EXAM I
HEAT TRANSFER

May 1, 2014

I. Explain the following terms: (18%)

(1) Newton's cooling law
(2) The zeroth law of thermodynamics
(3) Stefan Condition
(4) Thermal resistance
(5) Similarity transformation
(6) Biot number

II. Answer the following questions: (36%)

(1) What's the difference between heat transfer and thermodynamics?
(2) In what conditions can thermal resistances be applied?
(3) Why does a refrigerator need defrosting?
(4) Why is free convection important in the design of heat transfer?
(5) When a fin is attached to a high-temperature body, can it be regarded as a thermal resistance to the body? Why or Why not?
(6) 為何金屬材料的熱傳導係數普遍大於非金屬材料?
(7) 材質相同的條件下，結晶材料與非結晶材料哪個熱傳導係數較大?為什麼?
(8) In solving a 2-D steady heat conduction problem, the variable separation is used. It is assumed $T = X(x)Y(y)$. Put this relation into the energy equation and the equation can rearranged as

$$-\frac{1}{X}\frac{d^2X}{dx^2} = \frac{1}{Y}\frac{d^2Y}{dy^2} = \text{constant}$$

Why are they equal to constant?

(9) 臨界絕緣半徑(Critical radius of insulation)可適用於平板嗎?為什麼?
(10) A heat-insulated layer is put between two solids with different temperatures. Why can the layer not completely block the heat transfer between the two solids?
(11) What assumptions are assumed when the energy equation of a heat conduction problem is written as

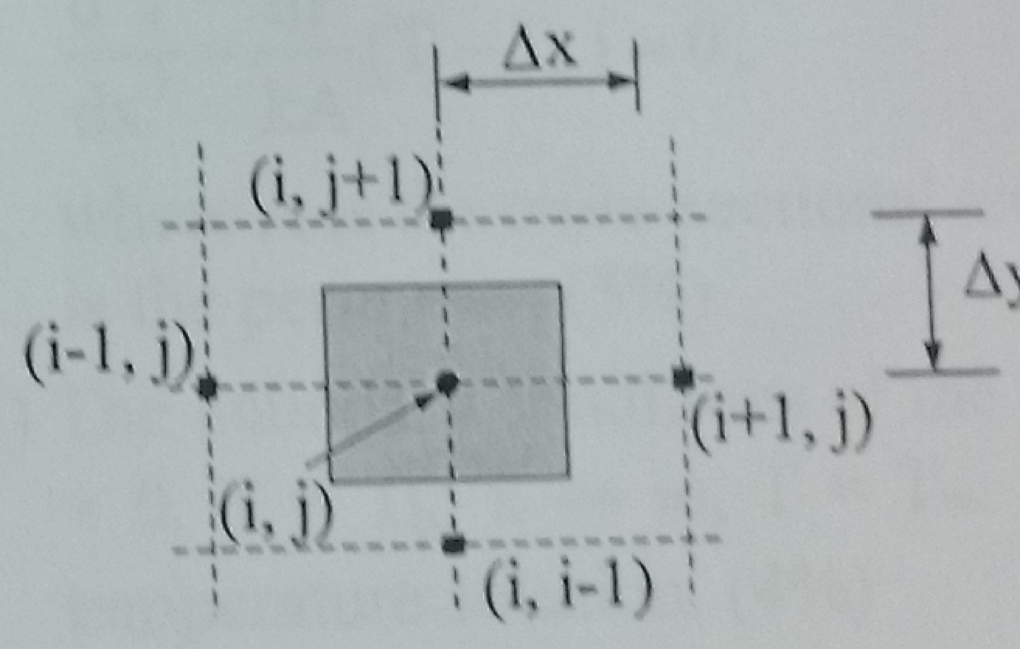
$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}$$

(12) In a finite difference formulation of the heat diffusion equation, the following difference expression is used for the time derivative $\partial T/\partial t$:

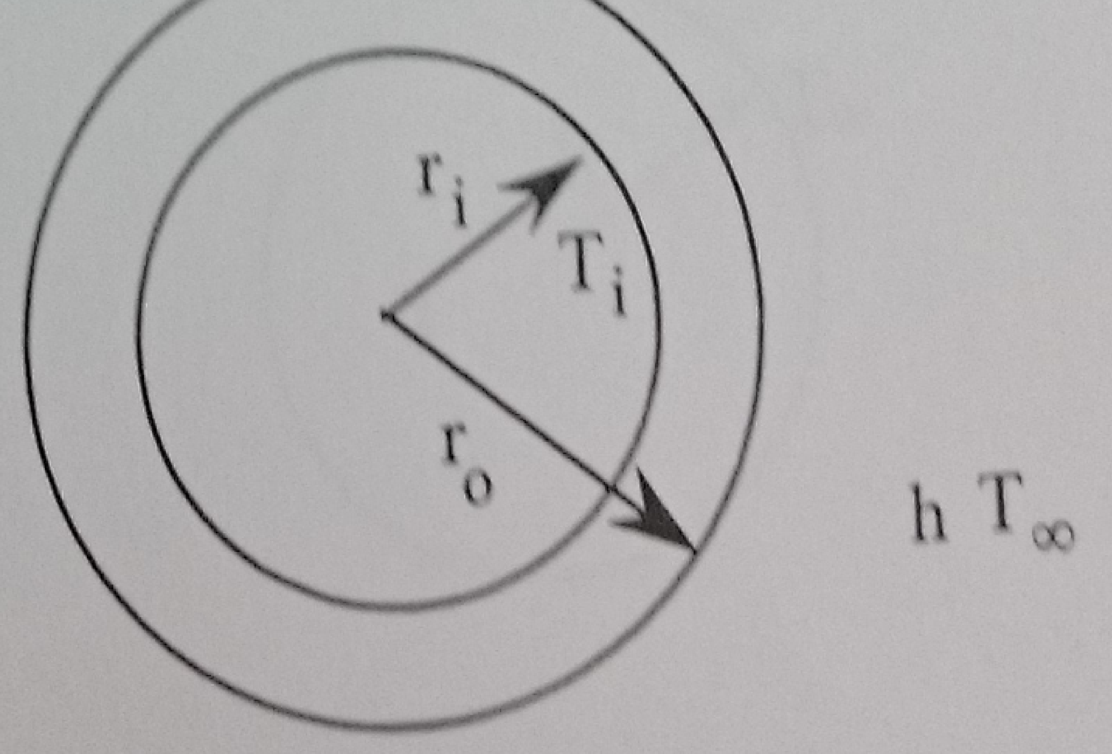
$$\frac{\partial T}{\partial t} \approx \frac{T_{i,j}^{n+1} - T_{i,j}^{n}}{\Delta t}$$

How do you judge whether this expression is forward difference or backward difference?

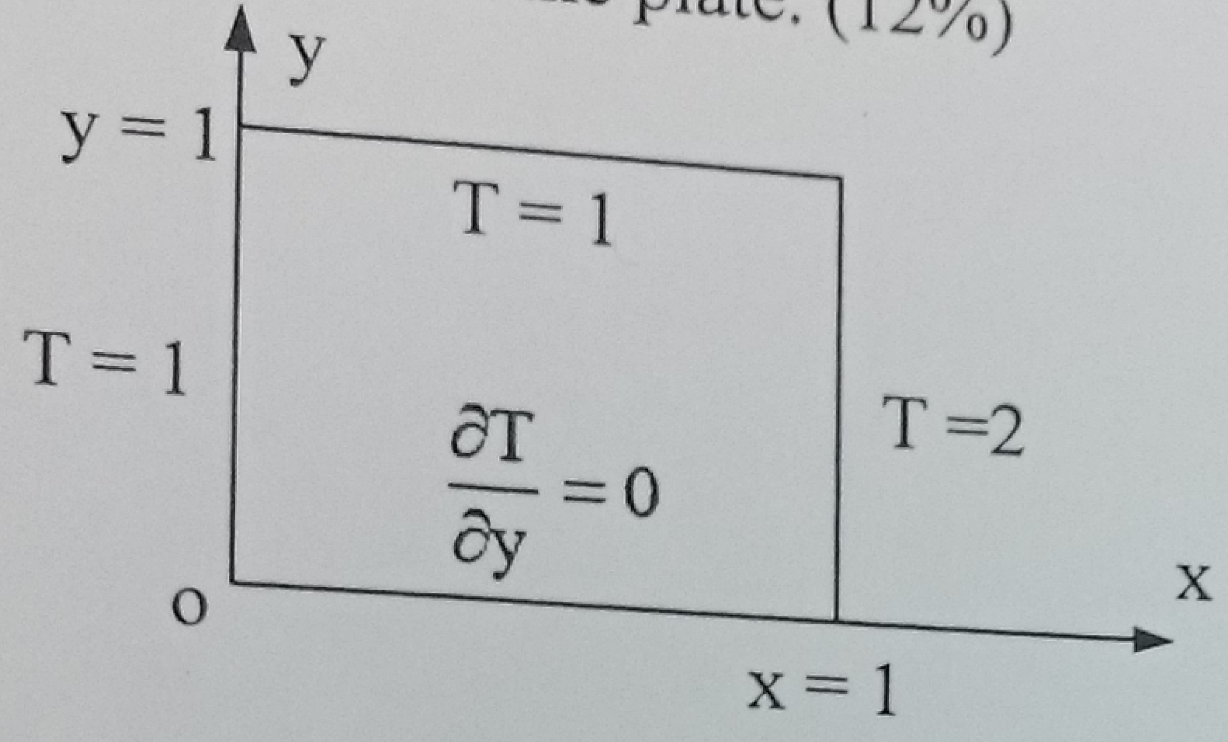
III. For a 2-D steady heat conduction problem with heat source $\dot{q}$, please derive the finite difference equation for point (i, j) shown in the following figure by considering the energy conservation in a control volume around that point (the shadow area). (8%)

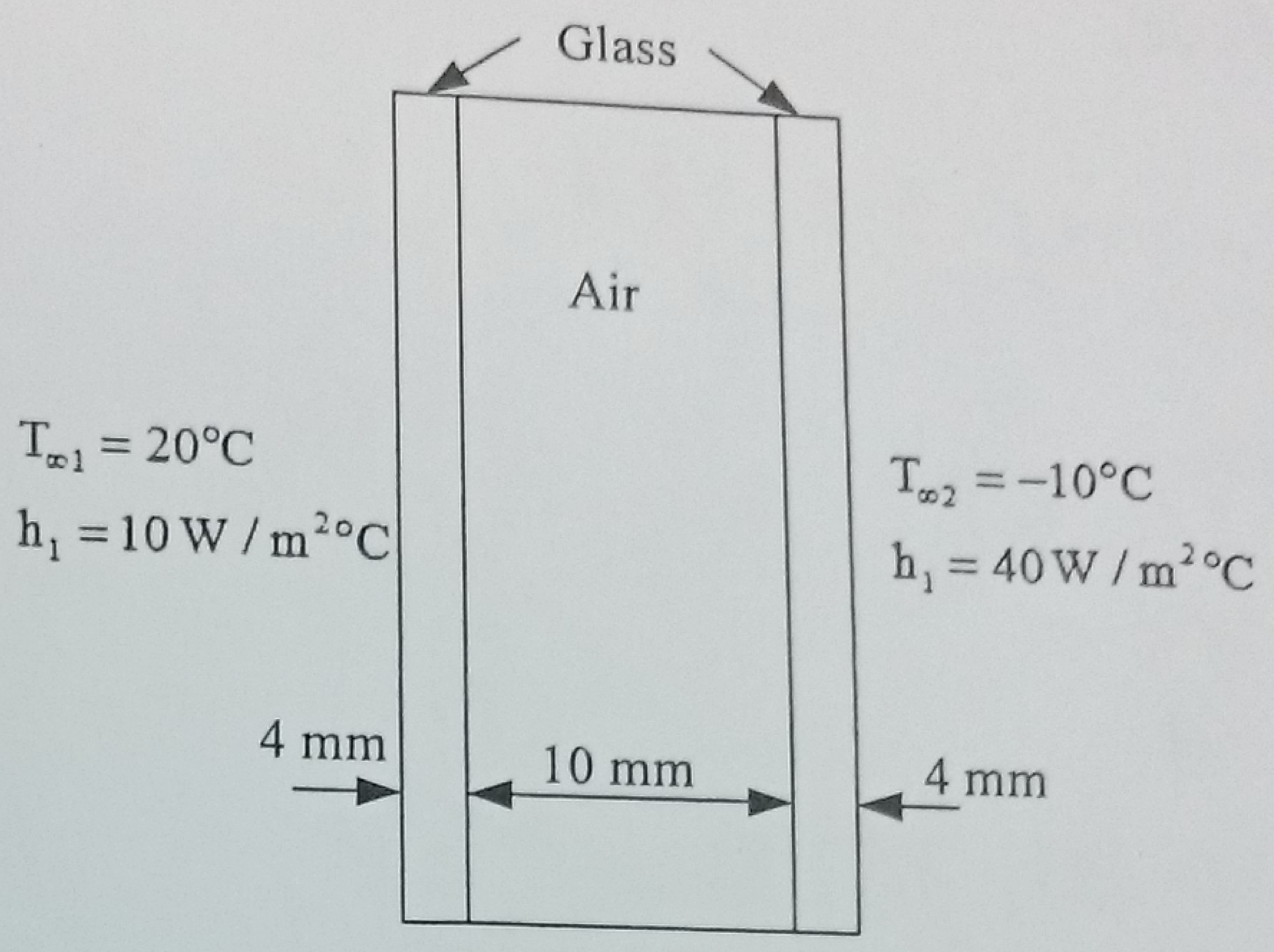


IV. Consider a layer of insulation which is installed around a circular pipe, shown in the following figure. The outer radius of the pipe is r_i and the outer radius of the insulation is r_o. Prove that the critical radius of insulation is $r_o = k / h$. (8%)

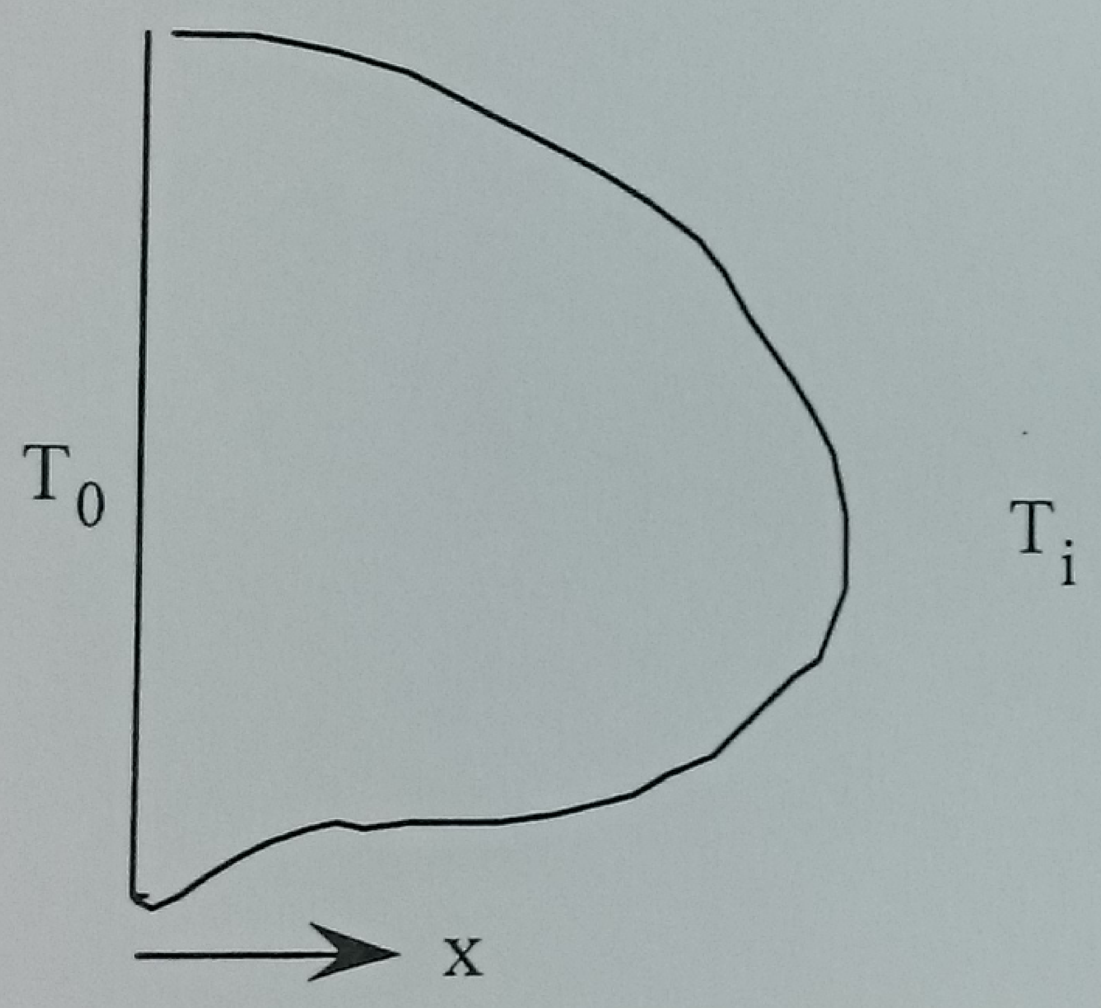


V. Consider a steady-state heat conduction problem of a rectangular plate. Its boundary conditions are indicated in the following figure. Find the temperature solution of the plate. (12%)





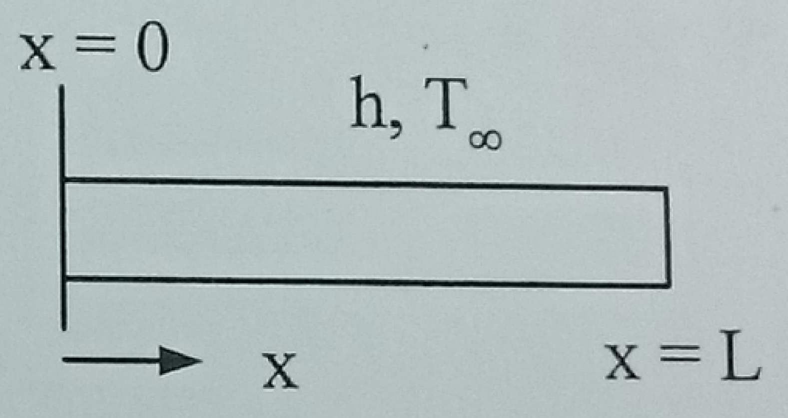
VI. Consider a semi-infinite solid shown in the following figure maintained at some initial temperature T_i. The surface temperature is suddenly lowered and maintain at a temperature T_0.



Solve the temperature distribution for this transient problem. (10%)

VII. Consider a 0.8-m-hight, 1.5m-wide double-pane window consisting of two 4-mm-thick layers of glass (k = 0.78 W/m·°C) separated by a 100-mm-wide stagnant air space (k = 0.0026 W/m·°C). Determine the steady rate of heat transfer through this double-pane window and the temperature of its inner surface for a day during which the room is maintained at 20°C while the temperature of the outdoors is -10°C. Take the heat transfer coefficients on the inner and outer surface to be h_1 = 10W/m^2·°C and h_2 = 40W/m^2·°C, which include the effect of radiation. (10%)

VIII. (1) In what conditions a fin can be regarded as a one-dimensional problem mathematically? (3%)



(2) Prove that the (one-dimensional) energy equation of a fin with constant cross-sectional area is

$$\frac{d^2T}{dx^2} - \frac{hP}{kA}(T - T_\infty) = 0,$$

where A is the cross-sectional area and P is the perimeter. (5%)

(3) The boundary conditions of the fin are x = 0, T = T_b; x → ∞, T = T_∞. Find the temperature solution. (4%)

(4) Calculate the heat loss by the fin. (3%)

IX. A one-dimensional steady heat transfer problem of a cylinder with a uniform heat source $\dot{q}$ is shown in the following figure. What is the heat flux on the cylinder surface (i.e., at r = R)? (8%)