, P = I\, A$

The answer is:

**T.12.4.3**A sound wave travelling in the positive *x* direction is given as (denoting pressure amplitude $\hat{p}$, angular frequency $\omega$, wave number *k*, and speed of sound *a*):

$a, p = \hat{p}\cos(\omega\, t)\cos(k\, x)$

$b, p = \hat{p}\cos(\omega\, t - k\, x)$

$c, p = \hat{p}\cos(\omega\, t + k\, x)$

$d, p = \hat{p}\cos\left(\omega\left(t - \frac{x}{a}\right)\right)$

The answer is:

**T.12.4.4** The correct form of the acoustic wave equation is (denoting sound pressure *p*, particle velocity *v*, speed of sound *a*):

$a, \frac{1}{a^2}\frac{\partial^2 p}{\partial x^2} = \frac{\partial^2 p}{\partial t^2}$

$b, \frac{\partial^2 v}{\partial x^2} = -\frac{1}{a^2}\frac{\partial^2 v}{\partial t^2}$

$c, \frac{\partial^2 p}{\partial x^2} = \frac{1}{a^2}\frac{\partial^2 p}{\partial t^2}$

$d, \frac{\partial p}{\partial x} = \frac{1}{a^2}\frac{\partial p}{\partial t}$

The answer is:

**T.12.5.1** The definition of acoustic sound levels:

*a, sound pressure level* $L = 20 \lg \frac{p}{p_0}$ [dB]

*b, sound pressure level* $L = 20 \lg \frac{p^2}{p_0^2}$ [dB]

*c, sound power level* $L_W = 20 \lg \frac{P}{P_0}$ [dB]

*d, sound power level* $L_W = 20 \lg \frac{I A_0}{P_0}$ [dB]

*e, sound intensity level* $L = 20 \lg \frac{p}{p_0}$ [dB]

The answer is:

**T.12.5.2** Assuming two sound sources creating the same intensity at a given point, the resultant sound pressure level related to the sound pressure level created by one source is:

*a, increased by 3* dB

*b, increased by 6* dB

*c, L (SPL) is doubled*

*d, intensity is doubled*

The answer is: