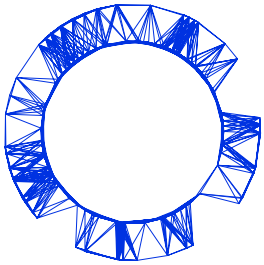
IPhO 2018
Lisbon, Portugal



Confidential

Detailed Marking Scheme Theory Problem 3

Physics of Live Systems

(Rui Travasso, Lucília Brito)

July 13, 2018

v1.0

Physics of Live Systems (10 points)

Part A. The physics of blood flow (4.5 points)

A.1

Flow in a $i+1$ level vessel is half of flow in a i level vessel	0.3
Obtain ΔP for all levels	0.3
Introduce radii dependences to obtain ΔP	0.3
Expression for Q_0	0.2
Expression for Q_i	0.2
Total	1.3

A.2

Replace values in formula with the correct units	0.3
Obtain final value in the requested units	0.2
Total	0.5

A.3

Obtain the current	0.5
Final expression for P_{out}	0.5
Arrive at intermediate condition $-2CL + C^2R^2 > 0$	0.5
Obtain the condition $\frac{64\eta^2\ell^2}{3Ehr^3\rho} > 1$	0.5
Total	2.0

A.4

Solve inequation in A.3 in order to h	0.2
Replace the values for the network	0.3
Obtain the maximum value for h	0.2
Total	0.7

Part B. Tumor growth (5.5 points)

B.1

Expressions for the masses of tumour and normal tissues (0.1 each)	0.2
Solve for the pressure	0.2
Equation without pressure	0.2
Solve to obtain the final solution for v (if not in reduced variables discount 0.2)	0.4
Total	1.0

B.2

Conservation of energy for $r < R_\mathrm{T}$	0.4
Solve to obtain the temperature difference to 37 °C	0.2
Conservation of energy for $r > R_\mathrm{T}$	0.4
Solve to obtain the temperature difference to 37 °C	0.2
Find the integration constant, C	0.2
Final result for $T(r = 0)$	0.3
Total	1.7

[Forget to add body temperature (between this question and the question below), discount 0.5 pt.]

B.3

Consider the increase of temperature at the tumour surface	0.2
Equate the temperature increase to 6.0 K	0.1
Obtain the numerical value for the power	0.2
Total	0.5

[Forget to add body temperature (between this question and the question above), discount 0.5 pt.]

B.4

Relate δr with pressure in tumour, up to leading order in $p - P_{\text{cap}}$	0.3
Relate pressure with tumour volume (discount 0.2 if p is not written as function of reduced variables)	0.4
Use the result of part A to calculate the new flow (include correctly the radius change at the capillary level)	0.3
Notice that $\frac{\delta Q_{N-1}}{Q_{N-1}} = \frac{\delta Q_0}{Q_0}$	0.3
Obtain $\frac{\delta Q_{N-1}}{Q_{N-1}} \simeq -\frac{4}{N}\frac{\delta r}{r_{N-1}}$	0.6
Final result for $\delta Q_{N-1}/Q_{N-1}$	0.4
Total	2.3