1. MEMORIAL UNIVERSITY OF NEWFOUNDLAND

Faculty of Engineering and Applied Science

Engineering 6003 - Ship Structures

FINAL EXAMINATION

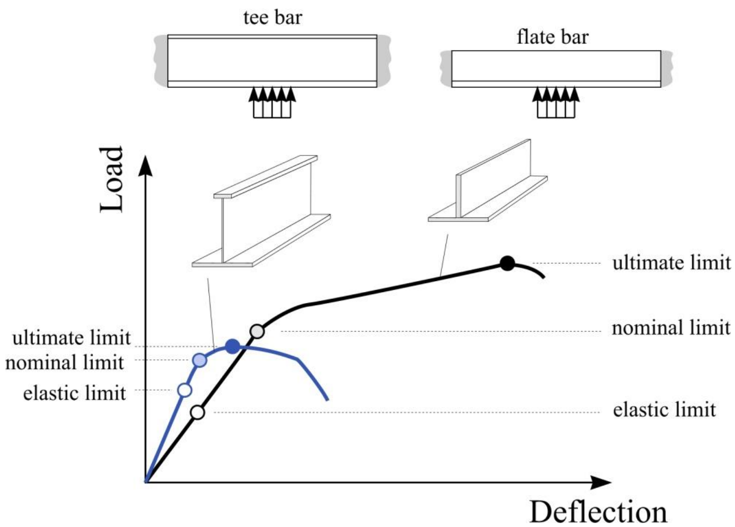
With solutions

Date: Monday December 15, 2014 **Professor: Dr. C. Daley**
Time: 1:00 -3:30 pm
Maximum Marks: 100

Instructions:
Please write/sketch clearly in the answer book, and keep your answers concise.

1. General Concepts (10 marks)

Consider the sketch show below. Discuss the meaning of the point called the nominal limit, and contrast it with the other two limits.



The elastic limit is the point where some material first reaches yield. It assumes that there were no initial (locked in) stresses. A very small volume of material is plastic at this point and there are no visible effects.

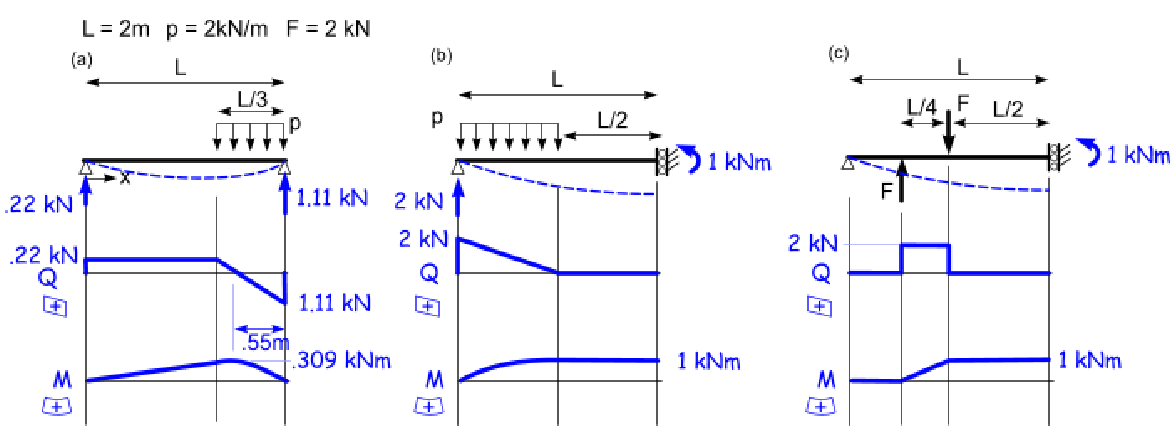
The nominal limit occurs when the first mechanism forms within the structure (such as a set of plastic hinges). At this point the structure begins to lose stiffness but can often take more load. Some might refer to this as structural yielding (in contract to material yielding)

The ultimate limit defines the maximum load bearing capacity of the structure. It is based on a general collapse mechanism which could be a system of plastic hinges, or overall buckling buckling or fracture.

2. Static Response (15 marks)

For the three beams shown below,

a) find the reactions and draw the shear force and bending moment diagrams (with values)
b) sketch the deflected shapes (no numbers)

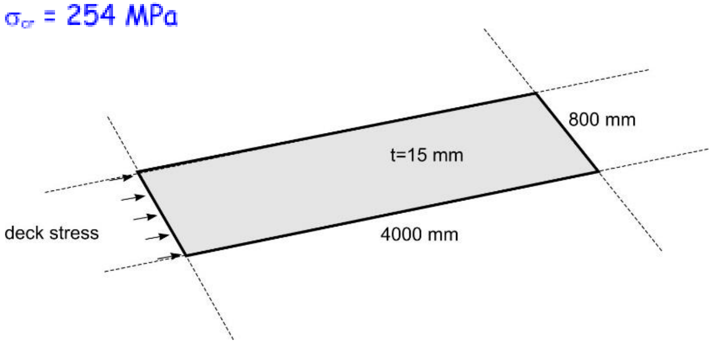


3. Buckling (20 marks)

a) Consider the rectangular plate in the deck of a ship a shown below. The longitudinal frames are spaced every 800mm, and the transverse web frames are spaced at 400 mm. The steel has a 400MPa yield strength. What stress would cause the onset of elastic buckling?

$\beta = 2.385$

$\sigma_{cr} = 254$ MPa



b) for the 15mm plating in part(a), what would the frame spacing need to be in order that the buckling stress and the yield stress were the same?

$\beta^2 = 3.62$

$\beta = 1.902$

$b = \dfrac{t\,\beta}{\sqrt{\dfrac{\sigma_y}{E}}}$ $\quad b = 638$ mm

c) For the 15mm plating in part(a), what is the maximum post-buckling average stress according to vonKarman's theory?

$\dfrac{\sigma_m}{\sigma_y} = \dfrac{1.9}{\beta}$

$\sigma_m = 318.7$ MPa

All formulae related to buckling from the notes:

$$F_{crit} = \frac{\pi^2 EI_z}{(kL)^2},\quad U_A = \frac{1}{2}\int_0^L EA\varepsilon^2 dx,\quad \varepsilon = \frac{\sigma}{E} = \frac{F}{AE},\quad U_B = \frac{1}{2}EI\int_0^L\left(\frac{d^2y}{dx^2}\right)^2 dx,\quad S = L + \Delta = \int ds,$$

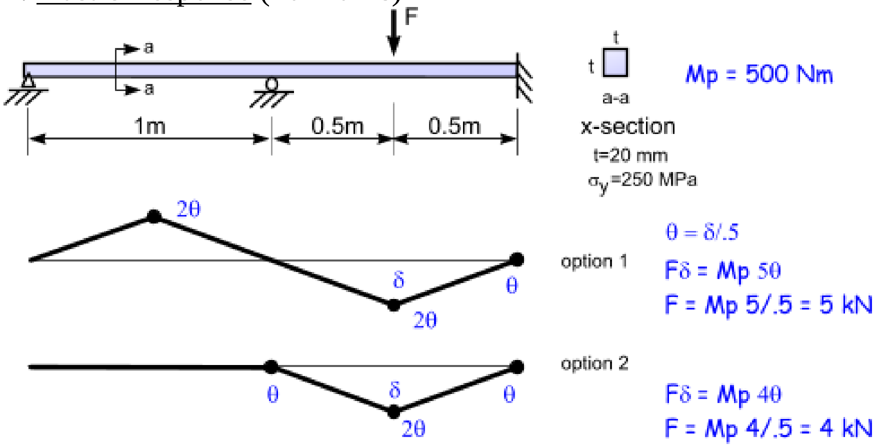
$$\Delta = \frac{1}{2}\int_0^L\left(\frac{dy}{dx}\right)^2 dx = \frac{1}{2}\int_0^L (y')^2 dx,\quad \sigma_{cr} = \pi^2\left(\frac{\rho}{L}\right)^2 E,\quad \rho^2 = \frac{t^2}{12} \Rightarrow \rho = 0.29t,\quad \frac{\sigma_{cr}}{\sigma_y} = \pi^2\left(\frac{\rho}{L}\right)^2\frac{E}{\sigma_y} = \frac{1}{\lambda^2}$$

$$\lambda \equiv \frac{L}{\pi\rho}\sqrt{\frac{\sigma_y}{E}},\quad \sigma_{cr} = \frac{\pi^2 D}{b^2 t}\left(\frac{mb}{a} + \frac{a}{mb}\right)^2 = k\frac{\pi^2 D}{b^2 t},\quad \sigma_{cr} = 4\frac{\pi^2 D}{b^2 t},\quad D = \frac{Et^3}{12(1-\nu^2)},\quad \sigma_{cr} = \frac{4\pi^2}{b^2 t}\frac{Et^3}{12(1-\nu^2)} = 3.62E\left(\frac{t}{b}\right)^2,$$

$$\frac{\sigma_{cr}}{\sigma_y} = \frac{3.62}{\beta^2},\quad \beta = \frac{b}{t}\sqrt{\frac{\sigma_y}{E}},\quad \frac{\sigma_m}{\sigma_y} = \frac{1.9}{\beta},\quad \frac{\sigma_m}{\sigma_y} = \frac{2}{\beta} - \frac{1}{\beta^2}$$

$$\frac{\sigma_m}{\sigma_y} = \begin{cases} -.032\beta^4 + .002\beta^2 + 1 & for \beta \le 1.5 \\ 1.247/\beta & for 1.5 < \beta \le 3.0 \\ 1.248/\beta^2 + .283 & for \beta > 3.0 \end{cases}$$

4. Plastic Response (20 Marks)



a) For the bar shown above what is the value of the plastic moment?

500 N-m

b) Compute and compare the plastic collapse forces for the two optional collapse patterns?

Option 1 : F = 5 kN

Option 2: F = 4 kN

The system will respond in option 2.

5. Fatigue (12 Marks)

a) For a Category E detail in a ship, what percentage of the fatigue strength would be used up by the combination of stresses in the table below? (Assume Miners rule and see table on next page)

set	Number of cycles	Level of stress
1	80,000	100 MPa
2	1,000,000	50 MPa
3	5,000,000	40 MPa
4	20,000,000	30 MPa

The sum of the partial damages gives 78% of the fatigue limit. The system will fail before this load is fully applied.

80,000/410,000
+ 1,000,000/7,400,000
+ 5,000,000/ 22,000,000
+ 20,000,000/90,000,000
= 78%

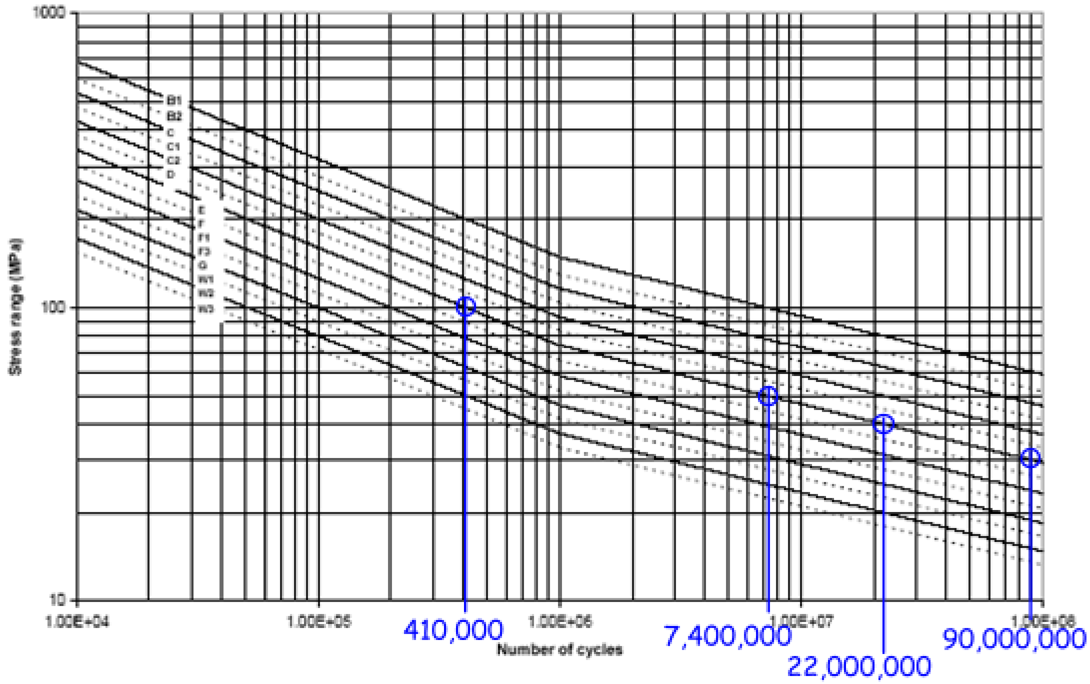


Figure 2.3-2 S-N curves in seawater with cathodic protection

6. Failure Probabilities (11 Marks)

The mean of the load Q is 400 kN. The standard deviation of Q is 100kN. The mean of the strength R is 1MN. The standard deviation of R is 100kN. With the above information, and assuming R&Q are Normal (see Table next page) , answer the following questions;

i) What are the values for $R_{5\%}$ and $Q_{10\%}$?
ii) What are the mean and standard deviation of the Margin?
iii) what is the safety index?
iv) What is the probability of failure?

$\overline{Q}$ = 400 kN σ_Q = 100 kN
$\overline{R}$ = 1000 kN σ_R = 100 kN

i) $R_{5\%}$ = 1000 - 1.645 x 100
= 835.5 kN lower srength

$Q_{10\%}$ = 400 + 1.28 x 100
= 528 kN higher load

ii) $\overline{M}$ = 1000 - 400
= 600 kN

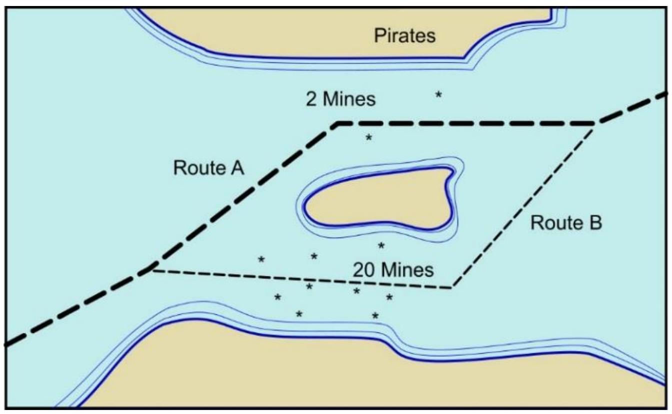
$\sigma_M = \sqrt{100^2 + 100^2}$
= 141.42 kN

iii) γ = 600 / 141.42 = 4.24

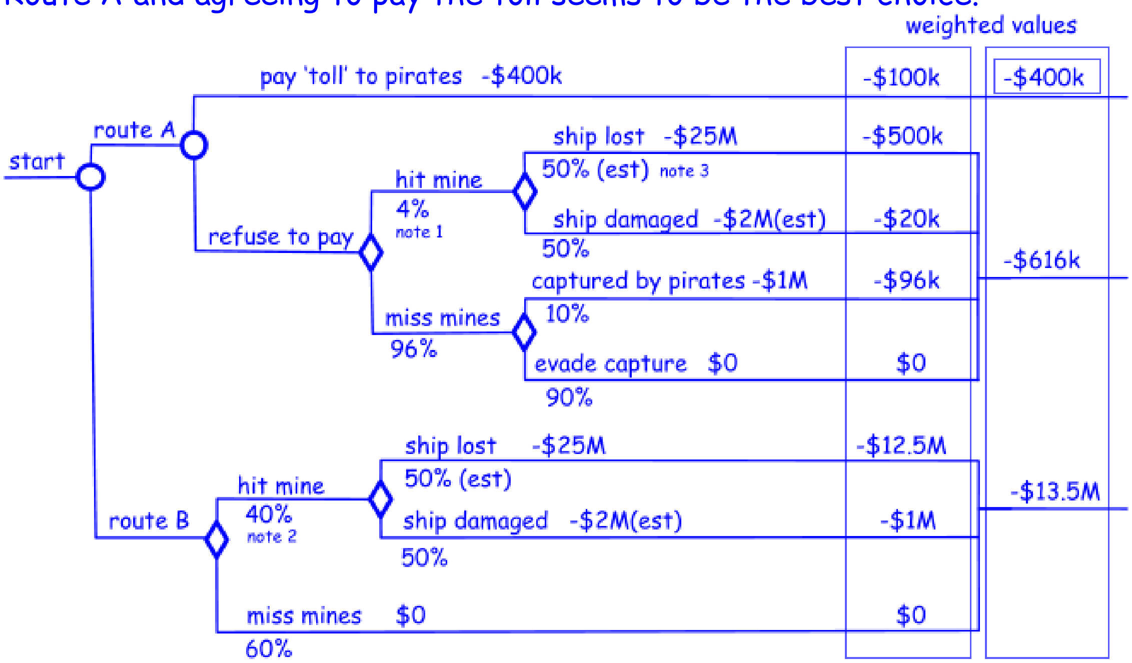
iv) p(fail) < 1-.9981 < 0.19% (off the chart)

7. <u>Risk Networks</u> (12 Marks)

The map below shows part of a shipping route. The area has pirates. Route A is closer to the Pirates, who put two explosive mines in that strait. The Pirates will tell ships the exact coordinates of the mines for $400,000. The Pirates have put 20 Mines on Route B (to encourage ships to take Route A). If ships try to run Route A without paying, not only is there as risk of hitting a mine, but there is a risk that the Pirates will board the vessel and ransom it and the crew. 10% is ships that don't pay are boarded. Ship/crew ransom costs are typically $1Million. The navigable channel in both straits are 1 km wide. The ship is 20m wide. The ship, cargo and crew are worth $25Million if totally lost.
Not all mine explosions cause ships to be lost.
Make a risk/decision network to help determine the best choice of route. Which route would you choose? Explain why.



Route A and agreeing to pay the toll seems to be the best choice.



note 1 2x 20m/1000m = .04 = 4%
note 2 20x 20m/1000m = .4 = 40%
note 3 estimated 50% of mine strikes result in survivale damage

choice

chance

Normal Distribution (Cumulative)

Pr(X<x)

x	0	1	2	3	4	5	6	7	8	9
0	0.5	0.503989	0.507978	0.511967	0.515953	0.519939	0.523922	0.527903	0.531881	0.535856
0.1	0.539828	0.543795	0.547758	0.551717	0.55567	0.559618	0.563559	0.567495	0.571424	0.575345
0.2	0.57926	0.583166	0.587064	0.590954	0.594835	0.598706	0.602568	0.60642	0.610261	0.614092
0.3	0.617911	0.621719	0.625516	0.6293	0.633072	0.636831	0.640576	0.644309	0.648027	0.651732
0.4	0.655422	0.659097	0.662757	0.666402	0.670031	0.673645	0.677242	0.680822	0.684386	0.687933
0.5	0.691462	0.694974	0.698468	0.701944	0.705402	0.70884	0.71226	0.715661	0.719043	0.722405
0.6	0.725747	0.729069	0.732371	0.735653	0.738914	0.742154	0.745373	0.748571	0.751748	0.754903
0.7	0.758036	0.761148	0.764238	0.767305	0.77035	0.773373	0.776373	0.77935	0.782305	0.785236
0.8	0.788145	0.79103	0.793892	0.796731	0.799546	0.802338	0.805106	0.80785	0.81057	0.813267
0.9	0.81594	0.818589	0.821214	0.823814	0.826391	0.828944	0.831472	0.833977	0.836457	0.838913
1	0.841345	0.843752	0.846136	0.848495	0.85083	0.853141	0.855428	0.85769	0.859929	0.862143
1.1	0.864334	0.8665	0.868643	0.870762	0.872857	0.874928	0.876976	0.878999	0.881	0.882977
1.2	0.88493	0.88686	0.888767	0.890651	0.892512	0.89435	0.896165	0.897958	0.899727	0.901475
1.3	0.903199	0.904902	0.906582	0.908241	0.909877	0.911492	0.913085	0.914656	0.916207	0.917736
1.4	0.919243	0.92073	0.922196	0.923641	0.925066	0.926471	0.927855	0.929219	0.930563	0.931888
1.5	0.933193	0.934478	0.935744	0.936992	0.93822	0.939429	0.94062	0.941792	0.942947	0.944083
1.6	0.945201	0.946301	0.947384	0.948449	0.949497	0.950529	0.951543	0.95254	0.953521	0.954486
1.7	0.955435	0.956367	0.957284	0.958185	0.959071	0.959941	0.960796	0.961636	0.962462	0.963273
1.8	0.96407	0.964852	0.965621	0.966375	0.967116	0.967843	0.968557	0.969258	0.969946	0.970621
1.9	0.971284	0.971933	0.972571	0.973197	0.97381	0.974412	0.975002	0.975581	0.976148	0.976705
2	0.97725	0.977784	0.978308	0.978822	0.979325	0.979818	0.980301	0.980774	0.981237	0.981691
2.1	0.982136	0.982571	0.982997	0.983414	0.983823	0.984222	0.984614	0.984997	0.985371	0.985738
2.2	0.986097	0.986447	0.986791	0.987126	0.987455	0.987776	0.988089	0.988396	0.988696	0.988989
2.3	0.989276	0.989556	0.98983	0.990097	0.990358	0.990613	0.990863	0.991106	0.991344	0.991576
2.4	0.991802	0.992024	0.99224	0.992451	0.992656	0.992857	0.993053	0.993244	0.993431	0.993613
2.5	0.99379	0.993963	0.994132	0.994297	0.994457	0.994614	0.994766	0.994915	0.99506	0.995201
2.6	0.995339	0.995473	0.995603	0.995731	0.995855	0.995975	0.996093	0.996207	0.996319	0.996427
2.7	0.996533	0.996636	0.996736	0.996833	0.996928	0.99702	0.99711	0.997197	0.997282	0.997365
2.8	0.997445	0.997523	0.997599	0.997673	0.997744	0.997814	0.997882	0.997948	0.998012	0.998074