The University of British Columbia

Supplemental Examination – Spring session 2004

BIO/P 438

Time 2 1/2 hrs

Candidates Name:.....

Registration #:.....

Candidates Signature .....

This is an open green book & your notes exam

The exam has three parts (pages 1-4);

Part A: Attempt 2 out of 6 questions
Part B: Attempt this question
Part C: Write an essay on one of the topics

show all your rough work

	A: select 2 out of 6						Part B	Part C	
Question	1	2	3	4	5	6	Dolphin	essay	total
max. mark	20	20	20	20	20	20	35	25	100
mark									

Metabolic rate $\Gamma_0 = b \times 3.6 \times M^{3/4}$

If you think some necessary information is missing from the exam or from the green lecture notes make an "educated guess"
namely quote a number and write down why this number would make sense.
Clarifying comments from you may give you bonus points.

When you use a number from the green book please quote the page number.

Having a new and creative thought is wonderful, but don't expect glory.
Just enjoy if your idea lives on and is used by others
The rewards go to the ones who come second.
Pioneers get arrows into their bums

Part A: Solve 2 out of the following 6 questions.

A1- (Thermodynamics - Energetics) A hippo-thetical question

A hippopotamus of M=900 kg has been sleeping in a thicket and it waddles into the open late in the morning. The hippo stands in the bright light of the sun overhead for 20 minutes before it starts its active day.

(a) How much radiation energy does the hippo absorb in the 20 minutes? Model the hippo body as a cylinder of radius R and length $L=4R$ supported by 4 chubby legs each having the mass of M_{leg} = 50 kg. The solar constant is S = 1.37 kW/m^2. Assume an absorption coefficient K= 0.65..

(b) It is getting very hot and the hippo decides to take a bath in a pool of T = 22 °C. The hippo loses heat in the pool by thermal conduction through its bum. What is the rate of heat loss? Assume a bum area A_b=0.4m^2, thickness of bum fat insulation ΔR=2.5 cm, thermal conductivity κ = 0.11W/K m.

Thereafter the hippo rolls in the mud, accumulating a healthy layer of wet dirt all over its body. Then standing in a gentle afternoon breeze the hippo cools off by evaporating some water from the mud. How much water must be evaporated to lower its average body temperature by 1.5°?

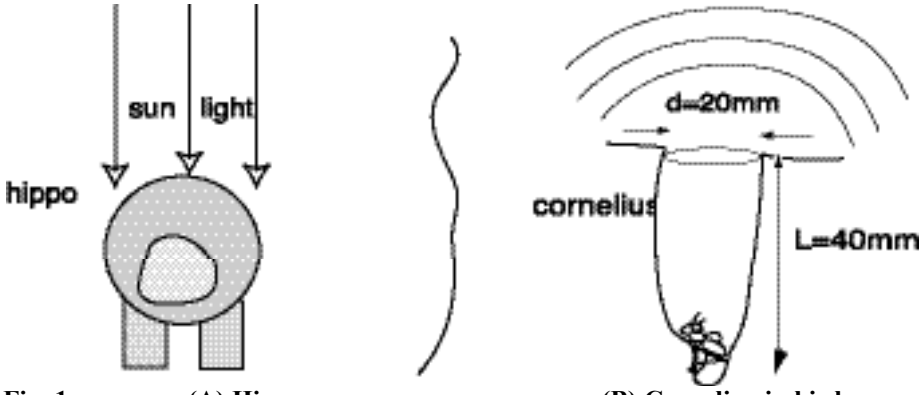

Fig. 1 (A) Hippo, (B) Cornelius in his burrow

A2 (Sound) The Crickets

Cornelius is an African burrowing cricket that makes its home in the ground. Cornelius makes sound with his wings, using the burrow as a secondary resonator. At a height of R_1=0.75m above the ground his song has an intensity of I_1=84 dB.

(a) What is his frequency?

(b) What is the oscillation velocity u_o of the air molecules due to the sound wave at the distance R_1?

(c) What is the acoustic power of his song emanating from the burrow?

(d) There is a female cricket R_2=40 m away. She has a hearing threshold of 45 dB. Will he catch her attention?

A3 (Statics) Toeholds

A person of M=80kg is standing with one foot on a book, as shown.

(a) Determine the tension T (force) in his Achilles tendon (diameter d=8mm), which is held by the calf muscles (A=90cm^2).

(b) Give the stress (F/A) in the muscles.

(c) Calculate the tension T if the foot is in the horizontal position (ø=0°).

(d) For ø=0° calculate the stress $=T/A_t$ in the tendon, and determine the safety margin, namely how much smaller . is than the maximum yield strength of tendon material, $_{max}$ = 1.4·10^8 N/m^2.

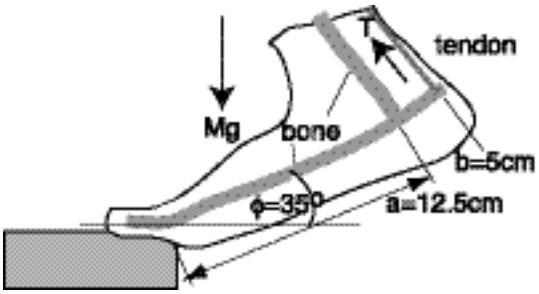

Fig. 2. Toehold

A4 (Fluid Flow) Is the lung ideal?

The lung of a typical person of M=75kg has a volume of V=5liter, and during maximum exhaling it is reduced in volume by 13%. The air is admitted through the windpipe, a tube of L≈20 cm length and R≈0.8cm radius. The O_2 and the CO_2 molecules are exchanged in a huge number of alveoli, tiny bubbles of r≈100μm radius. Assume allometric scaling, e,g, f (Hz) = 0.89 page 1-5. Viscosity of air $_{air}$=1.6 10^{-5} m^2/s.

(a) What is the breathing frequency. What is the exhaling time interval Δt_{ex} ?
(b) What is maximum exchanged volume ΔV_{ex}, and how large is the average volume flow . [m^3/s]?
(c) What is the flow velocity u , and what is the Reynolds number Re in the windpipe at this velocity? Is this flow laminar or turbulent?
(d) How large a pressure drop Δp is needed to drive the volume flow through the windpipe?
(e) Explain qualitatively why the lung has so many alveoli.

A5 (Locomotion) Extinct flying machines

The partial skeleton of a now extinct dinosaur *Pterodactyls phantasiensis elegans* has been excavated. The body had a length of L=2m, and an estimated body mass M=12.0 kg. The one recovered wing has a wing span of L_{wing}=2.4m with an average wing width of W=1.1m. Assume a lift coefficient C_L=0.6.

(a) Determine the velocity that the animal needs to stay aloft.
(b) Compare this speed to the velocity that the animal would have according to the great flight diagram $u_{fl}=17\cdot M^{1/6}$.
(c) Infer all you can on the dinosaur from your results from (a) and (b). (You may go beyond the physics of motion).

A6 (Optics) Eye damage

Roy Nodwell, head of the Physics Department UBC from 1978 to 1983 has a damaged retina in one of his eyes. When he was a small boy he watched a partial solar eclipse in his native Saskatchewan. Assume that the moon covered 40 % of the sun's disk. Everyone used a piece of glass blacked with soot as a filter to cut down the intensity of the sunlight. Little Roy wanted so see more and looked straight into the sun without a filter. The eye naturally contracts the iris in bright light. Assume that Roy's pupil contracted to a diameter of d=1.5mm, and use the focal length f=21mm. Roy looked at the sun for the 2 minute that it took the moon to cross before the sun.

(a) How much energy E_{phot} [J] passed through his pupil during this time?
(b) Calculate the number of photons (average photon energy of yellow light E_p≈3.4·!0^{-19}J, that entered his eye.
(c) The sun subtends an angle ø≈ 1/2°. How large was the burnt area of Roy's retina?

Bonus question

There must have been a burnt out spot in his retina, but Roy completely forgot about this damage. About 50 years later he worked at a laser research lab. In a routine eye check by the lab safety officer he was pulled out on the suspicion that he had damaged his eye with laser radiation. Why did Roy forget the damage he suffered as a boy?

Part B . attempt all parts of this problem

Flipper

A common dolphin of M=120kg can jump up into the air raising its center of mass by H=2.40m above the surface of the water, and it can easily dive down to D_1=65 m depth. Dolphins have a streamlined body with the diameter to length aspect ratio D/L≈ 0.25 of a fast swimmer. Dolphins talk to each other by whistling calls, and they explore their surroundings by sonar clicks.

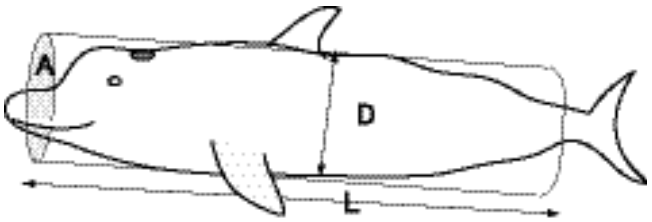

Fig. 3 Flipper

(c) What is its metabolic rate if the dolphin has an activity factor b=6? How many sardines (mass m= 7g ,) does the dolphin have to eat daily to support its metabolism? (for the sardines you may take an average heat of reaction Δh≈ 23 kJ/g)

(d) How much heat does the dolphin lose in the Juan da Fuca Straight (water temperature T≈ 8°C) through a surface section (A= 300 cm^2) on its belly where it is insulated by a ˙Δx=6cm thick layer of body fat?

(e) Comment on the fact that flippers do not have much body fat insulation. Would not the animal lose much heat from the flippers?

(f) How fast does the dolphin have to swim when leaving the water to reach a center of mass height of H=2.4m.

(g) If the dolphin swims at a speed u= 4.5 m/s what would be its drag resistance? (take C_D=0.02)

(h) What is the pressure in the water at D_1= 65 m depth?

(i) Suppose the dolphin dives in murky water (absorption coefficient = 0.15 m^{-1}) to the depth D_1 on a cloudy day when the light intensity is 40 % of the average solar intensity S=1.37 kw/m^2. What is the intensity at that depth? How many photons per second would pass through the dolphin's iris (assume a pupil diameter d=1.4 cm) when looking straight up from that depth?

(j) The dolphin emits a whistle of the intensity I=10^{-3} Watt/m^2 at the typical frequency f= 8.5kHz. What is the wavelength and the sound level in dB (re I_o=10^{-12} Watt/m^2) of this sound wave?

(k) Sketch a rough frequency - time plot for click and whistles

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Part C **Write an Essay** (typically 200- 300 words) on one of the topics

All essays must include relevant equations

a) Could the spermatic oil of a sperm whale be a diving weight? Discuss physical factors that are important for this question (Katie you cannot do this question)

b) Is the *Matrix* possible ? (sorry Victor you cannot work on this question)

(c) How might insects control their body temperature?

(d) Discuss how animals use sound for communication in the air, and in the water

(e) Is there a best sense for an animal? (Why do some animals mainly rely on their ears, other on their eyes, or detect electric and magnetic fields, and others on their sense of smell?)

(f) Describe some examples of resonance used by animals in locomotion and/or sound production.

(g) Describe some of the physical principles which one of the animals below uses to survive in their niche: alligator, bat, crow, dolphin, honey bee, monkey, octopus, pit snake, shark, wolf