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THE NATIONAL UNIVERSITY OF IRELAND, CORK

COLÁISTE NA hOLLSCOILE, CORCAIGH
UNIVERSITY COLLEGE, CORK

SUMMER EXAMINATIONS, 2005

B.E. DEGREE (ELECTRICAL)

PRODUCTION ENGINEERING
ME4002

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Time allowed**:** 3 hours

Answer any *five* questions

All questions carry equal marks

The use of a Casio fx570w or fx570ms calculator is permitted

The use of mathematics tables is permitted

1. The component shown in Figure 1 is to be cast in a eutectic alloy, and consists of a 15.0cm thick square upper plate with a 10.0cm x 40.0cm rectangular through slot, connected via two 15.0cm square pillars 50cm long to a 12.0cm thick cylindrical base plate with two 10.0cm diameter through holes. Using Chvorinov's modulus technique, and clearly stating any feeding criteria, calculate the solidification sequence of the component before riser placement. Show whether a single riser covering the shaded surface A for the full 15.0cm width of the pillar for a length L = 37.0cm is capable of feeding the entire component. Determine the minimum height of the riser. Figure 1 is not drawn to scale, all dimensions are in cm.

[*20 marks*]

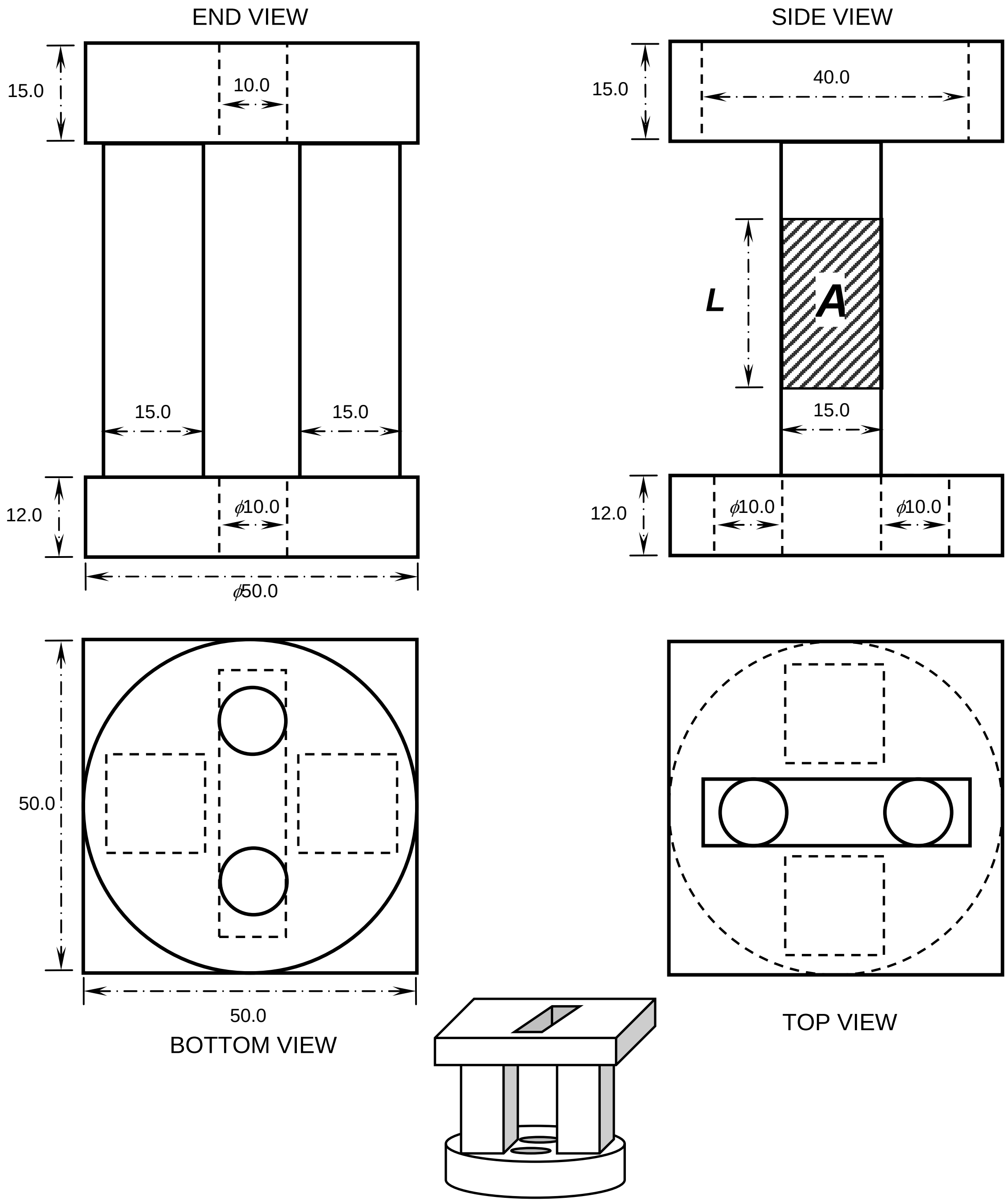

Figure 1: Component geometry for Question 1.

2. (a) Explain in detail what is meant by springback in sheet metal forming, and describe three ways in which it may be eliminated.

[*8 marks*]

(b) The bracket shown below in Figure 2 is to be manufactured from 3.0mm thick brass sheet, with four 110° bends as shown, produced by a sequence of punching, notching and wiping operations. The outer two bends have a radius of 8.0mm, the inner two bends have a radius of 5.0mm. (Diagram is not drawn to scale).

Calculate the following:

(i) the total length *L* of the starting blank and the location *y* of the central two holes. If $R < 2t$, $K_{BA} = 0.33$; If $R \geq 2t$, $K_{BA} = 0.5$

(ii) the hole clearance and the actual diameters of the punches and dies required, given an allowance *a* of 6%

(iii) the wiping tool angle, assuming a springback of 5%

[*12 marks*]

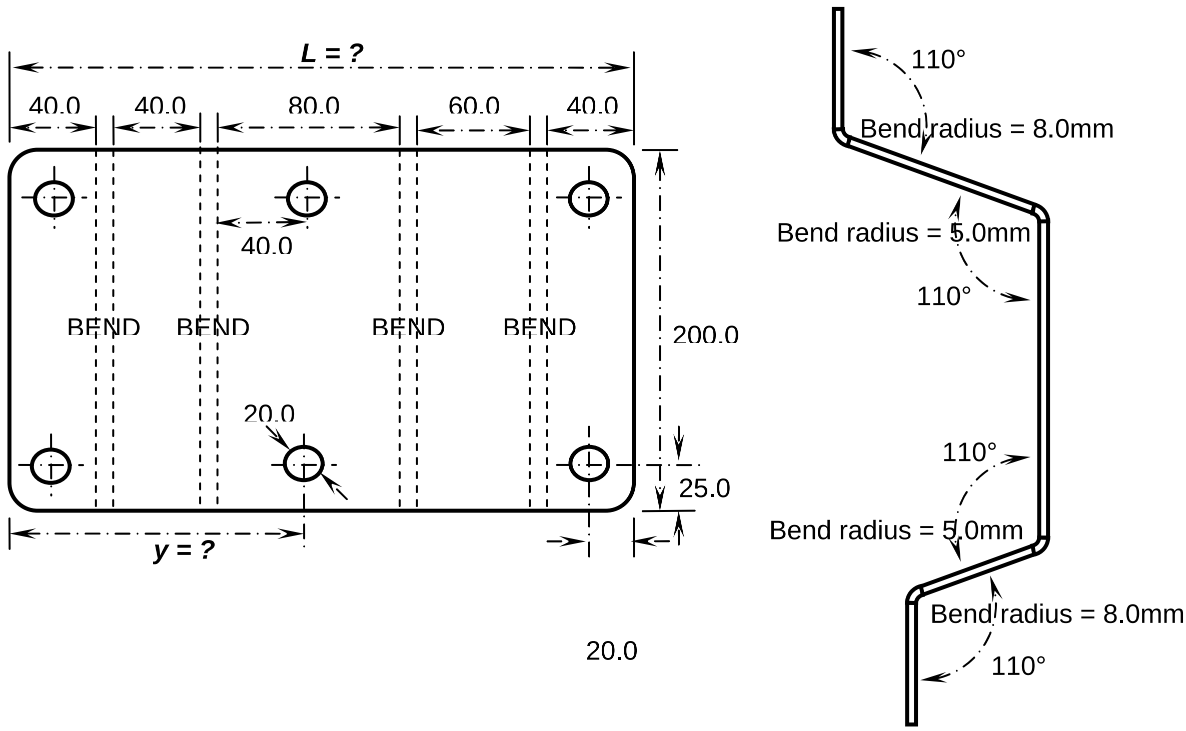

Figure 2: Component geometry for Question 2.

3. (a) Describe the sequence of cooling mechanisms that occur when a mild steel cylindrical bar is quenched from 1000°C in water. Explain how vapour traps are formed, and how they may be eliminated.

[*8 marks*]

(b) Using the continuous cooling transformation diagram in Figure 3 overleaf, determine the final composition and hardness value in 0.13%C steel for:

(i) a 0.2mm diameter bar cooled in air

(ii) a 20mm diameter bar cooled in oil

(iii) a 200mm diameter bar cooled in water

[*12 marks*]

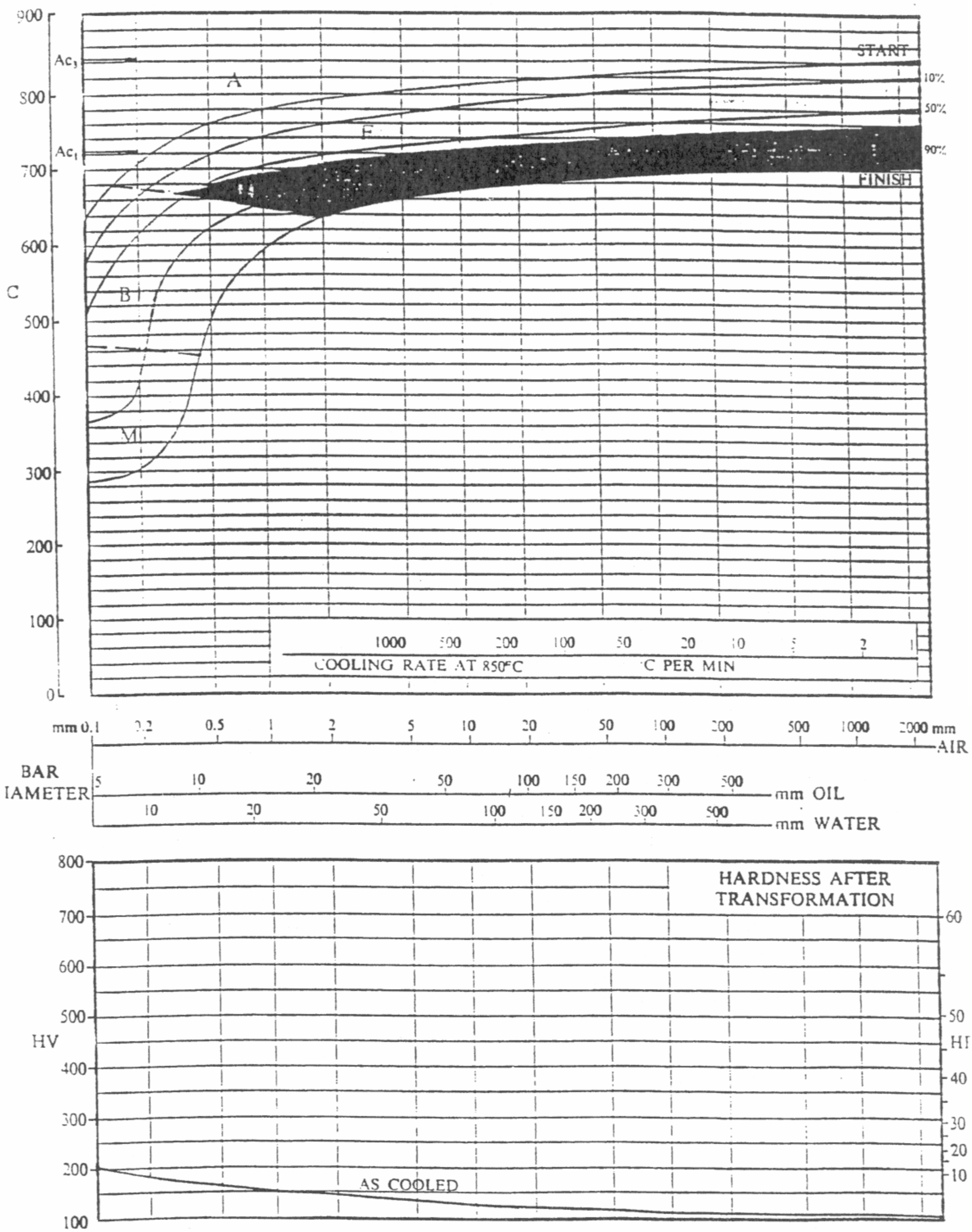

Figure 3: CCT diagram for Question 3.

4. (a) A high-sensitivity radiograph of 1mm wide surface-breaking cracks in an aluminium sample that varies in thickness from 150mm to 180mm is required. Given that:

$$d_{SF} = d_{SO}\left(1 + \frac{U_g}{s}\right)$$

where U_g is the geometric unsharpness, determine the minimum source-to-film distance for:

(i) a 200kV 10mA X-ray tube with an effective spot size of 3mm

(ii) a 4mm diameter Iridium-192 source with an activity of 3700GBq

(U_f for ^{192}Ir is 0.17mm, 1 Ci = $3.7\text{x}10^{10}$ disintegrations/second).

[*8 marks*]

(b) Calculate the required exposure time for both sources in part (a).

[*12 marks*]

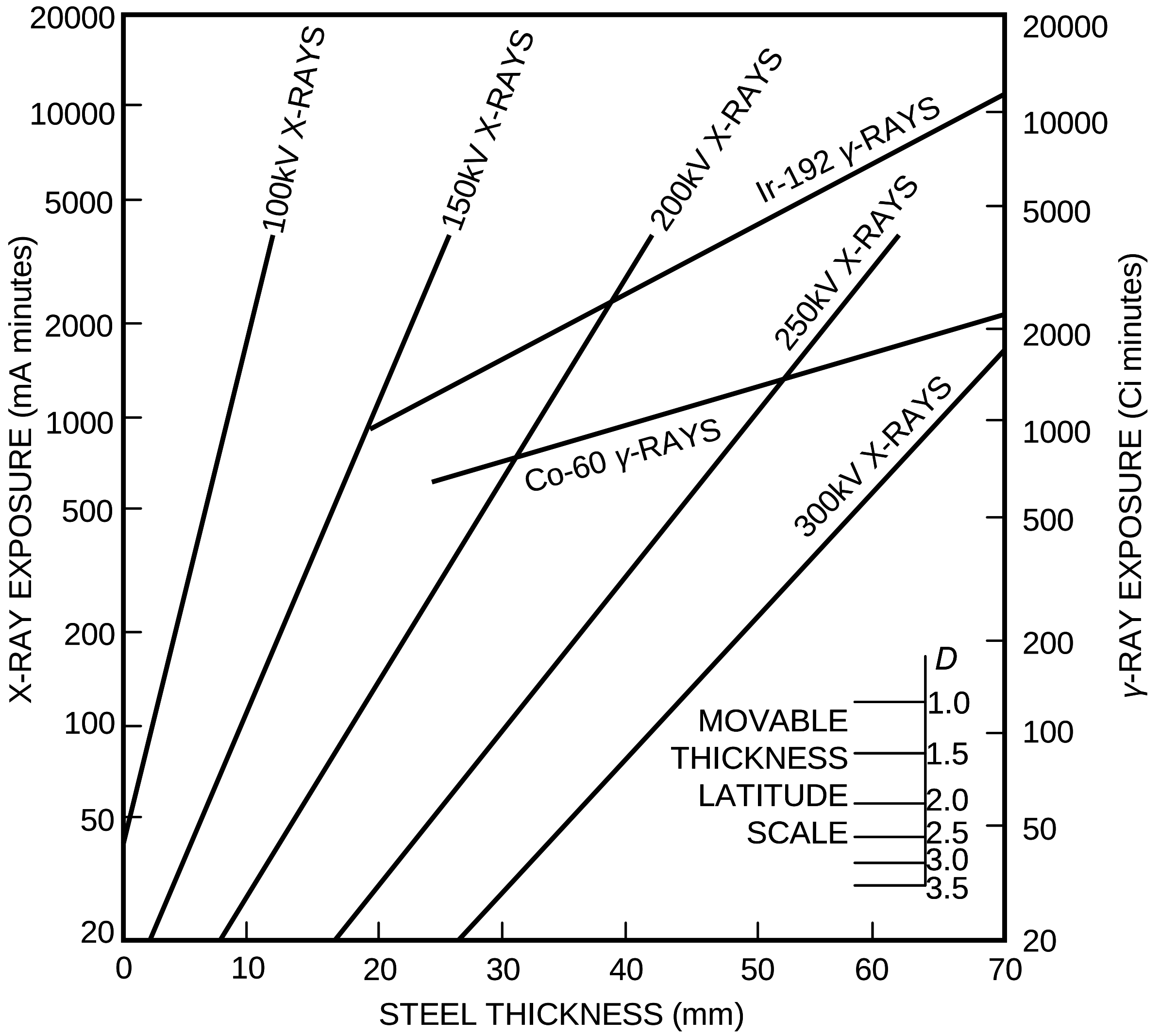

Figure 4: Exposure chart for Question 4.
(Chart shown is for a d_{SF} of 1m giving a density of 2.0)

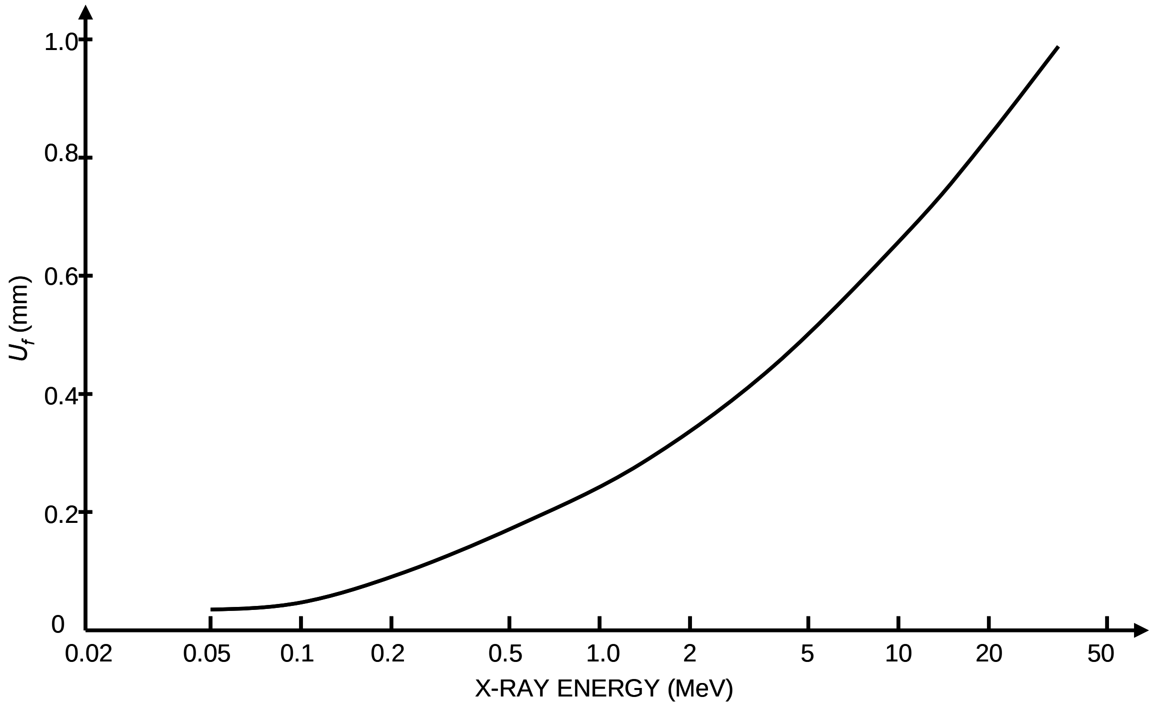

Figure 5: Film unsharpness *(U_f)* curve for Question 4.

RADIATION	STEEL	ALUMINIUM	MAGNESIUM	COPPER	LEAD
X-RAYS (kV):					
50	1.0	17.5	29.0	0.75	0.19
100	1.0	13.0	20.0	0.68	0.12
150	1.0	8.0	18.0	0.75	0.09
200	1.0	6.3	14.0	0.70	0.075
300	1.0	5.2	-	0.65	0.06
400	1.0	4.5	-	0.60	-
γ-RAYS:					
Ir-192	1.0	3.0	-	0.9	0.25
Co-60	1.0	-	-	0.9	0.65

Table I: Equivalent thickness factors for Question 4.

5. For each NDT requirement given below, describe the most 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. Support your answers with sketches as appropriate and qualitative arguments where possible.

(a) Detect all surface-breaking cracks wider than 1μm in ceramic insulators used on overhead electricity pylons.

[*6 marks*]

(b) Accurately determine the depth of surface-breaking cracks more than 2mm deep in an aluminium storage vessel with walls 20mm thick. The locations of the defects are known, having been determined previously by ultrasonic inspection.

[*7 marks*]

(c) Monitor the propagation of known cracks in a steel railway viaduct that has been in service for over 50 years.

[*7 marks*]

6. The component shown below in Figure 4 is manufactured from 3 pieces of mild steel by an automated precision welding process. The two flanges are welded circumferentially inside and outside to the ends of a section of rolled tube that has a longitudinal weld running its entire length. The overall length of the component is 800mm; all other dimensions may be estimated. Occasionally the following three critical defects are produced; circumferential cracks in the flange welds, longitudinal cracks in the tube weld, and lack-of-penetration defects between the two flange welds (arrowed). Outline the principles and methods that would be required to locate and characterise the aforementioned defects larger than 0.1mm in the component by ultrasonic techniques, using piezoelectric transducers. (The curvature of the tube and flanges may be ignored.) Answers should include critical parameters, and any special considerations to ensure reliable and consistent detection of the described defects. (Diagram is not drawn to scale).

[*20 marks*]

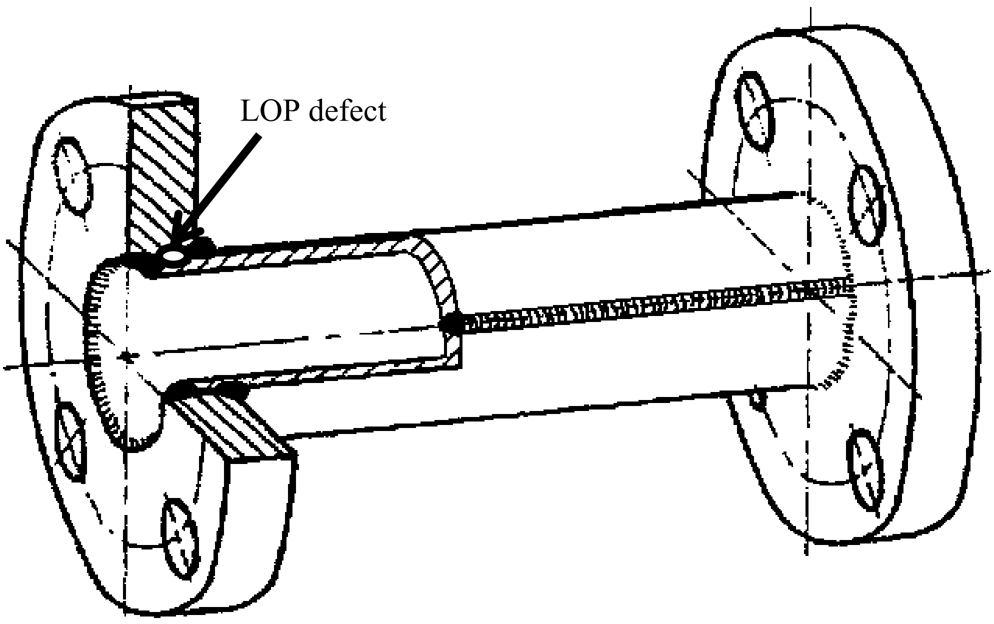

Figure 6: Component assembly for Question 6.

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.