Thermodynamics

1. State the conditions under which each of the following equations is true: (20%)

   (i) $\delta q = du + \delta w$

   (ii) $\delta q = du + p\,dv$

   (iii) $T\,ds = du + \delta w$

   (iv) $T\,ds = du + p\,dv$

2. Consider the flow of an incompressible fluid along a pipe of varying cross-sectional area and elevation. No shaft work is done, and we assume the flow to be adiabatic and frictionless.
   (i) Can you derive the steady Bernoulli's equation according to the first law of thermodynamics (i.e., the law of energy conservation) instead of Euler's equation? (10%)
   (ii) Are the physical assumptions the same for these two Bernoulli's equations? Please answer this question in detail. (10%)

3. Describe the third law of thermodynamics. (10%)

4. Please explain and rank the thermal efficiency of the Carnot, Ideal and Actual cycles and state the assumptions made. (5%)

5. Please derive the work required to compress an internally reversible process in an open system with a single inlet and exit where changes in kinetic energy and potential energy are negligible. (6%)

6. Please discuss the advantages and disadvantages of adopting intercooler, reheater and regenerator within the Brayton cycle. Please indicate how the above device can reach the theoretical maximum thermal efficiency.(8%)

7. Please define Dalton's law, Amagat's law, relative humidity and humidity ratio.(6%)

Fluid Mechanics

8. Please define the followings:
   (a) channel flow (2%)
   (b) fully developed channel flows. (5%)
   (c) Reynolds stress (2%)

9. Prandtl proposed that the Reynolds stress can be expressed as

$$\overline{uv} = -(\kappa y)^2 \left|\frac{dU}{dy}\right|,$$

where y is the distance from the wall and κ is a constant. If the contribution of the laminar stress is negligible, derive the profile of the gradient of velocity for the fully developed turbulent channel flow. Indicate any assumptions made. (16%)