1. A two-dimensional flow field has the velocity components as follows, Figure 1:

\[ u = ay e^{-t} \quad \text{and} \quad v = -ax e^{-t} \]

Please find the streamline equation \( f(x, y) = C \). (15%)

![Figure 1](image1)

2. The inlet and outlet diameter of a converging pipe is 10 cm and 5 cm, respectively. Oil with density of 1200 kg/m³ flows steadily through this pipe, where the friction effect can be neglected. The outlet is 3 m lower than the inlet. The gravitational acceleration is 9.81 m/s². Please determine the pressure drop between the inlet and outlet for a flow rate \( Q \) of 1000 L/min, Figure 2. (15%)

![Figure 2](image2)
3. Fluid from a stationary nozzle strikes a circular flat plate as shown in Fig. 1, where the plate is fixed on the ground. The fluid has the density of 10^3 kg/m^3 leaving nozzle steadily at the flow rate \( Q \) of 250 L/min and the diameter of nozzle is 15 cm. Fluid is directed normal to the plate and flows uniformly along the radial direction with a constant thickness on the circular plate after it hits the plate. The gravitational effect can be ignored. Please determine the normal force acting on the circular plate, in N. (10%) 

![Figure 3]

4. The mass of a model plane is 0.8 kg and the average chord length \( c \) of its two wings is 40 cm, where the span \( b \) is 120 cm. Air is assumed with the density of 1.2 kg/m^3. The gravitational acceleration is 9.81 m/s^2. The lift coefficient of the wing at sufficient large Reynolds number can be described as follows, where \( \Lambda \) is the aspect ratio \( = b/c \):

\[
C_L = \frac{(\Lambda + 1)(\Lambda + 2)}{(\Lambda + 3)^2}
\]

Please estimate the take-off speed of this model plane, in m/s, if the lift of model plane is mainly delivered by its two wings and the reference area of wing \( A \) for calculating lift is defined as by the product of the span \( b \) and the average chord length \( c \). (10%) 

![Figure 4]
5. A heat pump is absorbing heat from the cold outdoors at 7°C and supplying heat to a house at 27°C at a rate of 14,400 kJ/hr. If the power consumed by the heat pump is 2 kW, determine (a) the actual coefficient of performance of the heat pump (10%), (b) the highest possible coefficient of performance of the heat pump (10%).

6. Processes 1-2 and 2-3 are reversible and shown in Figure 5. Determine (a) the heat transfer, in kJ/kg, for the reversible process 1-3 (10%), (b) whether heat is absorbed or rejected during the reversible process 1-2 (10%).

![Figure 5](image)

7. A piston-cylinder device contains hydrogen gas initially at 400 kPa, 140°C, and 0.25 m³. The hydrogen is now expanded in a polytropic process ($P V^n = \text{constant}$) to 150 kPa and 20°C. Determine (a) the work done by hydrogen (5%), (b) the change in entropy of hydrogen, in kJ/K (5%). For hydrogen, $\gamma = 1.412$ kJ/kg K, $c_p = 14.307$ kJ/kg K.

**Summary of equations**

1. Continuity equation in the integral form
   $$\frac{\partial}{\partial t} \int_{\Omega} \rho v \, dV + \int_{\partial \Omega} \rho v \cdot n \, dA = 0$$

2. Linear momentum equation in the integral form
   $$\frac{\partial}{\partial t} \int_{\Omega} \rho v \, dV + \int_{\partial \Omega} \rho v \cdot n \, dA = \sum F_{\Omega}$$

3. Force balance along/normal to a streamline for steady, inviscid, incompressible flow
   - $F_x + \frac{1}{2} \rho V^2 + g h = C$ (along streamline)
   - $F_x + \int_{A} \rho h \, dA + g h = C$ (normal to streamline)

4. Lift and drag coefficient
   - $C_L = \frac{L}{\frac{1}{2} \rho U^2 A}$
   - $C_D = \frac{D}{\frac{1}{2} \rho U^2 A}$