The University of British Columbia

Sessional Examination - April 13 1999

Physics 438

Time 2 1/2 hrs

Candidates Name:...

Registration #:.......................................

Candidates Signature ....

This is an open -lecture -notes exam

The exam has three parts;

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

show all your rough work,

If you think some necessary information is missing make an "educated guess" namely quote a number and write down why this number would makes sense.

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

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

1) Metabolic rates of spiders and caterpillars

In summer time a 500 mg spider catches a meal about once a day (Δts,), in winter it goes on average for a 6 weeks without eating. (Δtw). Assume that the spider's prey weighs 100 mg on average. What the spider eats is going into its metabolic processes. The spider only "eats" the soft tissue (fat & proteins) and discards the empty shells. Assume that 1 g of fat and protein body tissue contains 25kJ

a) Make a reasonable assumption of the percentage of body mass of the prey which the spider eats and calculate the average energy content ΔQ of a meal extracted by the spider.

b) calculate the metabolic rate $\Delta Q/\Delta t$ in summer time and in winter.

c) Do a similar calculation for 100 mg plant eating caterpillar , who consumes 20 times its body weight in a day. Assume that the plant tissue contains about 6% of useful edible starches and proteins which have an energy content of about 21kJ/g.

d) Plot your results on the logarithmic plot Fig. 1, which already shows the metabolic rate curve of warm blooded animals (mouse to elephant curve), and explain if your results make sense compared to the mouse to elephant curve.

2) Heat transfer Ironman

You are sunbathing at noon in the midterm break on Whistler mountain lying with bare back on you belly and pretending to sleep. Since the sun is not directly overhead assume that the incident intensity is Isun= 0.8 kW/m2.

a) How much radiation energy will you absorb on a patch of skin on you back, A= 130 cm2 large in 3.5 minutes? Take an absorptivity of a = 0.4
Suddenly a good friend sneaks up on you and gently places a saucer shaped lump of wet snow onto your back (It makes contact with your skin on an area of 130 cm2). You pretend not to notice it snoring loudly. As a man of iron will you lie still for exactly 3.5 minutes as the water of some melted snow trickles down your belly. Both the sunlight and your warm body melts the snow.

b) Sunlight: How much snow melts during 3.5 minutes if 5% of the incident sunlight had been absorbed by the snow ? Lv= 333 J/g,

c) How much snow would melt during this time due to thermal conduction from you warm body?
Make a reasonable guess of the surface temperature of your skin, and the thickness Δx of your "thermal insulation" (skin plus fat layer on your back), and calculate the heat flux from your body to the snow. Assume an average thermal conductivity ks&f for skin and the fat layer below it of ks&f =0.09W/m°.

d) What is the total energy delivered in 3.5 minutes to the snowball while you lie motionless.

e) How much snow melts during the time of your ordeal?

f) What will you do to your friend afterwards ?

3) Relative motion: Cycling with and without wind

A cyclist on an old bike generates a steady output of 120W of mechanical power and makes 5.5 km in 15 min. Assume a drag coefficient of CD= 0.3 and a front surface cross section area A= 0.7 m2.

a) What is the average speed over ground ?

b) How large is the air resistance FD at this speed?

c) How munch mechanical energy $E = \Delta W$ [in J] does the cyclist generate on this trip?
Since energy E = F/distance, find the average total resistance force $F=F_D+F_{rolling}$, and determine the rolling resistance $F_{rolling}$

On the return trip he again generates a steady output of 120W of mechanical power and his bike has the same rolling resistance, $F_{rolling}$, however there is a head wind. It now takes him 25 minutes to get home.

d) What is the velocity of the head wind?
Hint: First find the total energy E_r expended on the return trip and then derive the total resistante force F_r

4) How large are Gaia's biggest flying birds?

A new small planet Gaia is discovered which has a gravitational constant is g_G= 3.0 m/sec2. This planet has a flora and fauna similar as earth, and an atmosphere with the same composition, pressure (p= 1 atm), temperature, and density ρ=1.29 kg/m3 as the earth.
Make a log-log sketch of the "great flight diagram" that you expect to find on this planet, (refer to pg 3-36 of the notes). Also show on your sketch the "flight by muscle power" curve for this planet ($v \leq f(M)$, and then estimate the mass M of the largest flying birds on this planet.

5) Sound of pain

A mosquito flips its wings at f= 120 Hz. You can barely hear the mosquito from a distance of 3 m. Assuming that "barely hear" is equivalent with an intensity at your ear of 5 dB. (Surface area of sphere $A= 4\pi R^2$. Speed of sound 340 m/s)

(a) Find the intensity I_1 at the location of your ear

(b) Estimate the surface area of you ear and calculate how much power you ear intercepts.

(c) How much sound power does the mosquito radiate into all direction as it makes this noise?

(d) What is the pressure fluctuation amplitude Δp_o , the displacement amplitude s_o and the velocity amplitude u_o of the sound waves in the air near your ear?

(e) Suppose the wing tip moves up and down in simple harmonic motion with an amplitude of A = 1.50 mm. Calculate the velocity U of the wing tip of the mosquito and compare it to u_o (namely calculate the ratio U/u_o.) Also determine the ratio A/s_o.

Isn't it amazing how small is compared to U, and how small s_o is compared to A.

6) Eye to eye (96)

The giant octopus living at large depth in the ocean has the biggest eyes of all animals. Typically the eyeball is the size of a basketball (estimate the diameter of a basketball). Assume that the octopus eye is a scaled up version the human eye, with iris, lens, and retina.

(a) Geometry: If the octopus would see an L= 8 m long whale from the side at a distance of 500m, how large (length and width) would be its image on the retina? The whale is a fast swimmer. (Remember that all fast swimmers have the same aspect ratio D/L.

(b) What is the diffraction limited angular resolution for blue light of the octopus's eye?(the angle at which the first order diffraction minimum occurs).##(c) Suppose the octopus looks at a point source (say a bioluminescent object) emitting 1 μ watt of blue light from a distance of 1000 m . How much light energy would his eye collect in one "blink" (1 blink = 0.3 sec).

Part B attempt all parts of this problem

The physics of our Dog Casey. Some numbers needed here: Casey's weight is 30 kg. Latent heat of evaporation Lv= 2257 kJ / kg, viscosity of blood nbl= 4 .10-6 m2/s

a) What is her basic metabolic rate in Watt = J /s? Express this number in Joule/day. How much dog food (25 kJ /g) does she have to eat just to support her basic metabolic rate?

b) If Casey runs up a flight of stairs 2.8 m high in 2 sec how much mechanical power does her leg muscles generate?

c) If Casey's leg muscles have an efficiency of 20% how much total power is generated by Casey as she runs up?

d) On a hot summer day Casey keeps cool by sticking out her tongue. When she is lying on her favorite spot, not doing any work (basic metabolic rate) how much water must she evaporate in an hour in order to get rid of the heat?

e) Casey often cracks nuts with her back teeth which are as close to the jaw joint as the chewing muscles. If it takes a force of 300 N to break a nut, how much force can she exert at location 1 with her incisors?

f) How fast is the blood flowing in her aorta? Assume that the Reynolds number of the flowing blood in the aorta is just below the laminar - turbulent transition

g) Casey's eye is somewhat like your own eye just smaller (let's assume the eye is exactly 1/2 the size of the human eye, but the rods and cones have the same lateral width Δ=1/400 mm)
Suppose she looks at a tennis ball (diameter 65 mm) at a distance of 3m. What is the diameter of the image on the retina, and

h) how many rods and cones does the image of the ball cover?

g)Sound level Casey can hear very faint sounds. She will raise her head when she hears a whisper of sound level ß-= 12 dB. What is the pressure amplitude of this sound.
Sound spectrum: Casey sometimes bangs her tail at a door in order to get in, and sometimes she howls with a clear tone (say of 880 Hz for about two seconds. Sketch the frequency - time traces of these two sounds into the f- time diagram.

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

(a) Describe some physical principles which animals in hot climates have adopted to control overheating and describe physical principles which animals living in cold climates utilize to avoid the loss of body heat.

(b) Why is breathing at high altitude or at the bottom of the ocean a problem for animals that normally live on the earth surface, and how do they over come the problem?

(c) Size:
What is the benefit of being small or large and what limits the size? :
Describe some physical effects which small animals can utilize in their niche, and what physical effects give a lower limit to the size, and describe some physical effects which big animals use to their advantage and what physical effects limit the maximum size of animals.

(d) Is there a the 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?)
You may discuss in your essay the points (i) Is there a relation between the size of the animal and the range of distance of its dominant distance sense? (ii) Do land animals rely more on sight and sea animals more on sound? If so why? (iii) How can the senses be confused. (iv) You may also describe some advantages and disadvantages of these senses
sense#eye#ears#electric/magnetic#smell##advantage ######disadvantages######
(e) From primitive cells to language: Describe some physical effects that evolution has "discovered" on the way from a single cell organism to Homo Sapiens.

(f) Describe the physical principles which one of the animals below uses to survive in its niche.
••••••• alligator, bat, crow, dolphin, honey bee, monkey, octopus, pit snake, shark, wolf. ••••••••