Solutions to exam in Material och tillverkningsteknik Z (2007-06-01)

1. Electron configuration and chemical bonding (4 P)

a) n: shell, n = 1, 2, 3, …
   l: subshell, l = 0,…, n-1
   m_l: number of energy states, m_l = -l, ….. +l
   ms: spin, m_s = +1/2, -1/2
   An energy state cannot hold more than 2 electrons (with different spin)!

b) see course book!

2. Bi-Sb phase diagram (4 P)

2a) T_L = 525°C, T_S = 370°C (1 P)

2b) The composition of the last liquid to freeze is the intersection of the 360°C tie-line and the liquidus curve that is 13 % Sb. (0.5 P)

2c) The composition of the last solid to melt is the intersection of the 520°C tie-line and the solidus curve that is 84 % Sb. (0.5 P)

2d) The composition of the solid and liquid phases are at the intersections of the 450°C tie-line with the solidus and liquidus curves, which are 71 % Sb and 29 % Sb. (1 P)

2e) the amounts of the phases are obtained using the lever rule. These are: (1 P)

$$\text{solid} = \frac{50-29}{71-29} \cdot 100 = 50\ \%$$

$$\text{liquid} = \frac{71-50}{71-29} \cdot 100 = 50\ \%$$

3. Joining techniques (5 P)

a) Is the contact angle between solder and substrate greater than 90° → no wetting; is the contact angle less than 90° → wetting. (see figures in handout).

b) (i) The best suited solder composition would be the eutectic composition because the material is instantly solidifying when cooled below the eutectic temperature. The eutectic temperature is also the lowest temperature where there is liquid. That would guarantee that the material to be joined are not (or only to minor extent) affected by heat.
   (ii) Other compositions are used, like Sn60Pb40. This would lead to a higher liquidus temperature and a longer solidification time. Furthermore, the microstructure consist of primary β (Pb-rich) and the eutectic/lamellar structure.

c) See course book!

4. Electrical properties (5 P)

a) The electron energy band structure describes a solid material (many atoms). This is necessary, because in a solid, the electrons and nuclei of adjacent atoms influence each other. The energy states split up into a series of closely spaced electron bands – this is called the electron energy band structure.

b) see course book!

c) In an insulator the band gap is more than 2 eV wide whereas in a semiconductor the band gap is below 2 eV.

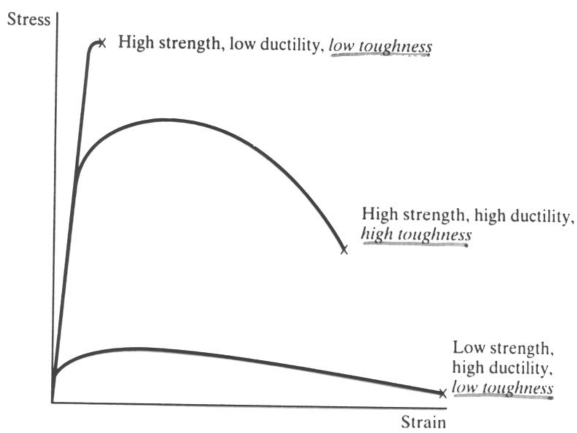
d) In a metal electrical conductivity can be achieved quite easily. In the valence band there are empty site directly adjacent to the filled ones. Hence it required only little energy to excite an electron in one of these empty sites (thermal energy). In an insulator there is a band gap between the filled valence band and the empty sites in the conduction band. Hence, quite high energy (> 2 eV) is required to excite an electron. That is usually not possible.

e) Doping means the impurities are added on purpose to change the electrical behaviour of the material. In case of an n-type semiconductor, an impurity of higher valence than the host material is added (ex. P in Si); in an p-type semiconductor, an impurity of lower valence is added (ex: B in Si).

f) see course book!

5. Mechanical properties (4 P)

a) Toughness describes the combination of strength and ductility.



b) At elevated temperatures, strength is reduced but elongation and in that sence also work hardening is increasing.

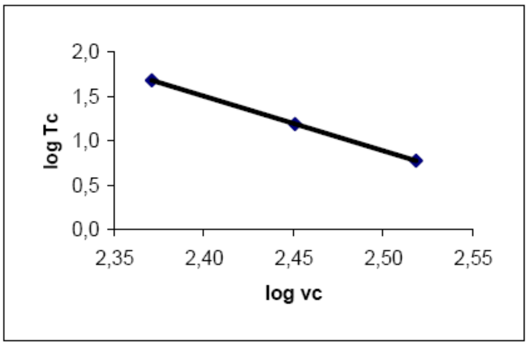
c)
1. Solid solution strengthening,
2. grain size strengthening,
3. Particle strengthening,
4. Work hardening

Metal Cutting economy 5p

a) Calculate the cutting speed

K_v	30	sek/edge
K_M	400	sek/h
t_b	1,25	min
t_{un}	0,33	min

v_c(m/min)	T_c(min)	log vc	log Tc
235	48	2,37	1,68
282,5	16	2,45	1,19
330	6,0	2,52	0,78



T_c and v_c behave linear in the double logarithmic coordinate system and therefore Taylors equation can be used.

$$v_c * T^{\alpha} = C$$

$$v_{c_1} * T_{c_1}^{\alpha} = v_{c_3} * T_{c_3}^{\alpha}$$

$$\log v_{c_1} + \alpha * \log T_{c_1} = \log v_{c_3} + \alpha * \log T_{c_3}$$

$$\alpha = \frac{\log v_{c_3} - \log v_{c_1}}{\log T_{c_1} - \log T_{c_3}}$$

$$T_{ce} = (\frac{1}{\alpha} - 1)\frac{60K_v}{K_m}$$

$$C = v_c * T_c^{\alpha}$$

$$T_{CM} = (\frac{1}{\alpha} - 1) * t_b$$

α	T_{CE}	C	v_{CE}	T_{CM}	C	v_{CM}
0,16	23,1	442	**265**	6,41	442	**326**

Answer: Cutting speed (skärhastighet) for minimum cost is 265 m/min
and for maximum production rate the cutting speed is 326 m/min.

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b) Machining cost per detail

$$C_b = \frac{Km}{60}(t_{un} + t_s) + K_v * \frac{t_s}{T_c}$$

$$t_s = \frac{L}{f * n}$$

$$n = \frac{v_c * 1000}{\pi * D}$$

f	0,3	mm/rev
n(min. kost.)	211	rev/min
n(max. prod.)	260	rev/min
L	150	mm
t_s(min. kost.)	2,37	min
t_s(max. prod.)	1,92	min
Cb(min. kost.)	21,1	sek
Cb(max. prod.)	24,1	sek

Answer: Machining cost per detail is 21 sek for the cutting speed (skärhastigheten) of minimum cost and 24 kr for the cutting speed of maximum production rate.

9. Unconventional machining methods: Laser cutting (3 P)

Se kap 6.2.2.4 sid 333.

Lokal stark uppvärmning p g a hög effektkoncentration. Yta oxideras – reflektion minskar – temp stegras – genombränning och start skärning. Under skärning smälts samt förångas material (det senare i centrum av strålen).
Gas tillförs för att föra undan / spruta undan smälta förångade materialet. I stål används ofta syrgas vilket ger exoterm reaktion (ökar värme). Om så krävs kan användas skyddsgas typiskt N2.
AWJ/Laser- Ytor har stora likheter geometriskt. Laserskuren yta har dock värmepåverkan (HAZ) vilket kan påverka mek. egenskaper. Vidare blir den ”blank”.

10. Glass transition and melting point of polymers (3 P)

a) Vid glasomvandlingstemperaturen övergår amorfa delar från fast fysikaliskt glas till vätska, medan kristaller smälter och övergår i vätska vid smältpunkten. Båda processerna är reversibla. (1 p)

b) Utvecklingen av den specifika volymen beskrivs i figur 10.14 s 487 (1 p)

b) Sfäruliter, bestående av kristall-lameller som växer radiellt, fringed mi-celles and single crystals. (1 p)

11. Processing of polymers (3 P)

a) Extrudering, Formpressning, Transferpressning och Formsprutning (1 P)
b) Plasticering (åstadkomma vätska), exempelvis smältning
Transport och formning, exempelvis fylla en form
Konsolidering (fast och dimensionsstabil form) exempelvis stelning (1 P)

c) De större tekniska utmaningarna dels
- att tillföra och bortföra värme, polymera material är bra termiska isolatorer, vilket alltså riskerar att göra tillvekningsprocesserna långsamma och därför kostsamma
- Viskositeten hos polymera material är relativt hög, alltså krävs höga tryck för snabba tilverkningsprocesser (1 P)

12. Commodity plastics (2 P)

a) PE, PP, PVC och PS, + repeterande enheter (1 P)

b) Se boken, mest förpackningar, rör, folier, lister etc (1 P)

13. Engineering plastics (3 P)

a) ABS, PA, POM, PC, PMMA, PET, PPO (2 P)

b) Användningstemperaturer, mekaniska egenskaper, kemiska egenskaper och elektriska egenskaper och tillverkningsaspekter. (3 av dessa ger 1 P)