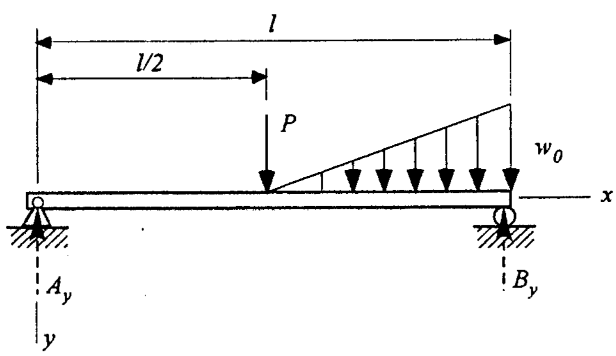
國立臺灣科技大學
九十一學年度碩士班招生考試試題

系所組別：機械工程系甲組
科　　目：機械元件設計

注意事項：1. 每題 20 分，共五題，總分 100 分
2. 試題末了附有部分應答所需公式與材料特性資料供查閱。

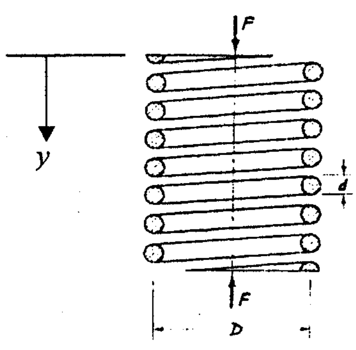
1. The following figure shows a simply supported bar with w_0=5kN/m, a concentrated force P=60 kN, and l=12m.
   (1) Find the reaction forces A_y and B_y
   (2) Use singularity functions to represent the shear force and the bending moment of the whole bar.
   (3) Find where the maximum bending moment occurs and the value of the maximum moment.



2. The spring rate of a round wire helical compression spring shown in the following figure can be approximated as follows if the mean spring diameter D is much greater than the wire diameter d:

$$k \approx \frac{d^4 G}{8D^3 N}$$

where G is the shear modulus of elasticity and N is the number of active coils. The amount of deflection y is in proportional to the compression force F, $F=ky$. Please use Castigliano's theorem to derive the spring rate k shown above.



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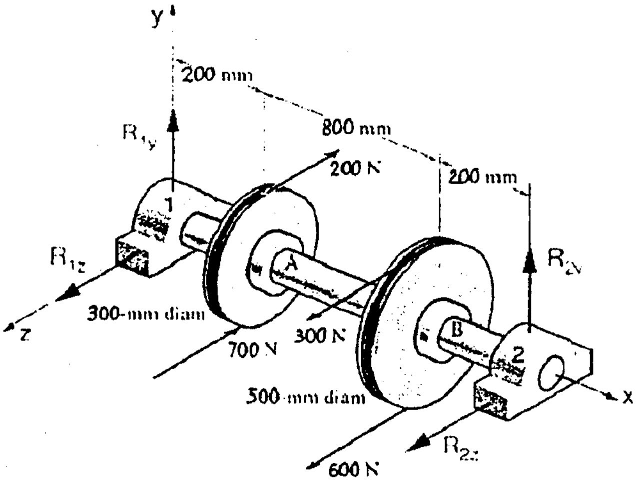
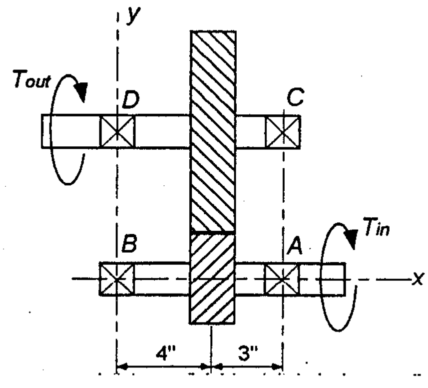
3. A shaft assembly shown in the following sketch is driven by a flat belt at location A and drives a flat belt at location B. The drive belt pulley diameter is 300mm; the driven belt pulley is 500 mm. The belts are long relative to the sheave diameter. The belts are horizontal and load the shaft in opposite directions. The shaft is made of cold-drawn steel AISI 1080. The shaft is solid and of constant diameter 30 mm.
   (1) Determine the reaction forces R_1 and R_2, and construct the Shear, Moment, and Torque Diagrams.
   (2) Determine the principal normal stresses at the most critical section.
   (3) Determine the safety factor of the shaft using the Distortion Energy Theory.



4. The following figure shows a pair of shaft-mounted helical gears having a normal diametral pitch of 6 teeth/in, a helix angle of 30° with a 28-tooth 22.5° pinion driving a 50-tooth gear. The hands of the helix are shown in the figure. The maximum input is 50 horsepower at 2000 rpm. The thrust force should be taken out at *A* and *C*.
   (1) Draw the free body diagram for the shaft C-D.
   (2) Find the direction and magnitude of the maximum forces acting on bearing *C*, and *D*.



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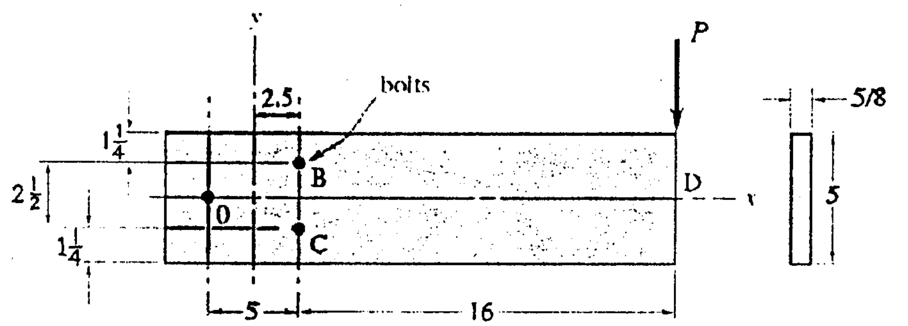
5. A steel plate in the following sketch is riveted to a vertical pillar. The pillar is made of the same material as the plate but has a larger thickness. The three rivets have a diameter d and carry the load and moment resulting from the external load of P. The yield strengths of the materials are S_{yrivet} and S_{yplate}. Please explain your solving procedures, all the important factors, and the formulas involved in details for the following questions. You DON'T need to calculate the exact solutions.

(1) How do you get the shearing stresses of each rivet? Which rivet will have the maximum shear? Why?

(2) How to determine where failure should first occur in this structure?



Properties of ferrous metals.

Material	Density, kg/m³	Modulus of elasticity, psi × 10^6 (GPa)	Yield strength, ksi (MPa)	Ultimate strength, ksi (MPa)	Ductility, %EL in 2 in.	Poisson's ratio	Thermal conductivity, W/m-°C	Coefficient of thermal expansion, $(°C)^{-1} \times 10^{-6}$
Iron	7 870	30 (207)	19 (130)	38 (260)	45	0.29	80	11.8
Gray cast iron	7 150	Variable	—	18 (125)	—	Variable	46	10.8
Nodular cast iron	7 120	24 (165)	40 (275)	60 (415)	18	0.28	33	11.8
Malleable cast iron	7 200–7 450	25 (172)	32 (220)	50 (345)	10	0.26	51	11.9
Low-carbon steel (AISI 1020)	7 860	30 (207)	43 (295)	57 (395)	37	0.30	52	11.7
Medium-carbon steel (1040)	7 850	30 (207)	51 (350)	75 (520)	30	0.30	52	11.3
High-carbon steel (AISI 1080)	7 840	30 (207)	55 (380)	89 (615)	25	0.30	48	11.0
Stainless steels								
Ferritic, type 446	7 500	29 (200)	50 (345)	80 (552)	20	0.30	21	10.4
Austenitic, type 316	8 000	28 (193)	30 (207)	80 (552)	60	0.30	16	16.0
Martensitic, type 410	7 800	29 (200)	40 (275)	70 (483)	30	0.30	25	9.9

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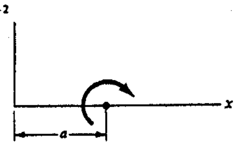
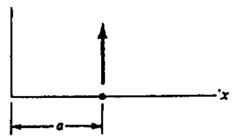
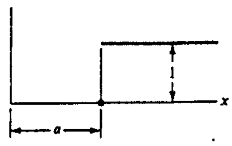
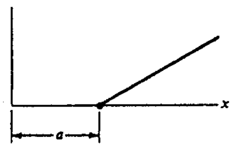
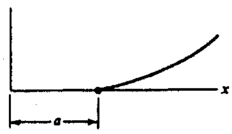
FUNCTION	GRAPH OF $f_n(x)$	MEANING
Concentrated moment (unit doublet)	$\langle x-a\rangle^{-2}$ 	$\langle x-a\rangle^{-2}=0 \quad x\neq a$ $\int_{-\infty}^{x}\langle x-a\rangle^{-2}\,dx=\langle x-a\rangle^{-1}$ $\langle x-a\rangle^{-2}=\pm\infty \quad x=a$
Concentrated force (unit impulse)	$\langle x-a\rangle^{-1}$ 	$\langle x-a\rangle^{-1}=0 \quad x\neq a$ $\int_{-\infty}^{x}\langle x-a\rangle^{-1}\,dx=\langle x-a\rangle^{0}$ $\langle x-a\rangle^{-1}=+\infty \quad x=a$
Unit step	$\langle x-a\rangle^{0}$ 	$\langle x-a\rangle^{0}=\begin{cases}0 & x<a\\ 1 & x\geq a\end{cases}$ $\int_{-\infty}^{x}\langle x-a\rangle^{0}\,dx=\langle x-a\rangle^{1}$
Ramp	$\langle x-a\rangle^{1}$ 	$\langle x-a\rangle^{1}=\begin{cases}0 & x<a\\ x-a & x\geq a\end{cases}$ $\int_{-\infty}^{x}\langle x-a\rangle^{1}\,dx=\frac{\langle x-a\rangle^{2}}{2}$
Parabolic	$\langle x-a\rangle^{2}$ 	$\langle x-a\rangle^{2}=\begin{cases}0 & x<a\\ (x-a)^2 & x\geq a\end{cases}$ $\int_{-\infty}^{x}\langle x-a\rangle^{2}\,dx=\frac{\langle x-a\rangle^{3}}{3}$

Loading type	Factors involved	Strain energy for special case where all three factors are constant with x	General expression for strain energy
Axial	P, E, A	$U=\frac{P^2 l}{2EA}$	$U=\int_0^l \frac{P^2}{2EA}dx$
Bending	M, E, I	$U=\frac{M^2}{2EI}$	$U=\int_0^l \frac{M^2}{2EI}dx$
Torsion	T, G, J	$U=\frac{T^2 l}{2GJ}$	$U=\int_0^l \frac{\tau^2}{2GJ}dx$
Transverse shear	V, G, A	$U=\frac{V^2 l}{2GA}$	$U=\int_0^l \frac{V^2}{2GA}dx$

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$$H = \frac{2\pi T n}{33\,000(12)} = \frac{FV}{33\,000} = \frac{Tn}{63\,000}$$

where H = power, hp
T = torque, lb · in
n = shaft speed, rev/min
F = force, lb
V = velocity, ft/min

HELICAL GEARS—FORCE ANALYSIS

$$W_r = W \sin \phi_n$$
$$W_t = W \cos \phi_n \cos \psi$$
$$W_a = W \cos \phi_n \sin \psi$$

where W = total force
W_r = radial component
W_t = tangential component; also called transmitted load
W_a = axial component; also called thrust load