The University Of Sheffield.

DEPARTMENT OF PHYSICS AND ASTRONOMY

Spring Semester 2006-2007

PHYSICS OF LIVING SYSTEMS 2 **2 HOURS**

The paper is divided into two sections: A and B.

The student should answer all questions in section A. One sentence answers are sufficient for all questions in this section.

The student should answer two questions from section B.

TURN OVER

SECTION A

Answer all questions in this section: 2 marks each

1. State Wolff's law.

2. Name two models of viscoelasticity.

3. Sketch models using springs and dashpots that describe the models named in question (2) above.

4. State equations for stress and strain.

5. What do the terms creep and relaxation describe?

6. What does a Poisson's ratio of 0.5 indicate?

7. At what muscle length is the force in a tetanised muscle greatest?

8. What is the difference between an isotropic and anisotropic material?

9. In the context of dynamic processes, what is a conservative system?

10. What is Kinematics?

11. What two operations are combined by the affine transform?

12. Explain the terms systole and diastole.

13. The Reynolds number for the flow of a liquid through a smooth walled tube is 10,000. What kind of flow would you expect?

14. Where in the cardiovascular system may turbulent flow occur in a human?

15. What does the Womersley parameter determine?

16. Approximately what distance is required downstream from a disturbance for laminar flow to develop in a 10 mm diameter tube?

17. Compare the difference between the Newtonian and Eulerian reference frames.

18. What is a pressure of 120 mm Hg in SI units?

19. Where does blood leaving the right ventricle go?

20. State the Moens-Korteweg equation for the speed of a pressure pulse.

SECTION B

Answer any two questions from this section: 30 marks each

B1.

(a) You have been asked to model blood flow through the aortic arch. The first step is to obtain images of aortic arches. Which two modalities would be most suitable for this? What factors will influence your decision? [9]

(b) Blood is often modelled as a Newtonian fluid in large arteries. Why is this? Is this a reasonable assumption? [7]

(c) Atherosclerosis is an inflammatory disease of the arteries. It is characterised by the build up of fatty deposits within artery walls. Problems can arise when the deposits reduce the lumen of an affected artery to the extent of restricting blood flow (stenosis). What change in diameter would cause a restriction in cross sectional area of 50%? [6]

(d) Draw a graph of strain rate versus shear stress for each of the following types of fluid: plastic, dilatant, frictionless and Newtonian. [8]

B2.

(a) Describe a lever system where a 40 g mass can be used to lift a 400 kg mass. What class of lever will you use? Assume that the experiment is to be conducted in a venue with gravity, and that the beam used is massless. [5]

(b) A person is lying face down and lifts their lower leg, bending at the knee so that the lower leg is at an angle of 50 degrees with the ground. The distance between the knee and the point of muscle attachment is a, and the mass, W of the lower leg and foot acts at a distance $b + a$ from the knee. The angle between the line of force of the muscle and the lower leg is α. Sketch the system. What class lever system is this? What are the advantages and disadvantages of this class of lever? Find an expression for the force required in the muscle to maintain equilibrium. If the person has a mass of 60 kg, and the mass of the lower leg and foot accounts for 1/20 of total mass, estimate the force in the muscle. [20]

(c) A 70 kg man falls 3.5 m from a bouldering wall. What is his change in potential energy on impact? What is his velocity at the point of impact? [5]

TURN OVER

B3.

Parallel plate flow chambers are used to create controllable shear rates and shear stresses. The chambers generally consist of two flat parallel plates separated by a small gap of less than a quarter of a millimetre, through which Newtonian fluids flow.
The wall shear stress experienced at the top and bottom of a flow chamber can be determined theoretically.

A parallel plate flow chamber has length L, width b and height h. Consider an element of the chamber, with length L, thickness $2y$, symmetric along the centreline of the chamber and with width b, and assume a differential pressure P with a constant gradient along the length of the chamber.

(a) Draw a diagram of the chamber and find an expression for the force on the element of the chamber, from the pressure difference in the direction of flow. [6]

(b) What is the name of the stress opposing the flow? [2]

(c) Ignoring the effect at the edges of the chamber, write down an expression for the force opposing flow arising from this stress, expressing the opposing force as f. [4]

(d) Write an expression for the opposing stress, τ, in a Newtonian fluid, where viscosity = μ. [2]

(e) Where in the chamber is the velocity of flow greatest, and where is it smallest? [4]

(f) Express the forces opposing flow, in terms of viscosity (μ), distance from the centre line (y), flow velocity (v), chamber width (b), and chamber length (L). [4]

(g) Write an expression for the forces on the element, if the flow is steady. [4]

(h) Find an expression for the flow velocity as a function of the distance from the centreline, y, remembering that the flow velocity at the chamber wall is 0. [4]

END OF QUESTION PAPER