Ollscoil na hÉireann, Gaillimh
National University of Ireland, Galway

Semester II Examinations, 2004/2005

Exam Code(s)	1BM121, 1BG121, 1BN121, 1BP121, 1EG121
Exam(s)	1st Engineering (Mechanical, Biomedical, Electronic, Electronic and Computer, Undenominated)
Module Code(s)	ME112
Module(s)	Fundamentals of Mechanical Engineering
Paper No.	
Repeat Paper	Special Paper
External Examiner(s)	Prof. J. A. Fitzpatrick
Internal Examiner(s)	Prof. J. F. McNamara Dr. N. J. Quinlan
Instructions:	Answer 3 questions. All questions will be marked equally.
Duration	2 hrs
No. of Answer books	
Requirements:	✓
Handout	
MCQ	
Statistical Tables	log tables
Graph Paper	
Log Graph Paper	
Other Material	
No. of Pages	5
Department(s)	Mechanical and Biomedical Engineering

1 Figure 1 is a schematic diagram of the musculoskeletal system of the human arm. Consider the loading on the forearm (i.e. all of the arm from the elbow to the fingertips) when it is stationary and horizontal, while the upper arm is vertical. Assume that the forearm acts as a single rigid beam, and that the biceps is the only muscle to act on it in this case. Neglect the weight of the forearm itself. Treat the elbow as a simple hinge, with its axis at the point shown on the diagram. A 10 kg load is supported in the hand, with is centre of mass 35 cm from the elbow, as shown. The biceps is attached to the forearm 5 cm from the elbow, and may be treated as if it acts vertically. Note: the area moment of inertia of a circle about an axis along its diameter is $\pi D^4/64$.

(a) Draw a complete free-body diagram of the forearm. **(4)**

(b) Draw a second free-body diagram, making an imaginary cut just to the left of the point of attachment of the biceps, and including only the region between that point and the fingertips. **(4)**

(c) Hence, calculate the bending moment and shear force in the forearm just to the left of the point of attachment of the biceps. **(6)**

(d) Approximate the forearm bone structure as a cylinder of diameter 40 mm. Calculate the shear stress and maximum bending stress just to the left of the point of attachment of the biceps. **(6)**

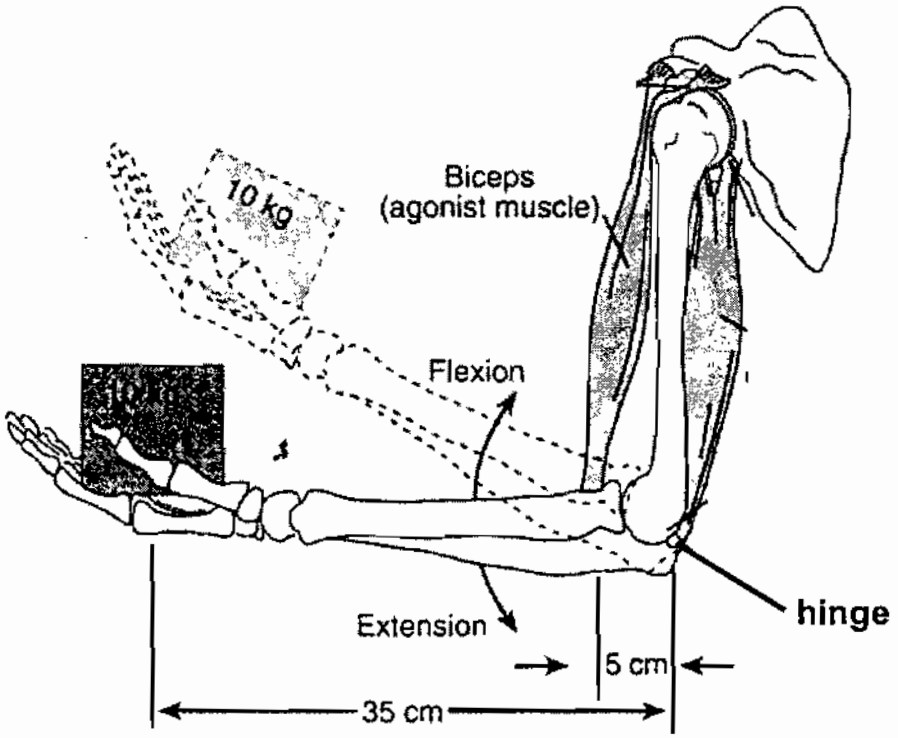

Figure 1 Schematic diagram of the musculoskeletal system of the human arm (adapted from Rhoades RA and Tanner GA, *Medical Physiology*, Lippincott Williams and Wilkins, 1995).

2 A gear with 12 teeth is mounted on the shaft of a motor (shaft A). This gear drives a gear with 40 teeth. A pulley wheel of diameter 240 mm is mounted on the same shaft as the larger gear (shaft B). A cable attached to this pulley wheel is used to raise a load of mass 20 kg.

(a) What torque is required on shaft B to hold the load steady? **(4)**

(b) What torque is required on shaft A to hold the load steady? **(6)**

(c) What torque is required on shaft A to accelerate the load upwards at 4 m/s^2? **(6)**

(d) What motor power is required to raise the load at a constant velocity of 1 m/s? **(4)**

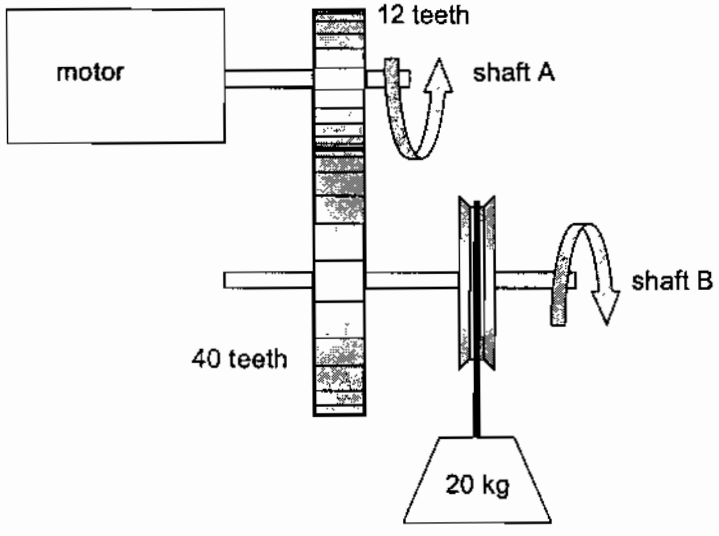

Figure 2 Schematic diagram of the mechanism described in Question 2.

3

(a) Explain the meaning of *brake work* and *indicated work*, clearly showing the difference between them, and why they are not the same. **(5)**

(b) The flame temperature in a particular four-stroke spark ignition engine is 1200°C and the ambient temperature is 21°C. What is the maximum efficiency the engine could achieve, theoretically? **(5)**

(c) On a test stand, the engine is found to develop torque of 76 Nm at a speed of 2000 rpm while burning fuel at a rate of 68.6 g/min. The calorific value of the fuel is 48 MJ/kg. Calculate the brake power and the overall efficiency of the engine. **(6)**

(d) Calculate the brake mean effective pressure of the above engine if its total displacement is 1.2 litres. **(4)**

4 Figure 4 shows the intake diffuser of a turbofan engine, typical of large passenger and freight aircraft. Consider cruise flight conditions when ambient temperature is –40°C, ambient pressure is 54 kPa, and forward flight velocity is 930 km/hr. The diameter of the intake diffuser is 2.0 m at section 1 in the diagram, and 2.5 m at section 2.

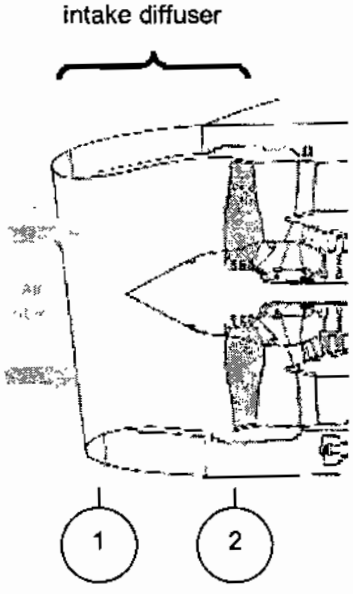

Figure 4 The intake of a turbofan jet engine.

(a) Calculate the density of air entering the engine. **(4)**

(b) Calculate the mass flow rate of air entering the engine (section 1). **(4)**

(c) Calculate the velocity and pressure of air at the fan (section 2), neglecting changes in air density. **(12)**

5 Comment on the design project you completed for this course, as directed below.

(a) Briefly describe the design concepts that your team considered, and explain the logic leading to the selection of one concept which you developed to the final design. **(8)**

(b) Describe one example of how scientific and/or mathematical analysis played a part in the design. **(6)**

(c) What have you learned from this project about the best way to approach engineering research, design and development and problems in general? **(6)**