2026

Ollscoil na hÉireann, Gaillimh
National University of Ireland, Galway

Semester I Examinations 2005 / 2006

Exam Code(s)	1MV1
Exam(s)	M.Sc. in Biomedical Science
Module Code(s)	BES558
Module(s)	Introduction to Physical Science and Biomedical Applications
Paper No.	1
Repeat Paper	
External Examiner(s)	
Internal Examiner(s)	Dr. Una FitzGerald

Instructions: Answer 3 questions. Each question must be from a different section. Use a separate answer book for each question.

Duration	2 hours
No. of Pages	7 (including cover)
Department(s)	National Centre for Biomedical Engineering Science
Course Co-ordinator(s)	Dr. Una FitzGerald

Requirements:

MCQ	
Handout	1
Statistical Tables	
Graph Paper	
Log Graph Paper	
Other Material	

Section A: Materials- Structure and Properties

Question 1. [20 marks total]

Part A.
Give one example each of a ceramic and a metallic material and list their respective properties.

Part B.
In the case of each example describe the atomic structure of the component elements.

Part C.
With the aid of sketches explain the atomic bonding which occurs in each of these materials

Part D.
Give reasons for the properties of each of the materials in terms of their characteristic crystalline granular structures

Question 2. [20 marks total]

Part A.
Describe briefly the phenomena which underpin the science of nanotechnology

Part B.
Give an example of a nanomaterial and describe how its properties differ from the bulk form of that material

Part C.
Give an example of a polymer composite material and briefly describe its advantages over the original component materials.

Part D.
Describe briefly two potential applications of nanomaterials in the biomedical field.

Section B: Solid Mechanics and Fluid Mechanics

<u>Question 3.</u> [20 marks]

Part A.
Define briefly the following, giving the unit where appropriate:

- Weight
- Pressure
- Stress
- Strain
- Poisson's ratio [5 marks]

Part B.
State the conditions necessary for a body to be in static equilibrium.

[2 marks]

Part C.
If the forearm of a person is held in a horizontal position with a mass of 10kg in the hand, find the force required in the supporting muscle. The length of the forearm is 30cm, of mass 2kg and the centre of mass is 18cm from the elbow. The muscle attachment is 4cm from the elbow. You may assume that the muscle is almost parallel with the upper arm.

[7 marks]

Part D.
The pressure of blood in an artery of radius 10mm and thickness 2mm is 120mm of mercury (density 13000 kg/m^3), find the stress in the artery wall in thecircumferential direction. (show all calculations). [6 marks]

<u>Question 4.</u> [20 marks]

Part A.
Define briefly the following terms:

- Elastic modulus
- Elastic limit
- Strain energy
- Work of fracture
- Stress concentration [5 marks]

Part B.
Define the condition for a material to fracture, and sketch / describe the three main modes of fracture. [5 marks]

Part C.
Outline briefly the consequences of Griffiths fracture theory for biological systems.

[4 marks]

Part D.
A piece of mild steel 2m long, is held in a vice. If its length is increased to 2.01 find the axial stress and strain. (E = 210GPa). Find the strain energy per unit volume. If the specific work of fracture is $500 kJ/m^2$ find the maximum crack length for the material to remain stable. (i.e. the critical crack length)

[6 marks]

Question 5. [20 marks]

Part A: **Short Answers**

1) Which is more viscous -- oil or water?

2) What is the Reynolds number? State the formula, defining each term.

3) What aspects of a flow does the Reynolds number represent?

4) Describe some differences between laminar and turbulent flow.

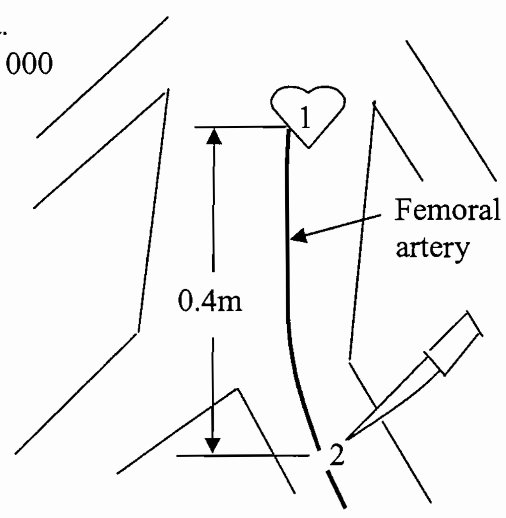
5) Name the conservation equations.

6) What is the boundary layer?

Part B: **Internal Flow**
A young man is separating frozen hamburgers with a large knife. The knife slips and the man stabs himself in the leg, severing the femoral artery. He knows that he will go into shock after loosing 40% of his total blood volume. After calling an ambulance, he gets his calculator and tries to figure out how long he has before going into shock.

Physical parameters and assumptions:

- The total head loss in the system is $h_T = 0.58$ m, which accounts for friction, branches in the arteries, and other losses in the system.
- Femoral artery length from heart to the cut is 0.40 m. Assume this is a straight, vertical tube of constant diameter.
- The internal diameter of the femoral artery is a constant 5 mm.
- Total blood volume is 5 litres.
- Atmospheric pressure (at wound exit) is 101 000 Pa.
- Assume pressure of blood in heart is a constant 103 000 Pa.
- Velocity of blood in the heart is 0 m/s.
- Blood viscosity is 0.003 kg/(ms).
- Blood density is $1060 kg/m^3$.
- Acceleration due to gravity (g) is $9.81 m/s^2$.



Useful conversions:

- $1 m^3 = 1000$ L
- 1 Pascal = $1 N/m^2$
- $1 N = 1 kg m/s^2$

Modified Bernoulli Equation:

$$\frac{P_1}{\rho_1}+\frac{1}{2}v_1^2+gz_1=\frac{P_2}{\rho_2}+\frac{1}{2}v_2^2+gz_2+gh_T$$

***Questions for Part B*:**

1. Assuming the man is standing (so the vertical change from the heart to the wound is the same as the artery length), find the velocity of the blood flow as it flows out of the wound. Use the modified Bernoulli equation including the total head loss.

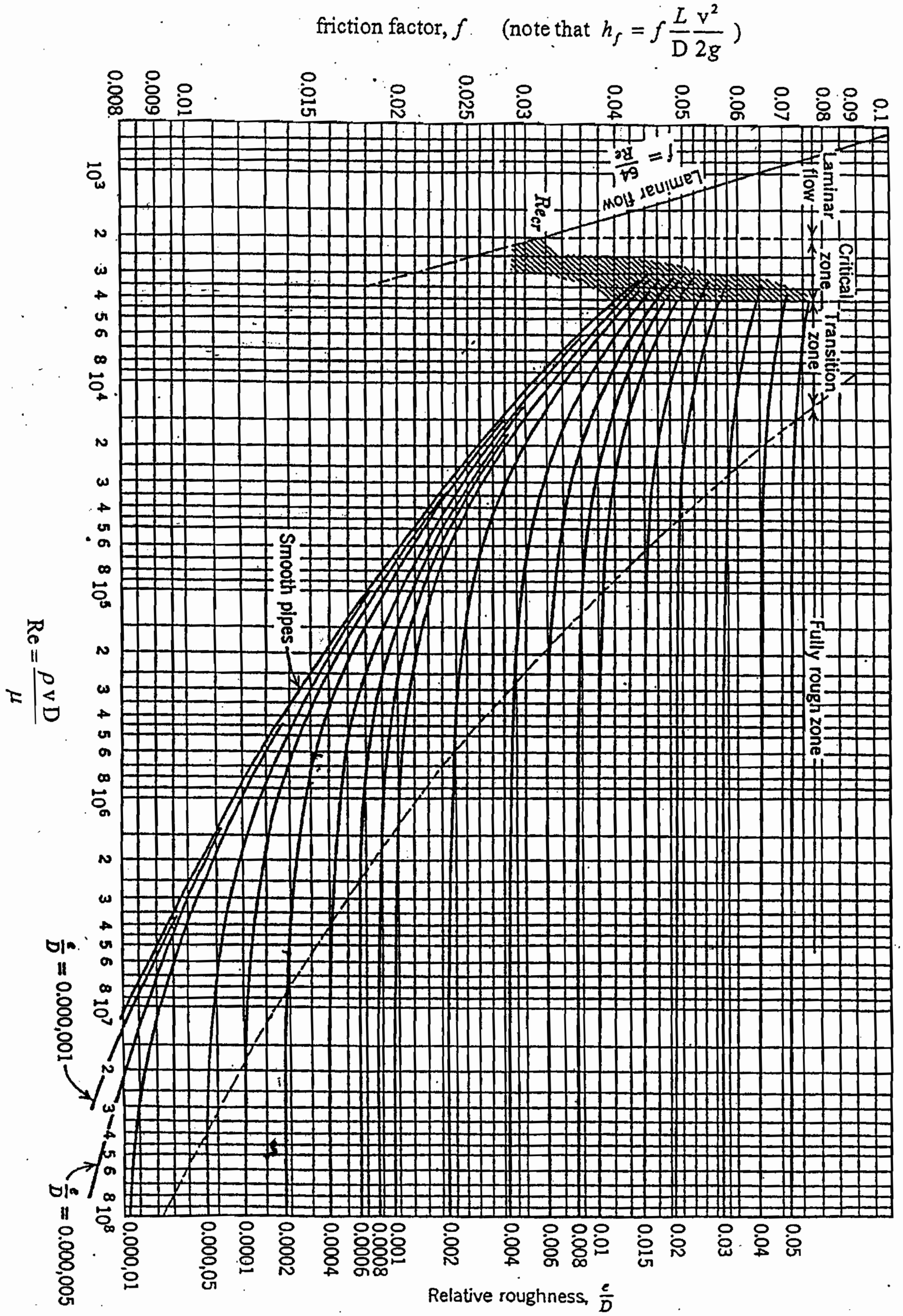
2. What is the Reynolds number of this flow? Is the flow laminar or turbulent?

3. Using the velocity from (1) and Reynolds number from (2), find the friction factor for this flow (use Moody diagram) assuming the walls of the artery are smooth. What portion of the 0.58 m total head loss (h_T) is due to friction head loss (h_f)?

4. Using the velocity from (1) and the internal diameter of the femoral artery, calculate how long the man has until he goes into shock (remember volume flow rate = velocity * area).

5. If pressure is applied to the wound, the end of the artery is pinched. This adds another source of head loss to the system and reduces the bleeding. How much time would the man have before going into shock if he were to lie down (so that his heart and the cut in the femoral artery are at the same height), and someone applied pressure to the wound? Assume the total head loss for this system is now $h_T = 0.192$ m. (Note that the head loss is lower than before since the blood flow velocity will be lower.)

<u>Aside</u>: If the values for total head loss were not provided in this problem, you would have to perform a few iterations of the calculations (since head loss depends on velocity). For example, you could guess a head loss, find the velocity, recalculate the head loss, then repeat.



friction factor, f (note that $h_f = f \frac{L}{D} \frac{v^2}{2g}$)
0.008 0.009 0.01 0.015 0.02 0.025 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
Laminar flow
$f = \frac{64}{Re}$
Re_{cr}
Critical zone
Laminar flow
Transition zone
Fully rough zone
Smooth pipes
$Re = \frac{\rho v D}{\mu}$
10^3 2 3 4 5 6 8 10^4 2 3 4 5 6 8 10^5 2 3 4 5 6 8 10^6 2 3 4 5 6 8 10^7 2 3 4 5 6 8 10^8
$\frac{\epsilon}{D}$ = 0.000,001
$\frac{\epsilon}{D}$ = 0.000,005
0.000,01 0.000,05 0.0001 0.0002 0.0004 0.0006 0.0008 0.001 0.002 0.004 0.006 0.008 0.01 0.015 0.02 0.03 0.04 0.05
Relative roughness, $\frac{\epsilon}{D}$

Section C: Tissue Interactions with Photons and Electrochemistry

Question 6. [20 marks]

Name and define four categories of fluorescence measurement. Describe in detail one fluorescence measurement system of your choice including the type of excitation used, emission collected, benefits and disadvantages of the system, and biomedical applications of the system.

Question 7. [20 marks]

Part A.
With the aid of diagrams describe both the direct and the indirect action of x-rays on DNA.

Part B.
Name the 2 types of radiosensitisers that have found practical use in radiotherapy. Describe the mechanisms underlying how they work to enhance radiation damage.

Question 8. [20 marks]

Answer (A), (B) and (C)

Part A.
Describe how the corrosion resistance of stainless steel stents are assessed using accelerated electrochemical corrosion test methods.

[10 marks]

Part B.
How do passivation processes in nitric acid improve the corrosion resistance of stainless steel stents?

[6 marks]

Part C.
Why are stents made from nitinol used in peripheral stenting?

[4 marks]