Major (MCL142),
Semester 2, 2017-2018

Time: 2 hours	Full marks: 45
Venue: LH 114	Date: 07/05/2018

- ***Attempt any three question, if you have been marked in both minors.*** *Students* ***absent in minor(s)*** *should* ***attempt all questions****, after attachment of necessary certificates. Students whose minors were not graded due to* ***attendance deficit*** *should* ***attempt all questions****.*
- *Clearly specify part numbers such as 1(a), 2(c) etc. corresponding to your answers. One mark will be deducted for unnumbered attempts. All parts of the same question must be placed together in your answer-script, e.g. your answer to 1(b) cannot be placed immediately after your answer to 2(a). Else, a penalty of two marks apply. A penalty of one mark applies for submitting an untidy answer-script.* ***Strike off unattempted questions, or else the first three of your answers in the order of appearance in the answer booklet will be graded.***

1) **(a)** The conductivity of a plane slab of thickness L changes linearly with location according to the relation $k(x) = k(0) + \frac{(k(L)-k(0))}{L}\, x$. Find the effective conductivity k_{eff}, such that the heat flux through the slab is given by $q'' = k_{eff}\frac{(T(0)-T(L))}{L}$. **(b)** For a single fin of surface area A_f and a base cross-sectional area A_b, derive a formula connecting effectiveness (ϵ) to efficiency (η). **(10+5)**

2) **(a)** Derive the differential equation to be solved for axial temperature distribution in a slender *conical spine* of length L, base radius r_0 subject to an environment with constant convection heat transfer coefficient h and temperature T_∞. Choose the *origin* for your axial coordinate (x) at the *tip of the spine*, and the shifted temperature $\theta = T - T_\infty$ as your dependent variable. You do not need to solve the differential equation. You do not need to mention the boundary conditions. **(b)** Derive an expression for temperature distribution and efficiency of an infinitely long fin of constant cross-section, showing all intermediate steps. Introduce your own symbols through a neat sketch. **(c)** Estimate the thermal diffusion distance as a function of time (t) in a material of density ρ, specific heat c and thermal conductivity k. **(7+6+2)**

3) Consider a spherical solid of volume V, surface area A_s, density ρ, and specific heat c, which is generating thermal energy at a uniform rate $\dot{E}_g$ per unit volume, at a temperature T_∞ at *t=0*. To stabilize its temperature, the body is immersed at time $t > 0$ in a coolant liquid with temperature T_∞ and a constant heat transfer coefficient h. *For parts (a)-(c), assume the validity of the lumped capacitance method.* **(a)** Find the temperature of the solid at steady state. **(b)** Find an expression for the temperature $T(t)$ as a function of time t, in terms of the given parameters, showing all steps of derivation. **(c)** Draw a neatly labeled circuit for this problem, showing thermal resistances, thermal capacitances and sources, in terms of the symbols provided. **(d)** Explain, if the steady state is also a thermodynamic equilibrium state. **(3+8+2+2)**

4) **Special instructions for Question 4:** *This question is compulsory for those who were* ***ABSENT*** *in any of the minors with a medical certificate for substantiation. This question is also compulsory for those whose* ***minor 2 answer scripts were not graded due to attendance deficit,*** *but their marks will be scaled by the penalty factor* $\frac{2}{3}$*. Marks obtained in this question will be treated as your marks of your missing minor. Write* ***REMINOR*** *in uppercase on your front page, if this applies to you. Only these students will get 10 minutes extra time. For all other students, this question is optional and no extra time is added.*

(a) Two reversible heat engines A and B are arranged in series, with A rejecting heat directly to engine B. Engine A receives 200kJ at a temperature of 694 K from a hot source, while engine B is in communication with a cold sink at a temperature of 277.4°C. If the work output of A is twice that of B find the temperature of the reservoir shared by A and B, the efficiency of A, the efficiency of B. **(b)** Provide the Kelvin-Planck statement of the second law. **(c)** Explain any special significance of the ratio $\frac{h_{fg}}{s_{fg}}$ in the saturation tables for water. **(9+3+3)**

$k\,\partial t = \rho c\, U(x)\, \partial x$ $\quad \frac{\partial t}{\partial q}$ $\quad r = c_1 x + c_2$ $\quad c_2 = 0$

$\frac{r_0 \cdot x}{L}$