OLLSCOIL NA hÉIREANN, CORCAIGH
THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

SUMMER EXAMINATIONS, 2003

B.E. DEGREE (ELECTRICAL)

PRODUCTION ENGINEERING
ME4002

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Time allowed**:** 3 hours

Answer *three* questions from *BOTH* sections

All questions carry equal marks

The use of a Casio fx570w or fx570ms calculator is permitted

SECTION A: MATERIALS PROCESSING AND DESIGN FOR MANUFACTURE

1. (a) In any manufacturing process that uses dies or moulds, the final geometry of any component may be difficult to control. Show that both mechanical and thermal effects may make dimensional accuracy difficult to achieve in the finished component. In each case, use example calculations for both a metal and a polymer to illustrate your answers.

[*12 marks*]

(b) Explain the concept of draft angles and where they are required in permanent dies and moulds, using diagrams to illustrate your answer as appropriate. Explain why draft angles are still required for components made in consumable moulds.

[*8 marks*]

2. (a) The component shown below in Figure 1 is to be cast in a eutectic alloy, and consists of an upper stepped plate connected via a 10mm diameter cylindrical pillar to a flat base plate with a 10mm diameter through hole as shown. Using Chvorinov's modulus technique, calculate the solidification sequence of the component. All dimensions are in mm. (Diagrams are not drawn to scale.)

[*15 marks*]

(b) A design engineer has suggested that by reducing the height *h* of the flat base plate from 10mm to 5mm it may be possible to cast the component using a single feeder located on the shaded end surface *F* of the top stepped plate as shown. Clearly stating any feeding criteria, prove the validity of the engineer's claim.

[*5 marks*]

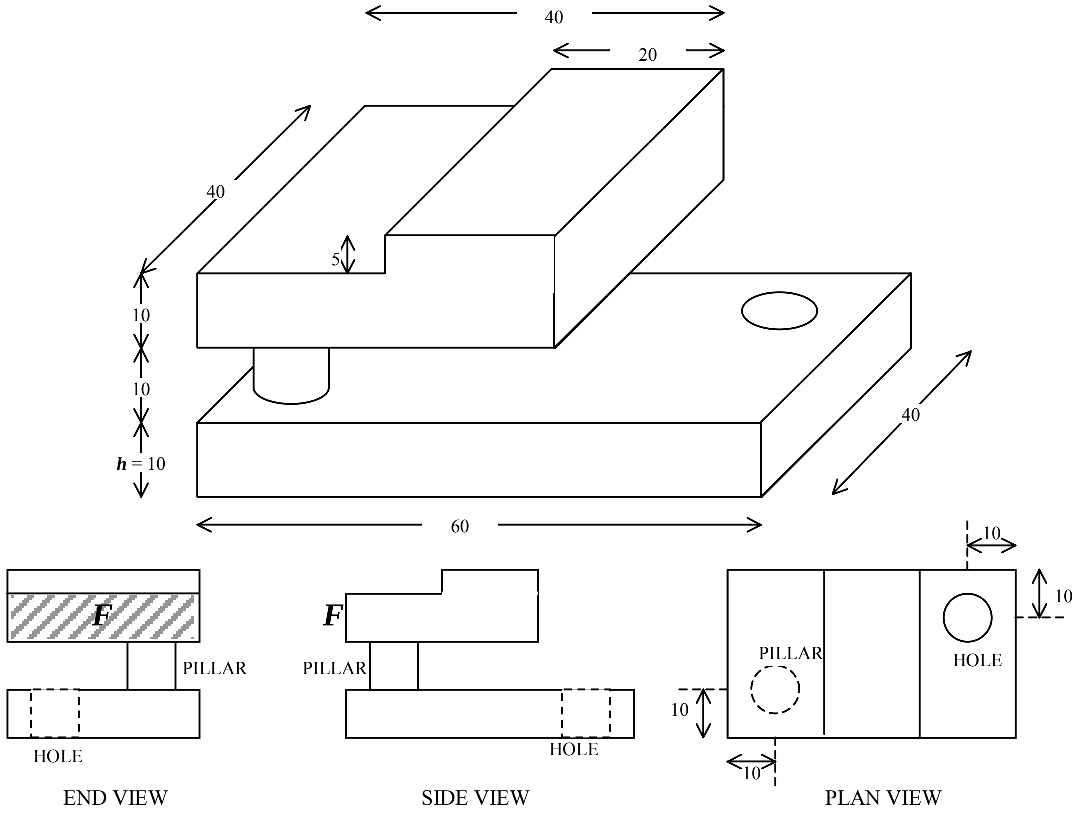
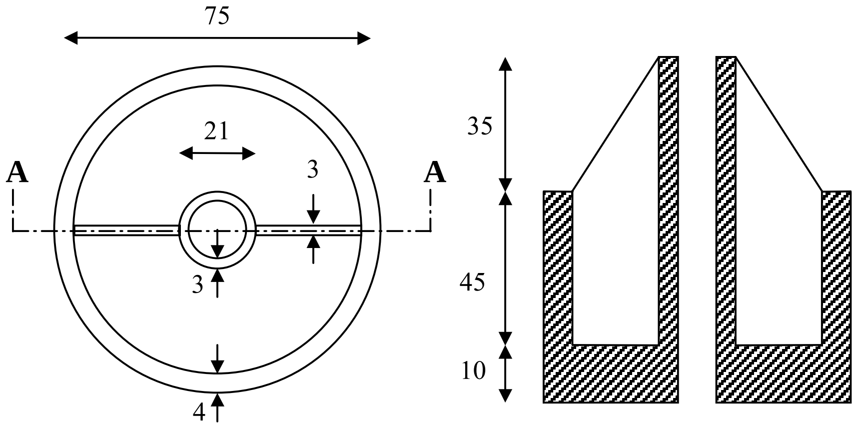


Figure 1: Component geometry for Question 2.

3. The prototype component shown below in Figure 2 is to be manufactured in a high shrinkage polymer by injection moulding. Criticise the design and suggest improvements. All dimensions are in mm. (Diagrams are not drawn to scale.)

[*20 marks*]



Top view

Section *A-A*

Figure 2: Polymer component for Question 3.

4. The 'T'-piece shown below in Figure 3 is to be constructed from 5 pieces of mild steel. The overall length of the component is 500mm; all other dimensions may be estimated. Discuss the suitability of the component for manufacture by (a) manual arc welding, and (b) adhesive bonding. For both manufacturing techniques, suggest design improvements to ensure the accuracy and integrity of the finished component. (Diagram is not drawn to scale.)

[*20 marks*]

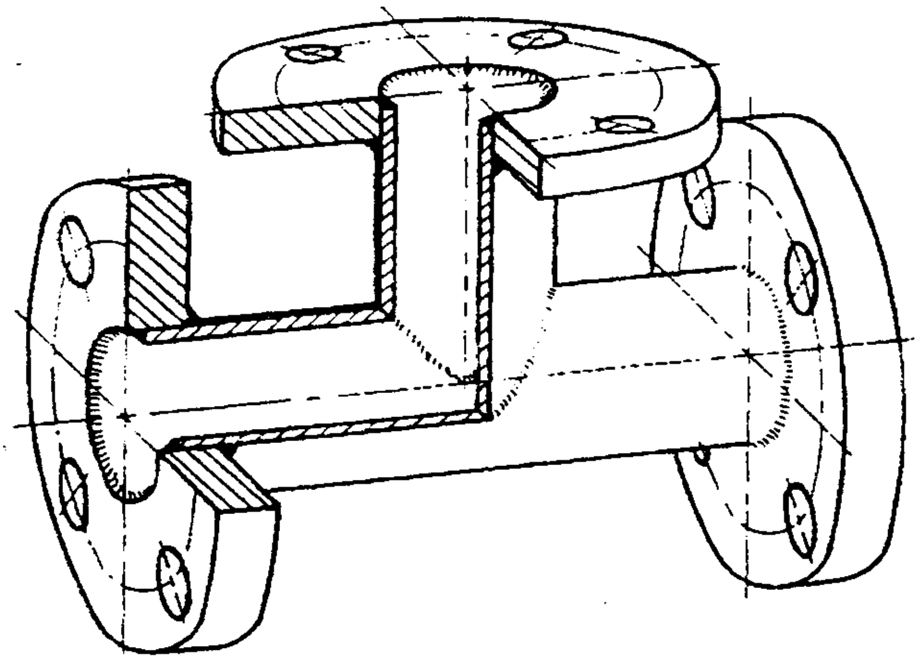


Figure 3: Component assembly for Question 4.

(End of Section A)

SECTION B: NON-DESTRUCTIVE TESTING

5. (a) Describe the four main scattering mechanisms which may occur as X-rays or γ-rays pass through a material. Explain how the scattered radiation may degrade the quality of a radiographic image, and hence define the term "build up factor".

[*10 marks*]

(b) A butt weld joining two lengths of steel plate 10 mm thick is to be inspected using X-rays. A radiographic film is placed 0·5 m from the far side of the joint, and an X-ray tube with a 5 mm diameter aperture and 150 kV potential is situated 150 mm from the near side of the joint. For a 2 mm wide defect located on the far side of the joint at the weld root, calculate:

(i) the minimum wavelength of the source;
(ii) the geometric unsharpness;
(iii) the magnification of the defect;
(iv) the size of the defect as it appears on the radiograph.

($h = 6{\cdot}626 \times 10^{-34}$ J·s, $c = 3 \times 10^{8}$ m·s^{-1}, $e = 1.602 \times 10^{-19}$ C)

[*10 marks*]

6. For each NDT requirement given below, describe a suitable method of achieving the stated objective. Give a brief outline of the underlying theory and outline any precautions to be taken to ensure consistent, reproducible results. State any advantages or limitations of the particular methods chosen, supporting your answers with quantitative arguments wherever possible.

(a) detecting surface-breaking cracks 1μm or more wide in ceramic insulators used on overhead electricity pylons.

[*6 marks*]

(b) detecting areas of delamination in composite panels, consisting of five layers of 1 mm thick polymer sheet, bonded together with adhesive. The technique should be capable of determining which of the layers have delaminated.

[*7 marks*]

(c) measuring the variations in conductivity of copper alloy bar produced in long lengths 1 cm in diameter intended for carrying very high electrical currents.

[*7 marks*]

7. A company wishes to use ultrasound to monitor steel for internal shrinkage cavities and inclusions as it emerges from a continuous casting process. The steel section will be moving at speeds of up to 2 m/min and will be at a temperature of between 800°C and 1100°C. Describe a suitable non-contact ultrasonic inspection system based on laser generation of ultrasound, and detection of ultrasound by EMATs. The system should use both longitudinal and shear waves. Answers should include details of the generation and detection principles, any precautions required to ensure consistent and reliable results, and advantages and disadvantages of the proposed inspection technique.

[*20 marks*]

8. Outline the basic principles and methods involved in non-destructive testing (NDT) of engineering materials by magnetisation. Answers should include a description of an application in which such magnetic methods of NDT could be used, the nature and type of defects that the test could be expected to reveal, the advantages and disadvantages of using magnetic methods, any special considerations to ensure reliable and consistent results, and ways of improving the sensitivity of the technique.

[*20 marks*]

(End of Section B)

PROPERTIES OF TYPICAL ENGINEERING MATERIALS

Material	Alloy constituents	0.1% proof (yield) stress	Young's modulus	Density	Specific heat capacity	Coefficient of linear thermal expansion	Thermal conduct-ivity	Electrical resistivity (per cube)	Relative cost	
METALS AND ALLOYS	% by mass	σ_y (MPa)	E (GPa)	ρ x 10^3 (kg·m^{-3})	c (10^3 J·kg^{-1}·K^{-1})	α (10^{-6}·K^{-1})	λ (W·m^{-1}·K^{-1})	ρ_e (Ω·m)	(k€·m^{-3})	Notes
CAST IRON grey	3.5C	100-250	100-150	7.0-7.4	0.52	11	50	700x10^{-9}	0.8	
malleable	2.5C	250-500	170	7.3	0.52	11	40	340x10^{-9}	1.0	
STEEL mild	0.06-0.25C	250-500	210	7.9	0.45	11	50	120x10^{-9}	1.2	
medium carbon	0.25-0.6C	250-700	210	7.9	0.45	11	50	230x10^{-9}	1.5	
alloy	Ni Cr Mo	700-1000	215	7.9	0.45	11	30	300x10^{-9}	2	
stainless	0.2C 16Cr	500-1000	215	7.8	0.5	10	25	720x10^{-9}	4-7	Martensitic
	0.1C 18Cr 8Ni	200-800	215	7.8	0.5	16	16	740x10^{-9}	4-7	Austenitic
MAGNESIUM alloy	8Al 0.5Zn	150-250	40	1.8	1.0	25	100	600x10^{-9}	7	
ALUMINIUM pure		30-140	70	2.7	0.88	27	240	36x10^{-9}	2.2	
alloy	4Cu 1Mg	125-400	70	2.8	0.9	27	180	38x10^{-9}	3.4	"Duralumin"
TITANIUM alloy	4Al 4Mn	1000	110	4.5	0.5	9	17 (1)	500x10^{-9} (1)	80	(1) Pure metal
ZINC alloy	4Al 1Cu	250	108	7	0.4	30	100	700x10^{-9}	3.2	"Mazak"
NICKEL alloy	Cr Co	100-800	190	8.5	0.4	13	15	1200x10^{-9}	30	"Inconel"/"Nimonic"
COPPER pure		50-300	130	8.9	0.38	17	400	17x10^{-9}	8	
bronze	7.5 Sn	150-750	100	8.9	0.38	18	60	140x10^{-9}	20	
brass	30-40 Zn	150-500	100	8.5	0.37	18-23	130	65x10^{-9}	9	

THERMOPLASTIC POLYMERS	Ultimate tensile stress (MPa)								
Polyethylene PE	5-25	0.1-1.0	0.9-0.95	2.3	100-200	0.4	>10^{14}	0.6	
Polypropylene PP (g)	25-35	1-1.5	0.9		110-170	0.2	>10^{14}	0.7	
Polyvinyl chloride PVC	60	2.5	1.4	1-2	50	0.15	>10^{14}	1	
Polytetrafluoroethylene PTFE	15-40	4-6	2.2	1	100-200	0.25	>10^{17}	22	"Fluon"/"Teflon"
Polystyrene PS	50	1-3	1.1	1.3	60-80	0.15	>10^{11}	0.7	
Polymethylmethacrylate PMMA	50-70	3	1.2	1.5	50-90	0.2	>10^{12}	1.6	"Perspex"
Polyamide (nylon) PA (g)	50-90	1-3	1.1	1.6	80-150	0.22	>10^{10}	2.5	
Polyacetal (Polyoxymethylene) POM	65	3	1.4	1.4	30-35	0.25	>10^{11}	2.0	"Kematal"
Acrylonitrile-butadiene styrene ABS	20-40	2	1-1.1		60-100		>10^{15}	1.2	
Polyethylene terephthalate PET (g)	70-170 (1)	2.3	1.3	1.3	20 (1)		>10^{19}	2.2	"Melinex"/"Mylar" (1) Oriented film
Polycarbonate PC (g)	60-70	2.8	1.2		70	0.15	10^{16}	2.4	
THERMOSETTING POLYMERS									
Epoxy and polyester: 'GRP', 'DMC', 'SMC'	90-130	20-30	1.5-2.0	1.7	15-30	0.2-0.4	>10^{16}	1.7	'Glass fibre reinforced plastics'
Phenol, urea, melamine- formaldehyde (g)	30-50	5-8	1.4-2.0	1.7	30-45	0.2	>10^{12}	1.1-2.4	

(g) With glass fibre filler, UTS and E increased by x2 to x3, density by +0.2

Note: Polymers exhibit creep at room temperature. The given values for σ and E are for short-term loading only.

RUBBERS					Max usable temp. (°C)				
Natural (polyisoprene)	20		0.9-1.2	1.9-1.4	85	0.13-0.16	10^{6}-10^{16}	0.5	Soft →Hard
Polyurethane	25	0.001 to	1.1		85			3.0	
Neoprene (polychloroprene)	20	1.0 as	1.2		95			2.0	
Nitrile	15	required	1		115			1.0	
Fluorocarbon	15		1.8		290			35.0	

WOOD pine	20-100	15 (1) 1 (2)	0.5	2.8	3-5 (1) 35-60 (2)	0.15	10^{10} (dry)	0.4	(1)along grain (2)across grain
GLASS crown	30-90	70	2.5	0.7	8.5	1	>10^{9}	1.0	
CONCRETE	15-70(1)	15-40	2-2.5	0.8-1.2	10-20	1.5-2.5	10^{2}-10^{9}	0.25	(1) compressive (cube)

FLUIDS	Viscosity	Bulk Modulus			Coefficient of volumetric expansion			Relative cost	
	η (10^{-3} Pa·s)	k (Pa)			β (10^{-3} K^{-1})			(€·m^{-3})	
WATER pure	1 (1)	2.2x10^{9}	1	4.19	0.2	0.67	5x10^{3}	0.2	(1) tap water at 20°C
sea	1		1.03	3.9			1		
OIL engine (10W50)	300 (1) 20 (2)	1.7x10^{9}	0.9	2	1	0.15	>10^{10}	400	(1)at 20°C (2)at 100°C
AIR at 20°C, 10^{5} Pa	0.02	10^{5}	1.2x10^{-3}	1	3.7	0.032	→∞		
HYDROGEN at 20°C, 10^{5} Pa	0.009	10^{5}	0.084x10^{-3}	14	3.7	0.14	→∞	2	

ACOUSTIC PROPERTIES*	Density (kg·m^{-3})	Longitudinal velocity (m·s^{-1})	Shear velocity (m·s^{-1})	
ALUMINIUM ("Duralumin")	2790	6320	3130	
BRASS (70Cu 30Zn)	8640	4700	2100	
COPPER	8930	5010	2270	
IRON (Cast)	7220	4600	2600	
LEAD	11200	200	700	
MAGNESIUM	1738	5800	3000	
NICKEL	8840	5600	3000	
STEEL mild	7800	5900	3200	
STEEL stainless	7890	5790	3100	
TITANIUM	4510	6100	3100	
TUNGSTEN	19400	5200	2900	
ZINC	7000	4200	2400	
AIR (@20°C and 1 atm)	1.2 x 10^{-3}	344	-	
OIL	880	1700	-	
WATER (@20°C)	1000	1480	-	

ACOUSTIC PROPERTIES*	Density (kg·m^{-3})	Longitudinal velocity (m·s^{-1})	Shear velocity (m·s^{-1})	
CARBON (Pressed graphite)	1800	2400		
EPOXY RESIN	1100	2440		
GLASS	2240	5100	2800	
NYLON	1120	2600	1100	
PERSPEX (PMMA)	1180	2700	1300	
POLYETHYLENE	900	1950	540	
POLYPROPYLENE	880	2660		
RUBBER (Neoprene)	1310	1600		
SILICON NITRIDE	3270	11000	6250	
WOOD pine	450	3500		
PIEZOELECTRIC MATERIALS			Piezoelectric pressure (V·m·N^{-1})	
LITHIUM NIOBATE	4700	7080	0.37	
LEAD-ZIRCONATE-TITANATE (PZT)	7500	4440	0.24	
PVDF	1800	2300	0.23	
QUARTZ	2650	5750	0.58	

*Shear velocity may be approximated to one half of the longitudinal velocity. All values shown vary with exact material composition. Many materials exhibit significant anisotropy.