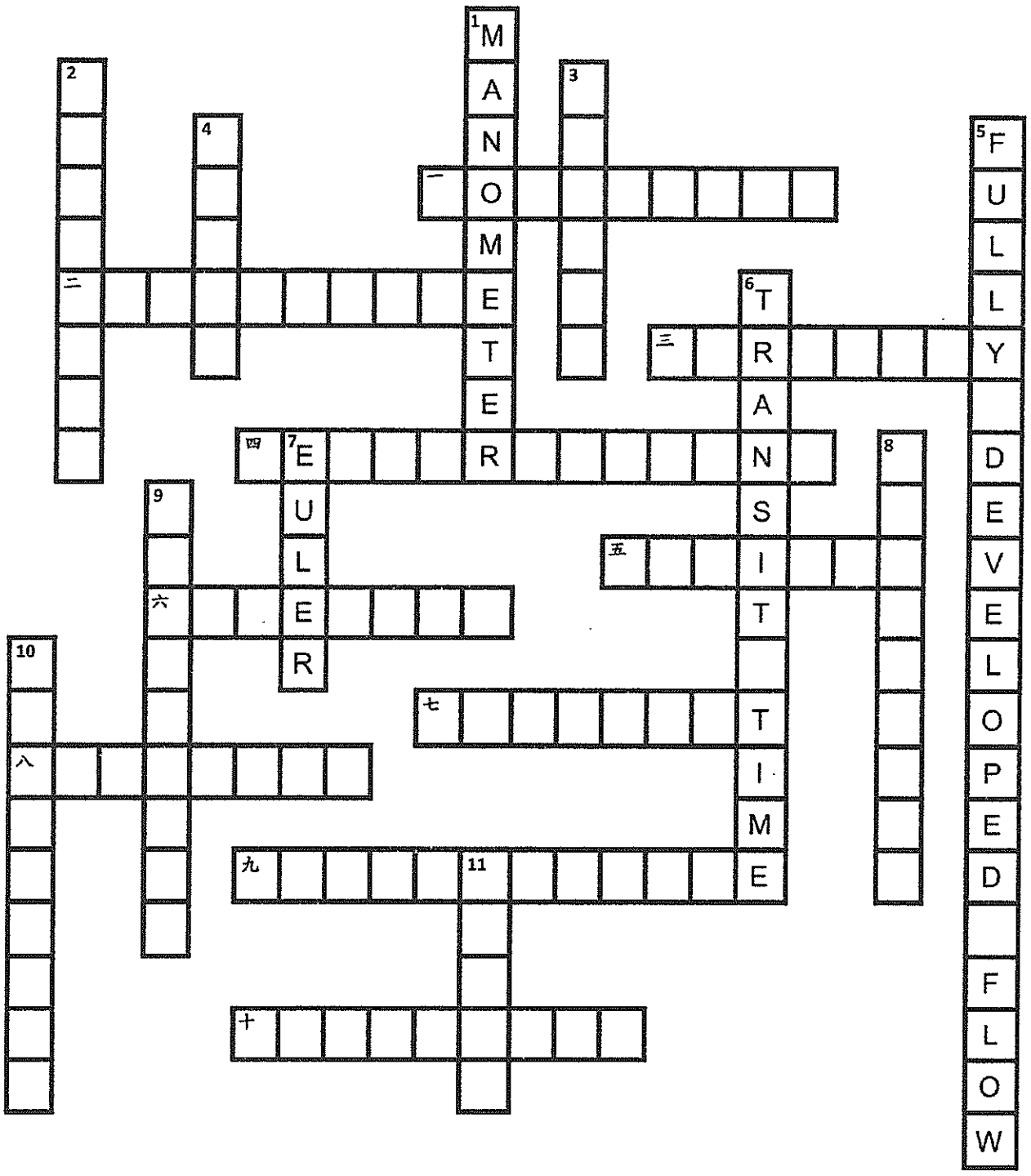
注意：請考生依題號順序作答

1. **(12 points)** Fill the crossword puzzle related to fluid and particle mechanics. For the items 1, 5, 6, and 7, which are filled, explain the terms.



Down

1.
2. velocity of an object falling in air, with no acceleration
3. independent of time
4. substance that does not resist distortion permanently
5.
6.

見背面

7.
8. the principle of conservation of mechanical energy
9. physics of the behavior of objects under application of force
10. velocity profile of Newtonian fluid in laminar flow in a circular pipe
11. mathematical model for packed beds

Across

一. incompressible flow with no shear

二. type of liquids separated by decanters

三. fraction of the voids

四. type of pump employing check valves

五. flow with no lateral mixing

六. flow observed in case of small objects moving in viscous fluids

七. type of fluid if flow behavior index is > 1

八. dimensionless number: ratio of inertial to viscous forces

九. density is not constant

十. diameter = flow cross-sectional area/wetted perimeter

2. True or False **(10 points)**

A. The thermal conductivity of a metal is proportional to the electric conductivity.
B. Boiling water is an example of forced convection.
C. The blackbody radiant emittance is directly proportional to quadratic root of the temperature.
D. Number of transfer units (NTU, *UA*/*C*min) is indicative of the size of the heat exchanger. For a parallel flow heat exchanger,

$$\mathrm{NTU} = -\frac{1}{1+C^*}\ln\left[1-\varepsilon(1+C^*)\right],$$

where *Cmin*/*Cmax* = C^*, ε : the effectiveness of a heat exchanger

E. For heat transfer through a wall, the film resistance can be decreased by increasing the surface area by finning.
F. Nusselt's film condensation theory describes the heat transfer in the case of laminar film condensation on horizontal surfaces.
G. The Fick's law describes the transport of mass due to concentration gradient.
H. The Sherwood number is the ratio of the shear component for diffusivity viscosity/density to the diffusivity for mass transfer.

接次頁

I. The Reynolds–Colburn analogy is for heat transfer, while the Chilton–Colburn is for mass transfer.
J. Darcy's law describes the flow of a fluid through a porous medium.

3. Penicillin has become the most demanded antibiotic for treatment of bacterial infections worldwide. Penicillin is produced from fungi when the fungi are under stress in fermentation. After fermentation, the first thing is to remove large solid particles and microbial cells from the fermentation broth. The harvested penicillin rich solution is cooled to 5°C because penicillin only has a half-life 15 minutes at pH 2 at 20°C. Penicillin can be transferred from an aqueous phase into a solvent butyl acetate or amyl acetate easily in an acidic condition such as pH 2.5-3.0. The penicillin-rich solvent is then treated with 0.25-5% activated carbon to remove pigments and impurities. The penicillin-rich solvent is passed into a fresh aqueous phase in the presence of potassium or sodium hydroxide to bring the pH back to 5.0-7.5, creating the penicillin salt. Penicillin crystals are formed, collected, washed and dried as the final products.
Draw a flow diagram for penicillin production, including all the necessary unit operations. **(13 points)**

4. Using *M (mass)*, *L (length)*, *T (time)*, and *θ (temperature)* system of fundamental units, develop the functional relation for forced convection heat transfer using dimensional analysis. Specify the dimensionless groups. **(15 points)**

5. **(20 points)** A long solid circular cylinder with a length of 6m and a radius of 2m is falling at a velocity of 2m/sec through a liquid held within a cylindrical vessel with a radius of 3m closed at the bottom, as shown in Figure 1. The movement of the cylinder is coaxially with the vessel. The liquid is an incompressible Newtonian fluid with a viscosity of 1 Pa・s and a density of 1200 kg/m^3. Consider the situation at steady state and note that we already know that pressure does not vary with r location in the gap.

(a) **(7 points)** Write the equations of change and boundary conditions required to obtain the flow velocity profile in the gap region between the cylinder wall and the vessel wall. Clearly specify which terms in the equations can be neglected or equal to zero and why.
(b) **(5 points)** Sketch the flow velocity profile in the gap region.
(c) **(8 points)** Solve the flow velocity profile in the gap region.

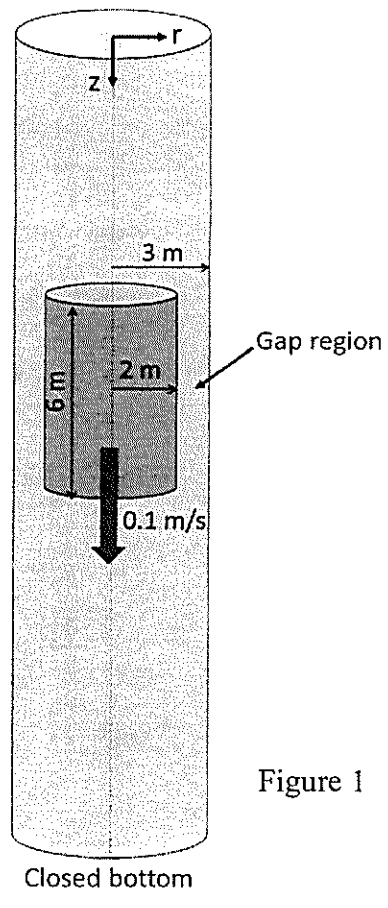


Figure 1

6. **(10 points)** A cooling water jacket is put outside a cylindrical flow reactor to remove heat from the reactor (Figure 2). The flow rate and the temperature of the cooling water stream are V_C and T_C; the flow rate and the temperature of the fluid in the reactor are V_H and T_H. The inner and outer radii of the reactor tube wall are R_i and R_O, and the length of the reactor tube is L. The thermal conductivity of the reactor tube wall is k; the heat transfer coefficients of the cooling water and of the fluid in the reactor in this system are h_C and h_H. Please use the given parameters to derive how much heat can be removed from the reactor tube per unit time.

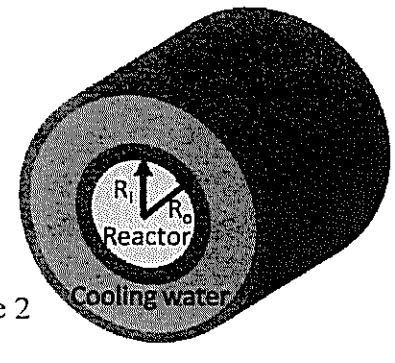


Figure 2

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7. **(20 points)** A pump draws water (density=1000kg/m^3, viscosity =0.001 Pa・s, vapor pressure=0.02atm) from a storage tank (exposed to atmosphere) and sends water to exits A and B through pipes. All of the used pipes are circular pipes with a diameter of 0.1m and are made of concrete. The length of each pipe is shown in Figure 3. Both exit A and exit B locate at 10m above the pump. You can assume that all of the frictions are from the pipe walls and the frictions from the fittings are negligible. The storage tank is large enough so that the change of the water level is negligible during the process. The average velocity of water at steady state in the suction line of the pump is 6m/s. The efficiency of the pump is 70 percent.

(a) **(5 points)** Calculate the average velocity coming out from exit B.

(b) **(8 points)** Calculate the power (J/sec) provided by the pump.

(c) **(7 points)** What is the net positive suction head (NPSH) of the pump? If the minimum required net positive suction head (NPSHR) is set as 6m, would the pump be able to properly work?

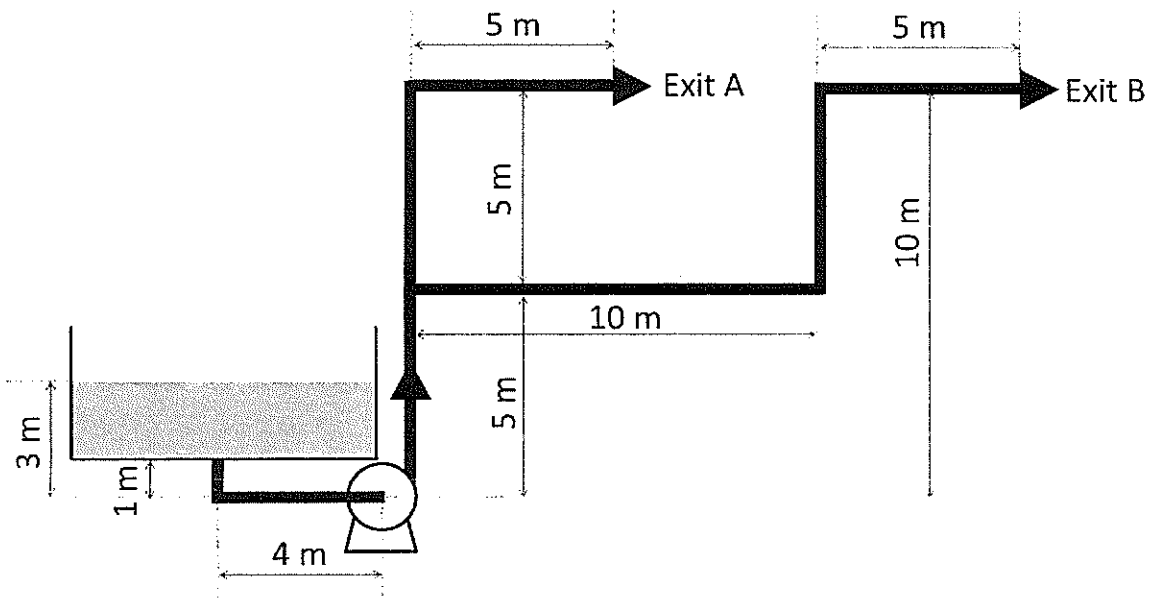
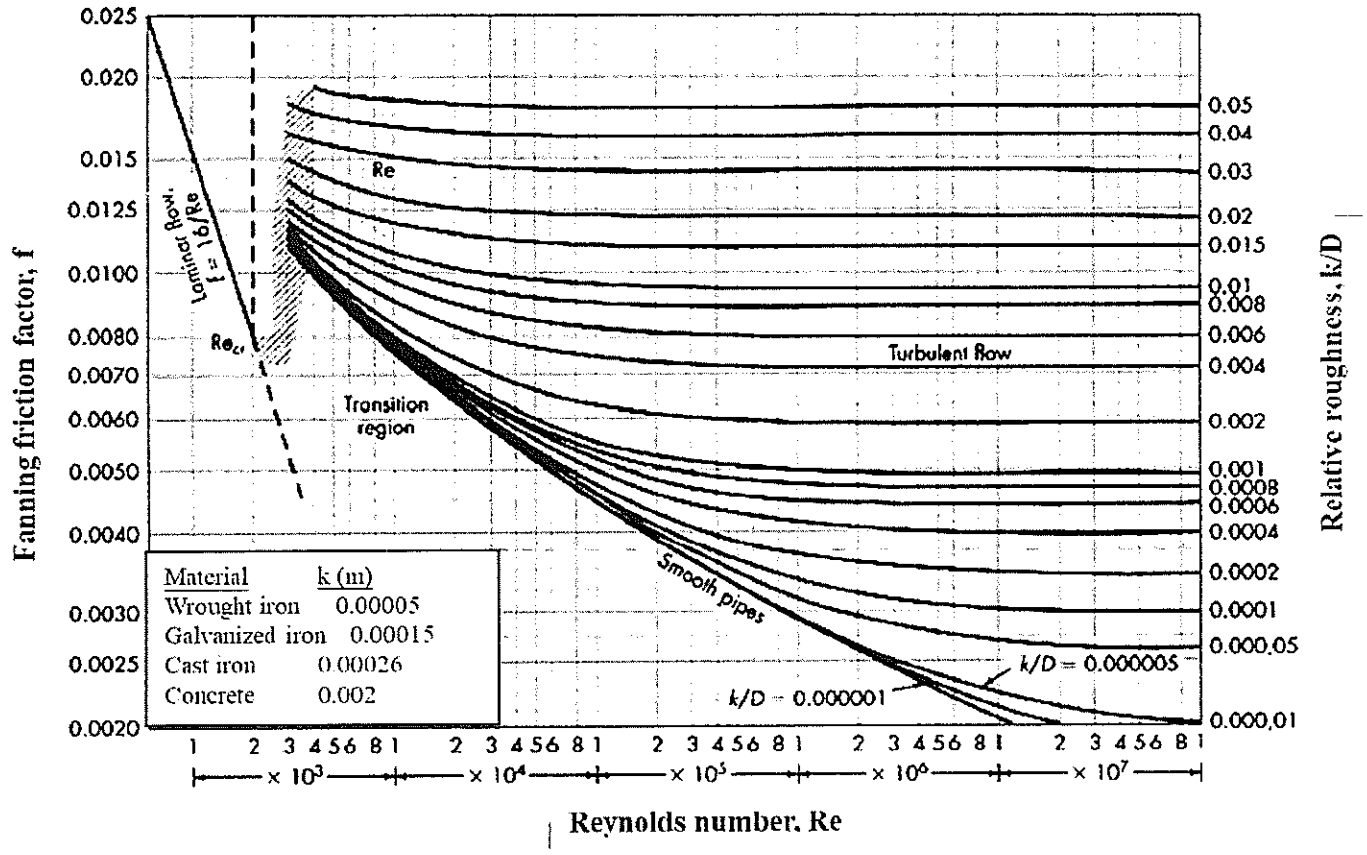


Figure 3

Friction factor chart



$$f \equiv \frac{2|\tau_w|}{\rho V^2} \qquad \mathrm{Re} \equiv \frac{\rho V D}{\mu} \qquad h_f = 4f\frac{L}{D}\frac{V^2}{2}$$

試題隨卷繳回