THE UNIVERSITY OF NEW SOUTH WALES

SCHOOL OF PHYSICS

EXAMINATION – November 2009

PHYS 2410
INTRODUCTORY BIOPHYSICS

Time Allowed – 2 hours

Total Number of Questions – 8

Answer **ANY FIVE** questions

The questions are of equal value

Please, write answers to questions 1 - 4 and 5 - 8 in separate books.

This paper may be retained by the candidate

All answers must be written in ink.
Except where they
are expressly required, pencils may be used
only for drawing, sketching or graphical work.
The students provide their own calculators

$$F = 2\gamma L$$

$$\gamma = \frac{\Delta E}{\Delta A}$$

$$P_i - P_o = \frac{2\gamma}{r}$$

$$h = \frac{2\gamma\cos\theta_c}{\rho r g}$$

$$P = -\frac{B}{V_o}(V - V_o)$$

$$U - U_o = \frac{1}{2}B\frac{(V - V_o)^2}{V_o}$$

$$dW = 4\pi r(2\gamma + Pr)dr$$

$$W = 4\pi r^2\gamma - \frac{4}{3}\pi r^3\, P$$

$$F = \eta A\frac{v}{d}$$

$$v = \frac{\Delta P}{4\eta\ell}(a^2 - r^2)$$

$$Q = v_{av}A$$

$$Q = \frac{\pi\Delta P a^4}{8\eta\ell}$$

$$N_R = \frac{\rho d v}{\eta}$$

$$F = 6\pi r\eta v$$

$$v_T = \frac{2r^2 g}{9\eta}(\rho_o - \rho_f)$$

$$F = c_D A(\frac{1}{2}\rho v^2)$$

$$N_j = N_o e^{-\frac{\varepsilon_j}{kT}}$$

$$N_j = N_o e^{-\frac{\xi_j}{RT}}$$

$$\mu_T = \mu_0 + RT\ln c + PV + zF\phi + mgh$$

$$\Psi = P - \Pi$$

$$\frac{\partial c}{\partial t} = D\left(\frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2} + \frac{\partial^2 c}{\partial z^2}\right) = D\nabla^2 c$$

$$c(x,t) = \sqrt{\frac{1}{4\pi Dt}}\exp\left[\frac{-x^2}{4Dt}\right]$$

$$t = \frac{x^2}{4D}$$

$$\frac{1}{2}mv_{rms}^2 = \frac{3}{2}kT$$

$$v_s = \sqrt{\frac{\gamma kT}{m}}$$

$$v = \sqrt{\frac{T}{\mu}}$$

$$SL = 10\mathrm{Log}\left[\frac{I}{I_o}\right]$$

$$I_o = 10^{-12}$$

$$\frac{1}{f} = \frac{1}{o} + \frac{1}{i}$$

$$P = \frac{1}{f} = (n-1)\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

$$\frac{n_1}{o} + \frac{n_2}{i} = \frac{n_L - n_1}{R}$$

$$\sin\theta \approx \theta = 1.22\frac{\lambda}{d}$$

$$r = D\tan\theta \approx D\theta$$

Constants:

$k = 1.38\text{x}10^{-23}$ J K^{-1} ,

$\varepsilon_o = 8.85\text{x}10^{-12}$ F m^{-1}, $q = 1.6\text{x}10^{-19}$ C

$R = 0.0083143$ liter MPa mol^{-1}K^{-1}

$g = 9.8$ m.s^{-2}

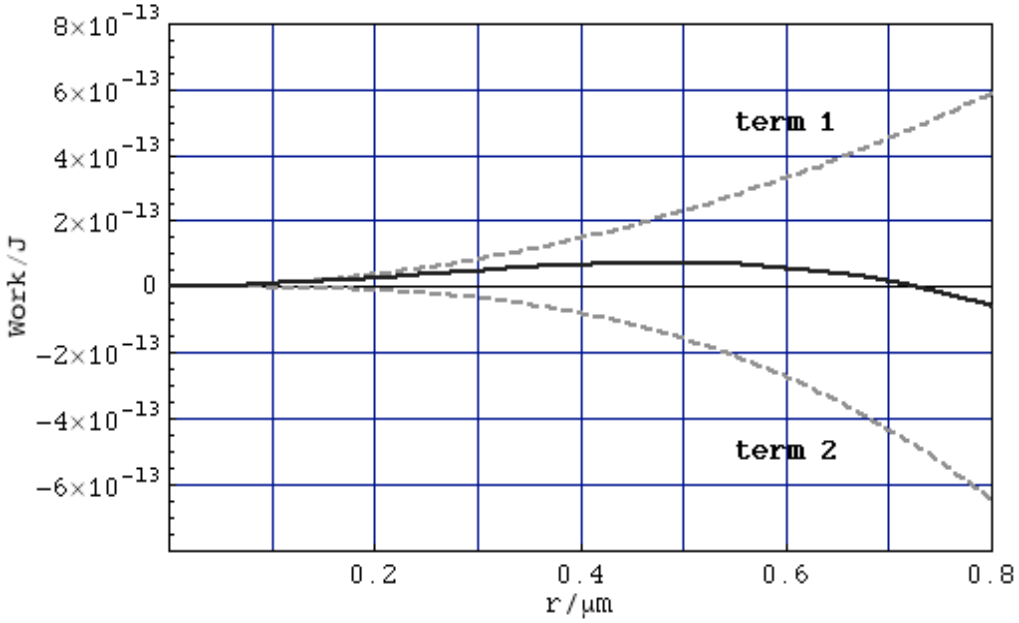
Avogadro's number = $6.02\text{x}10^{23}$

Question 1

(a) Describe the unusual properties of water at (and near) the freezing point. How is this relevant to aquatic life in geographical locations with temperatures below 0 ^{o}C? Illustrate your answer with relevant diagrams.

(b) Cylinder with a piston is totally filled with pure water. Negative pressure P is applied by pulling a piston in horizontal direction to increase the volume. The molecular bonds are stretched and eventually break forming a spherical bubble filled with water vapour, with radius r. The graph below shows the work required to expand this cavity. The solid line is the sum of terms 1 and 2. Identify terms 1 and 2 and calculate P, using the graph or appropriate equation. Indicate on the graph below, when critical radius r_c is reached. What happens to the cavity at r_c? How is this relevant to water transport in plants?

(c) Explain how negative pressure is generated in xylem vessels of plants. What would be the radius of water film curvature to generate negative pressure of same magnitude as in part (b)?



Data: density of water: 10^3 kg/m^3
surface tension of water at 20 ^{o}C: 72.8 x 10^{-3} N/m

Question 2

(a) An elephant with a trunk 2.0 m long is squirting water at a tourist. The trunk contains two nostrils, which are the length of the trunk and have an internal diameter of 2.0 cm. The total flow rate from both nostrils is 5.0 litres/s .

(i) Draw a diagram of this situation.
(ii) What is the average velocity of the water in the trunk?
(iii) With what pressure is the elephant blowing to squirt the water? What assumption do you have to make?
(iv) How hard would the elephant have to blow, if he were to squirt custard?
(v) Calculate the Reynold's number to find whether the water and custard flows are laminar or turbulent. Comment on your answers.

Data: $\rho_{water} = 1000$ kg.m^{-3}, $\rho_{custard} = 900$ kg.m^{-3}
1 litre = 10^{-3} m^3
$\eta_{water} = 1.005 \times 10^{-3}$ Pa.s, $\eta_{custard} = 2.5$ Pa.s

(b) A plant cell with turgor pressure P_i of 0.2 MPa, containing 0.3 M sucrose solution is dropped into a container of 0.1 M sucrose solution. Showing all your reasoning, calculate the final water potential, Ψ_f, and the final turgor pressure, P_f, of the cell. (Remember that plant cells have tough cell walls, which prevent them from change of volume).

data: universal gas constant R = 0.00831 J.mol.K, the room temperature T = 300 K

Question 3

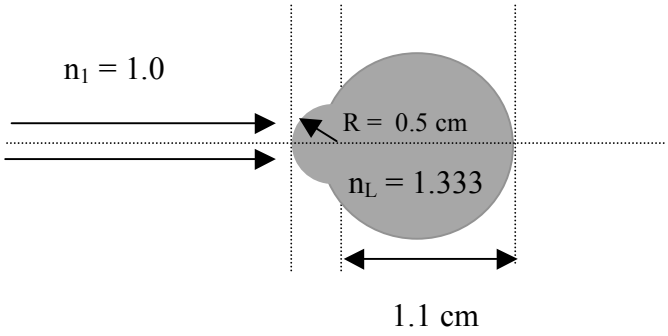
(a) A student with normal hearing participates in a hearing test. She is exposed to 20 Hz and 1 kHz test signals at 20 dB and then at 80 dB.

(i) What is the difference in intensity of the two signals?
(ii) What loudness does she perceive for each pair of signals?

(b) Describe the physiology of the inner ear and the transduction of the vibration at the oval window into electrical signals. Illustrate with relevant diagrams.

Question 4

(a) A long-sighted eye is shown as a "reduced eye model" below. Where will the parallel light rays (from infinity) focus? How would you apply laser surgery to the cornea to correct this defect? Show all your reasoning, including equations and diagrams.



(b) What is the physical process that evokes sensation of different colours in the normal human eye? Your description should include the properties of the receptors on the retina.

(c) In the picture below a large creature appears to be chasing a smaller creature, when in fact the two figures are exactly the same size. Explain how this illusion is created by describing how the human brain perceives objects in 3D space.