UNIVERSITI SAINS MALAYSIA

First Semester Examination
Academic Session 2010/2011

November 2010

EMM 213/3 – Strength of Materials
Kekuatan Bahan

Duration : 3 hours
Masa : 3 jam

INSTRUCTIONS TO CANDIDATE:
ARAHAN KEPADA CALON:

Please check that this paper contains **EIGHT (8)** printed pages, **TWO (2)** pages appendix and **SIX (6)** questions before you begin the examination.
*Sila pastikan bahawa kertas soalan ini mengandungi **LAPAN (8)** mukasurat bercetak, **DUA (2)** mukasurat lampiran dan **ENAM (6)** soalan sebelum anda memulakan peperiksaan.*

Answer **FIVE (5)** questions.
*Jawab **LIMA (5)** soalan.*

Appendix/*Lampiran*:

1. Table of Average Mechanical Properties of Typical Engineering Materials (SI Units) [1 page/*mukasurat*]
2. Beam Deflection Formulae [1 page/*mukasurat*]

You may answer all questions in **English** OR **Bahasa Malaysia** OR a combination of both.
*Calon boleh menjawab semua soalan dalam **Bahasa Malaysia** ATAU **Bahasa Inggeris** ATAU kombinasi kedua-duanya.*

Answer to each question must begin from a new page.
Jawapan untuk setiap soalan mestilah dimulakan pada mukasurat yang baru.

In the event of any discrepancies, the English version shall be used.
Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.

Q1. **[a]** **(i)** **For the hollow shaft and loading shown in Figure Q1[a], determine the maximum shear stress.**

Bagi shaf berlubang dan bebanan seperti dalam Rajah S1[a], tentukan tegasan ricih maksimum.

(ii) **Determine the diameter of a solid shaft for which the maximum shear stress under the loading shown is the same as part (i) above.**

Tentukan diameter shaf padu di mana tegasan ricih maksimum bagi bebanan yang ditunjukkan adalah sama seperti bahagian (i) di atas.

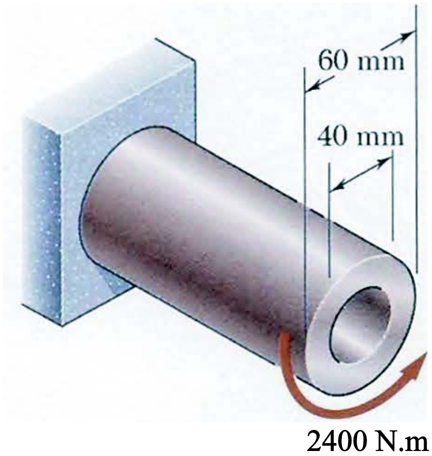

Figure Q1[a]
Rajah S1[a]

(40 marks/*markah***)**

[b] **The 304 stainless steel hollow shaft is 3 m long and has an outer diameter of 60 mm. When it is rotating at 60 rad/s, it transmits 30 kW of power from the engine *E* to the generator *G* as shown in Figure Q1[b]. The allowable shear stress of the shaft is 150 MPa and the shaft is restricted not to twist more than 0.08 rad. If the inner diameter of shaft is 29.0 mm, determine the possible cause of failures. Then, explain the failure of the shaft.**

Syaf rongga keluli tahan karat 304 adalah 3 m panjang dan berdiameter luar 60 mm. Apabila berputar pada 60 rad/s, ia menghantar kuasa 30 kW dari enjin E ke penjana G seperti ditunjukkan dalam Rajah S1[b]. Tegasan ricih terizin bagi shaf adalah 150 MPa dan kilasan shaf dihadkan tidak melebihi 0.08 rad. Jika diameter dalam syaf adalah 29.0 mm, tentukan kemungkinan sebab-sebab kegagalan syaf tersebut. Seterusnya, terangkan kegagalan bagi syaf tersebut.

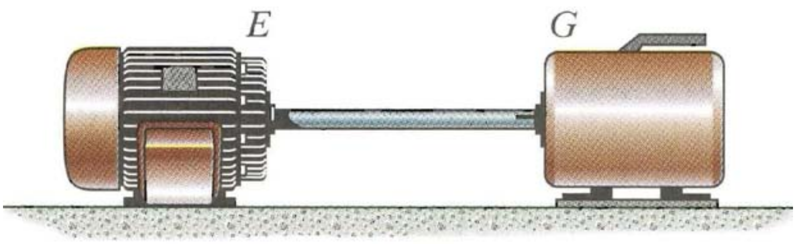

Figure Q1[b]
Rajah S1[b]

(60 marks/*markah*)

Q2. **The 304 stainless steel beam ABCD is subjected to a uniform load *w* as shown in Figure Q2.**

(i) **Determine the shear force and bending moment in the beam as functions of *x*, where $0 \leq x \leq 2a+l$. Then, draw the shear force and bending moment diagrams for the beam.**

(ii) **Determine the placement *a* of the supports so that the bending stress in the beam is as small as possible. Then, calculate the bending stress in term of *w, a, b, d* and *l*.**

(iii) **In the bending testing experiment where the objectives is to determine the beam's deflection and to calculate the modulus of elasticity E of the beam, a point load P is being applied at the middle of the two supports. By using the equation below, E can be calculated. If the own weight of the beam must be considered, discuss and compare the result of E with material properties of beam in Appendix 1.**

$$\delta = \frac{P(2a+l)^3}{48\mathrm{EI}}$$

Rasuk tahan karat 304, ABCD dikenakan beban taburan seragam w seperti dalam Rajah S2.

(i) *Tentukan daya ricih dan momen lenturan untuk rasuk sebagai fungsi x, di mana, $0 \leq x \leq 2a+l$. Seterusnya lukis rajah daya ricih dan momen lenturan bagi rasuk tersebut.*

(ii) *Tentukan kedudukan a bagi penyokong-penyokong di mana tegasan lentur dalam rasuk adalah sekecil mungkin. Seterusnya, kirakan tegasan lentur tersebut dalam sebutan w, a, b, d dan l.*

(iii) *Di dalam ujian lenturan yang bertujuan untuk menentukan pesongan dan mengira modulus elastik bagi rasuk, daya berpusat P dikenakan pada tengah antara dua penyokong. Dengan menggunakan persamaan di bawah, E dapat dikira. Jika berat sendiri rasuk perlu diambilkira, bincang dan bandingkan keputusan E dengan sifat bahan dalam Lampiran 1.*

$$\delta = \frac{P(2a+l)^3}{48\text{EI}}$$

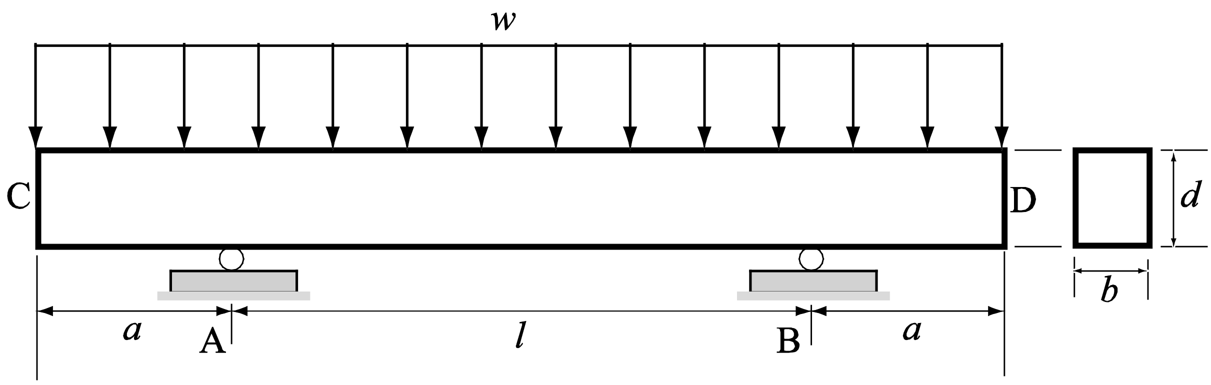

Figure Q2
Rajah S2

(100 marks/*markah*)

Q3. [a] Determine the equation of the elastic curve for the beam that is subjected to moment M as shown in the Figure Q3[a] using the *x* coordinate. Calculate the slope at A and the maximum deflection of the beam. EI is constant.

Tentukan persamaan lengkungan elastik untuk rasuk yang dikenakan momen M seperti dalam Rajah S3[a] menggunakan koordinat x. Kirakan kecerunan pada A dan pesongan maksimum bagi rasuk. EI adalah malar.

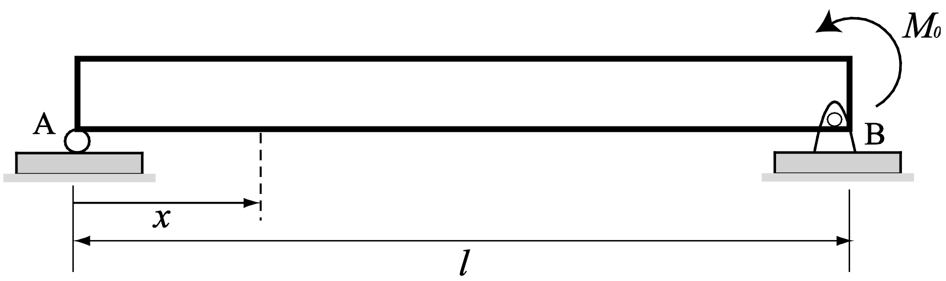

Figure Q3[a]
Rajah S3[a]

(60 marks/*markah*)

[b] The box frame ABCD in the Figure Q3[b] is subjected to a uniform distributed loading *w* along each of its sides. Determine the moment developed in each corner. Neglect the deflection due to axial load. EI is constant and use formulae in Appendix 2 to solve this problem.

Kerangka ABCD *dalam Rajah S3[b] dikenakan daya taburan seragam w pada setiap sisinya. Tentukan momen yang terhasil pada setiap sudut. Abaikan pesongan yang terhasil akibat daya paksi. EI adalah malar dan sila gunakan persamaan dalam Lampiran 2 untuk menyelesaikan masalah ini.*

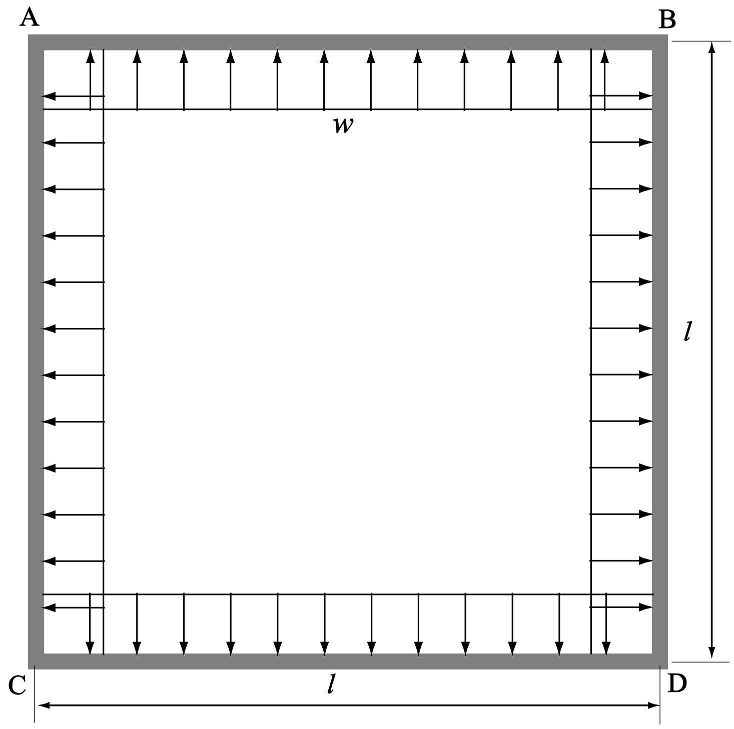

Figure Q3[b]
Rajah S3[b]

(40 marks/*markah*)

Q4. [a] Define the following term and cite *an example for each case* together with a sketch showing the condition reflecting such case

(iv) Plane stress
(v) Plane strain
(vi) Principal plane

Berikan definisi istilah berikut dan nyatakan satu contoh bagi setiap kes dengan lakaran yang menggambarkan contoh tersebut

(i) Tegasan satah
(ii) Terikan satah
(iii) Satah utama

(40 marks/*markah*)

[b] For the loading condition shown in the component below calculate the principal stresses and the maximum shear stress at the point A and draw the Mohr's circle representing the stress condition at that point

Bagi keadaan tegasan yang ditunjukkan di dalam unsur-unsur di bawah, kirakan tegasan utama dan tegasan riceh utama A dan lakarkan Bulatan Mohr yang mewakili keadaan tegasan bagi setiap unsur.

Diameter of shaft = 100 mm (solid)

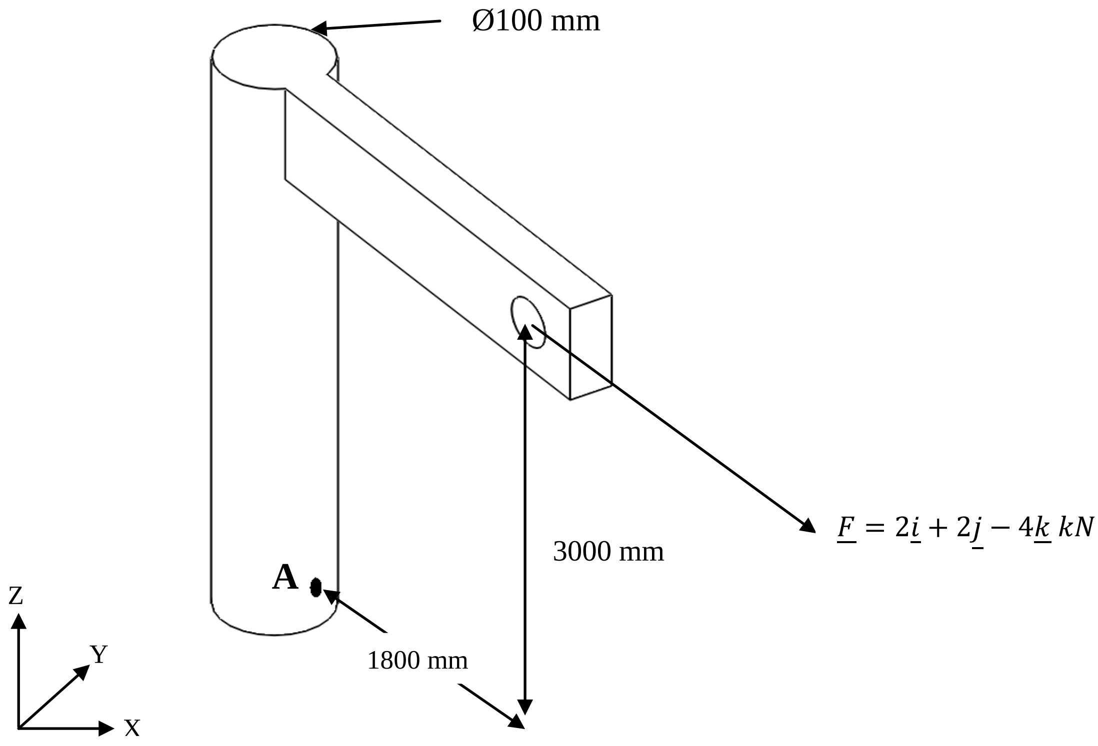

Figure Q4[b]
Rajah S4[b]

(60 marks/*markah*)

Q5. An electric drill is shown in Figure Q5. The drill bit is subjected to a compressive axial force of 500 N, an end bending moment of 20 Nm (in the y-z plane) and a torque of 4 Nm (in the x-z plane). The length of the drill from the bit end to the support at the shank is 100 mm. Based on the stress level at point A determine the suitable diameter of the drill bit made of solid high speed steel if the allowable normal stress is 200 MPa and the allowable shear stress is limited to 60 MPa.

Sebuah gerudi elektrik ditunjukkan di dalam Rajah S5. Mata gerudi itu mengalami daya paksi mampatan 500 N, momen lentur hujung 20 Nm (di dalam satah y-z) dan kilas 4 Nm (di dalam satah x-z). Panjang mata gerudi dari hujung gerudi ke bahagian disangga ialah 100 mm. Berdasarkan keadaan tegasan di titik A tentukan diameter yang sesuai untuk mata gerudi yang diperbuat daripada keluli kelajuan tinggi jika tegasan normal yang dibenarkan ialah 200 MPa dan tegasan riceh yang dibenarkan ialah 60 MPa.

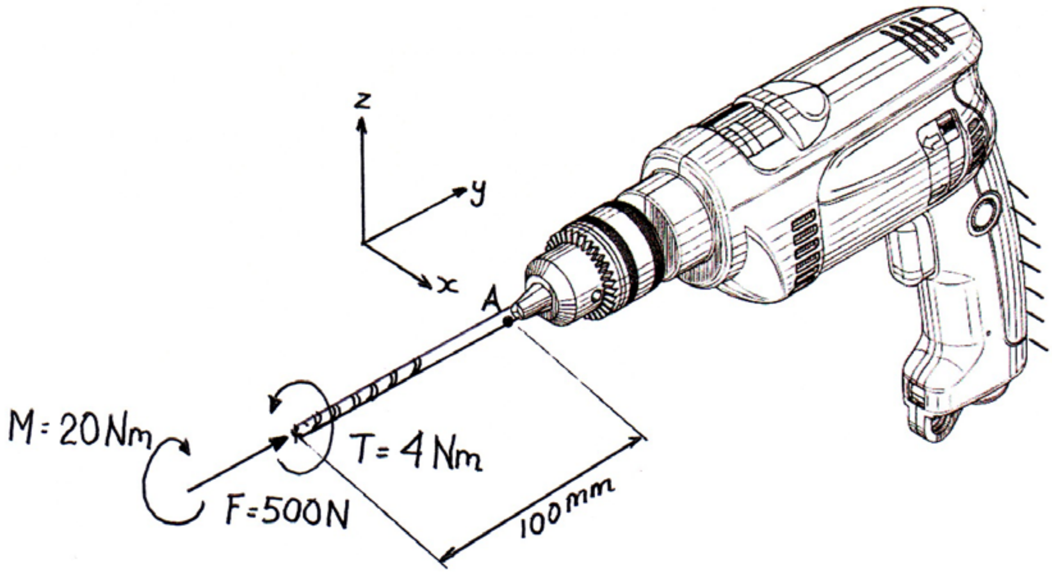

Figure Q5
Rajah S5

(100 marks/*markah*)

Q6. **Figure Q6[a] shows three different level of fit between the hole and the shaft.**

[a] **For each case determine the maximum and minimum force needed to push the shaft through the disc given the thickness of the disc is 20 mm and the outer diameter is 70 mm. Both the shaft and the disc are made of steel (E=200 GPa, ν = 0.28) and the friction coefficient is 0.3.**

Rajah S6[a] menunjukkan tiga paras padanan antara lubang dan syaf.

[a] *Bagi setiap kes padanan tentukan daya maksimum dan minumum yang diperlukan untuk menolak syaf menerusi lubang cakera jika ketebalan setiap cakera adalah 20 mm dan diameter luaran adalah 70 mm. Kedua-dua syaf dan cakera diperbuat daripada keluli (E=200 GPa, ν = 0.28) dan pekali geseran ialah 0.3.*

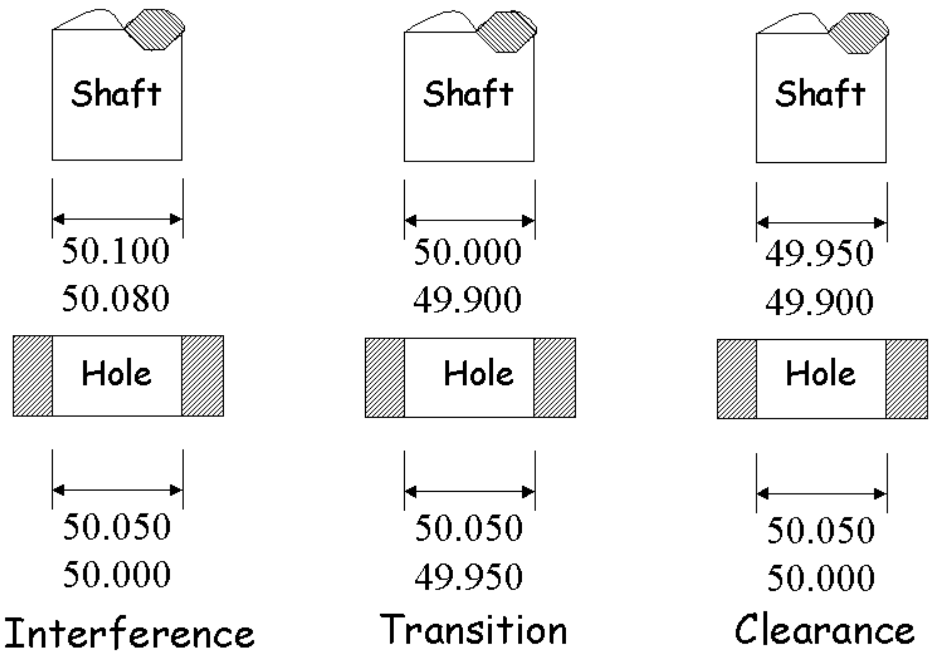

Figure Q6[a]
Rajah S6[a]

(70 marks/*markah*)

[b] **Cite an example of the use of each type of fit in machine design and comment on the manufacturing challenges to produce each type of fit.**

Bagi setiap kes padanan nyatakan contoh aplikasi di dalam rekabentuk mesin dan berikan komen anda tentang cabaran proses pembuatan bagi menghasilkan setiap jenis padanan.

(30 marks/*markah*)

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APPENDIX 1/*LAMPIRAN 1*

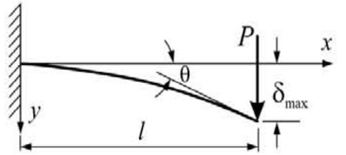
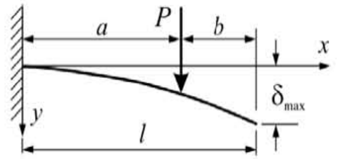
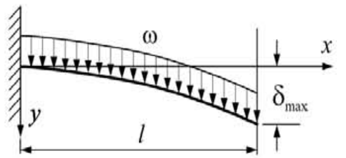
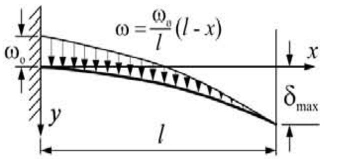
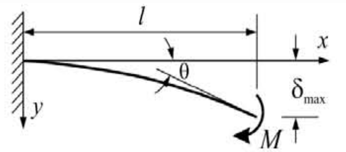
Table of Average Mechanical Properties of Typical Engineering Materials (SI Units)

Materials		Density ρ (Mg/m^3)	Modulus of Elasticity E (GPa)	Modulus of Rigidity G (GPa)	Yield Strength (MPa)	Coef. of Therm. Expansion α (10^{-6})/°C
Metallic						
Aluminum Wrought Alloys	2014-T6	2.79	73.1	27	414	23
	6061-T6	2.71	68.9	26	255	24
Cost Iron Alloys	Gray ASTM 20	7.19	67.0	27		12
	Malleable ASTM A-197	7.28	1.72	68		12
Copper Alloys	Red Brass C83400	8.74	101	37	70.0	18
	Bronze C86100	8.83	103	38	345	17
Magnesium Alloy	[Am 1004-T61]	1.83	44.7	18	152	26
Steel Alloys	Structural A36	7.85	200	75	400	12
	Stainless 304	7.86	193	75	517	17
	Tool L2	8.16	200	75	800	12
Titanium Alloy	[Ti-6A 1-4V]	4.43	120	44	1000	9.4
Nonmetallic						
Concrete	Low Strength	2.38	22.1	-	-	11
	High Strength	2.38	29.0	-	-	11
Plastic Reinforced	Kevlar 49	1.45	131	-	-	-
	30% Glass	1.45	72.4	-	-	-

APPENDIX 2/*LAMPIRAN 2*

Beam Deflection Formulae

BEAM DEFLECTION FORMULAE

BEAM TYPE	SLOPE AT FREE END	DEFLECTION AT ANY SECTION IN TERMS OF x	MAXIMUM DEFLECTION
1. Cantilever Beam – Concentrated load P at the free end			
	$\theta = \frac{Pl^2}{2EI}$	$y = \frac{Px^2}{6EI}(3l - x)$	$\delta_{max} = \frac{Pl^3}{3EI}$
2. Cantilever Beam – Concentrated load P at any point			
	$\theta = \frac{Pa^2}{2EI}$	$y = \frac{Px^2}{6EI}(3a - x)$ for $0 < x < a$ $y = \frac{Pa^2}{6EI}(3x - a)$ for $a < x < l$	$\delta_{max} = \frac{Pa^2}{6EI}(3l - a)$
3. Cantilever Beam – Uniformly distributed load ω (N/m)			
	$\theta = \frac{\omega l^3}{6EI}$	$y = \frac{\omega x^2}{24EI}(x^2 + 6l^2 - 4lx)$	$\delta_{max} = \frac{\omega l^4}{8EI}$
4. Cantilever Beam – Uniformly varying load: Maximum intensity ω_o (N/m)			
	$\theta = \frac{\omega_o l^3}{24EI}$	$y = \frac{\omega_o x^2}{120lEI}(10l^3 - 10l^2 x + 5lx^2 - x^3)$	$\delta_{max} = \frac{\omega_o l^4}{30EI}$
5. Cantilever Beam – Couple moment M at the free end			
	$\theta = \frac{Ml}{EI}$	$y = \frac{Mx^2}{2EI}$	$\delta_{max} = \frac{Ml^2}{2EI}$