Delft University of Technology
Faculty of Civil Engineering and Geosciences
Structural Mechanics Section

Exam CIEM5301 Shell Structures
Wednesday 28 January 2026, 9:00 – 12:00 hours

Choose A, B, C or D.

1 Consider a corbel dome. The meridional force forms …

A … a parabola.
B … a hyperbolic cosine.
C … a circle.
D … not any defined function.

2 A large moment can occur in the edge of a thin shell. What do we do with this?

A Let it yield.
B Include solid edge beams.
C Design thick edges.
D Support the shell by rollers.

3 A dome is loaded by self-weight. The moment in the top is not completely zero.
What causes this?

A The load is not evenly horizontally distributed.
B An edge disturbance
C A measuring error
D Change in shape

4 A surface has principal curvatures of 3 /m and -5 /m. The surface is dented. The dent has a depth of 5 mm (in the z direction) and a diameter of 100 mm. This dent increased the Gaussian curvature. By how much?

A 31 /m^2
B 15
C 8
D 0

5 k_x = 1/(2 m)
k_y = 1/(5 m)

A k_G = -0.810 / m^2
B k_G = -0.540
C k_G = -0.290
D k_G = -0.180

6 What is a Lamé parameter?

A A factor between the coordinate system and the physical dimensions
B A material constant
C A curvilinear coordinate
D An orthogonal tensor property

7 A reinforced concrete dome has the shape of half a sphere. Its span is 12 m and its thickness is 100 mm. What is the deflection due to self-weight?

A 14 mm
B 12
C 10
D 0.1

8 Consider the derivation of membrane equation 1. First, we give u_x an increasing value. Then we give u_z a uniform value. Finally, we give u_y a uniform value. Why is u_x an exception?

A It is a Taylor expansion. The first term is zero, so we use the second term.
B We do this to isolate the effect of membrane deformation.
C It is the opposite of the equilibrium equation, following the static-geometric analogy.
D Otherwise u_y and u_z would not be in the equation.

9 Consider Bernoulli's hypothesis. It is not called Bernoulli's theorem. Why not?

A This is a mistake. It should be called theorem.
B Simply supported tubes are an exception because they have no shear deformation.
C It is not exactly true.
D No reason; hypothesis is the same as theorem.

10 The Sanders-Koiter equations include … [1]

A … extension.
B … extension and bending.
C … extension, bending and shear deformation.
D … extension, bending, shear deformation and large displacements.

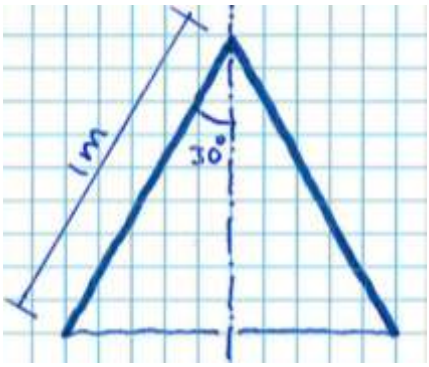
11 A shell edge has a thickness of 23 mm. The shear force is 735 kN/m. The torsion moment is -9.02 kNm/m. The y axis points outwards. What is the shear stress?

A 223 N/mm^2
B 150
C 129
D -33

12 m_{xx} = 13 kNm/m m_{yy} = -4 kNm/m m_{xy} = 7 kNm/m

A V = 10 kN
B V = 7 kN
C V = 4 kN
D V = 2 kN

13 See the section of a cone. Thickness t = 1 mm
How large should the edge finite elements be? [2]



A 18.3 mm
B 9.6
C 5.0
D 1.0

14 We do a shell finite element analysis. In the shell middle the shear force is 23.5 kN/m. We repeat the analysis with half element size. Now, the shear force is 25.1 kN/m. We again halve the elements and now the shear force is 25.9 kN/m. What is the best estimate for the shear force?

A 23.5 kN/m
B 25.9
C 26.2
D 26.7

15 Consider the Bohemian dome. What is the curvature in the top?

A 0
B $\frac{1}{a}$
C $-\frac{1}{a}$
D $-\frac{1}{a^2}$

16 Why is nodal averaging used for FEM results? [3]

A To determine if elements need to be smaller.
B To reduce computed reinforcement.
C To show accurate results.
D To remove singularities.

17 The following membrane forces occur in a reinforced concrete shell element.
n_{xx} = 50 kN/m n_{yy} = -25 kN/m n_{xy} = 5.0 kN/m n_{yx} = 4.5 kN/m
The element thickness is 100 mm.
We design reinforcement. What is the concrete stress σ_c ? [4]

A -0.34 N/mm^2
B -0.26
C -0.45
D -0.75

18 A cylindrical tank with a floating roof has a foundation settlement. At two positions the steel bottom plate has settled 32 mm. At two other positions there is a gap of 32 mm between the bottom plate and the foundation. The tank diameter is 12 m. The tank height is 18 m. What is the largest horizontal displacement of the top edge?



A 384 mm
B 192
C 96
D 48

19 What does it mean to have priority for a formula?

A It is used before other formulas.
B The formula is used, when all other options failed.
C Others are not allowed to copy it without my permission.
D I discovered it.

20 “An orthogonal parameterisation of a monkey saddle is not available.” What does this mean?

A Nobody derived it.
B Nobody did a serious attempt to derive it.
C Somebody derived it but he/she does not want to tell everybody.
D Somebody proofed it does not exist.

21 Yoshimura buckling is preceded by …

A … ring mode buckling.
B … chess board buckling.
C … elephant foot buckling.
D … column buckling.

22 The CNIT shell consists of two layers connected by walls. Why?

A To reduce weight
B To absorb thermal expansion
C To prevent buckling
D To facilitate construction

23 When do we apply a knockdown factor?

A Linear elastic analysis
B Linear buckling analysis
C Modal analysis
D Nonlinear analysis

24 The smallest natural frequency of a sphere on Earth is 10 Hz. Another sphere, on the Moon, has twice the radius. What is the smallest natural frequency of the latter sphere? [5]

A 20 Hz
B 10
C 5
D 3

25 Extra membrane tension … [6]

A … increases the natural frequency.
B … does not affect the natural frequency.
C … reduces the natural frequency.
D … removes the natural frequency.

26 The shell roof and floors of a museum vibrate with a frequency of 1 Hz and an amplitude of 1 mm. Do visitors feel dizzy?

A No, it is not noticeable.
B No, it is hardly noticeable.
C Yes, it is strongly noticeable.
D Yes, it is unpleasant.

27 Which distribution do we need for Monte Carlo analyses of a shell structure?

A The mean wind speed in the World.
B The largest wind speed in 50 years in Europe.
C The largest wind speed in one year in the Netherlands.
D The largest wind speed in one year at the location of the shell.

28 There is a probability that a person dies in a structural collapse this year. Which probability is negligible for all persons in a developed country?

A 1 / 10 000
B 1 / 100 000
C 1 / 1000 000
D 1 / 10 000 000

29 Consider the Weibull distribution. $\sigma / \mu = 0.18$.

A $k = 6.69$
B $k = 6.50$
C $k = 5.51$
D $k = 5.38$

30 Write a good shell multiple choice question for next year's exam. The question needs to be not too easy and not too difficult. The question needs to be not just copied and not copied-and-modified-a-bit. (Unless the latter modification is substantial and original.)

Answers

1 D 88% of the answers are correct.
2 A 100%
3 D 88%
4 C 75% .....

> $k1 := \frac{3}{m}$: $k2 := -\frac{5}{m}$: $d := 5 \cdot mm$: $l := 100 \cdot mm$:

> $km := \frac{k1 + k2}{2}$: $mm := \frac{m}{1000}$: $-16 \cdot \frac{d}{l^2} \cdot km$;

$$\frac{8}{m^2}$$

5 C 63% .....

> $kx := \frac{1}{2. \cdot m}$: $ky := \frac{1}{5 \cdot m}$: $kG := -diff(kx, y) - diff(ky, x) - kx^2 - ky^2$;

$$kG := -\frac{0.2900000000}{m^2}$$

6 A 100%
7 D 88% .....

> $l := 12. \cdot m$: $t := 100 \cdot mm$:

> $\mathrm{rho} := 2400 \cdot \frac{kg}{m^3}$: $g := 9.8 \cdot \frac{m}{s^2}$: $E := 0.1e5 \cdot \frac{N}{mm^2}$: $\mathrm{nu} := 0.0$:

> $m := 1000 \cdot mm$: $kg := \frac{N}{\frac{m}{s^2}}$:

> $p := \mathrm{rho} \cdot g \cdot t$: $a := \frac{1}{2} + \frac{t}{2}$: $uz := (1 + (1 + \mathrm{nu}) \cdot \ln(2.)) \cdot \frac{p \cdot a^2}{E \cdot t}$;

$$uz := 0.1457614831\ mm$$

8 A 50% ..... B 50% is nonsense.
9 C 100%
10 B 88%
11 C 88% .....

> $t := 23 \cdot mm$: $vx := 735 \cdot \frac{kN}{m}$: $mxy := -9.02 \cdot \frac{kN \cdot m}{m}$:

> $m := 1000 \cdot mm$: $kN := 1000 \cdot N$:

> $sxz := \frac{3}{2} \cdot \frac{vx}{t} - \frac{3}{2} \cdot \mathrm{sqrt}(10.) \cdot \frac{mxy}{t^2}$;

$$sxz := \frac{128.8149655\ N}{mm^2}$$

12 A 75% .....

> $mxx := 13.$: $myy := -4$: $mxy := 7$: $V := \mathrm{sqrt}(mxy^2 - mxx \cdot myy)$;

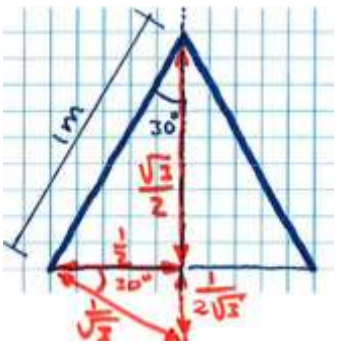
$$V := 10.04987562$$

13 B 75% .....

> $t := 1 \cdot mm$: $m := 1000 \cdot mm$: $assume(mm > 0)$:

> $a := \frac{1}{\mathrm{sqrt}(3.)} \cdot m$: $li := 2.4 \cdot \mathrm{sqrt}(a \cdot t)$: $h := \frac{li}{6}$;

$$h := 9.611245657\ mm$$



14 D 100% .....

> $v1 := 23.5$: $v2 := 25.1$: $v3 := 25.9$:

> $b := log2\left(\frac{v2 - v1}{v3 - v2}\right)$;

$$b := 1.000000000$$

> $v3 + (v3 - v2)$;

$$26.7$$

15 B 75% ……

$> A := 1 + \cos(u+v)\cdot\cos(u-v) : \quad B := 1 - \cos(u+v)\cdot\cos(u-v) :$

$> kxx := \frac{\sin(u)\cdot\cos(v)}{a\cdot A\cdot \mathrm{sqrt}(A\cdot B)} : \quad kyy := \frac{\sin(u)\cdot\cos(v)}{a\cdot B\cdot \mathrm{sqrt}(A\cdot B)} : \quad kxy := -\frac{\cos(u)\cdot\sin(v)}{a\cdot A\cdot B} :$

$> limit\left(limit\left(kxx, u = \frac{\mathrm{Pi}}{2}\right), v = 0\right);$

$$\frac{1}{a}$$

$> limit\left(limit\left(\mathrm{kyy}, u = \frac{\mathrm{Pi}}{2}\right), v = 0\right);$

$$\frac{1}{a}$$

$> limit\left(limit\left(\mathrm{kxy}, u = \frac{\mathrm{Pi}}{2}\right), v = 0\right);$

$$0$$

16 C 100%

17 B 63% ……

$> nxx := 50\cdot\frac{kN}{m} : \quad nyy := -25\cdot\frac{kN}{m} : \quad nxy := 5.0\cdot\frac{kN}{m} : \quad nyx := 4.5\cdot\frac{kN}{m} : \quad t := 100\cdot mm :$

$> m := 1000\cdot mm : \quad kN := 1000\cdot \mathrm{N} : \quad assume(m > 0) : \quad assume(kN > 0) :$

$> nxx > \frac{nxy\cdot nyx}{nyy};$

$$-\frac{0.9000000000\ N\sim}{mm\sim} < \frac{50\ N\sim}{mm\sim}$$

$> nyy < -\mathrm{sqrt}(nxy\cdot nyx);$

$$-\frac{25\ N\sim}{mm\sim} < -\frac{4.743416490\ N\sim}{mm\sim}$$

$> sc := \frac{nyy}{t} + \frac{nxy\cdot nyx}{nyy\cdot t};$

$$sc := -\frac{0.2590000000\ N\sim}{mm\sim^2}$$

18 A 75% ……

$> w := 32\cdot mm : \quad a := 6\cdot m : \quad l := 18\cdot m : \quad m := 1000\cdot mm : \quad uz := \frac{4\cdot w\cdot l}{a};$

$$uz := 384\ mm$$

19 D 38% …… A 50% is what Google AI chooses, which is nonsense.

20 A 50% …… D 50% is what Google AI chooses, which is nonsense.

21 B 100%

22 C 75% …… A 25% is wrong. We should not see CNIT as a 3 m thick shell with voids.

23 B 100%

24 C 100%

25 A 100%

26 B 100%

27 D 88%

28 C 88%

29 B 25% ……

$> cov := 0.18 :$ *k* determined by trial and error

30 88%

$> k := 6.4988 :$

$> \mathrm{GAMMA}\left(1 + \frac{1}{k}\right)^2\cdot\left(1 + \mathrm{cov}^2\right) - \mathrm{GAMMA}\left(1 + \frac{2}{k}\right);$

$$1.306 \times 10^{-7}$$

The grade is (40 *s* – 290) / 91 rounded to the closest halve, where *s* is the number of correct answers.

$$> \ g := a + b \cdot s :$$

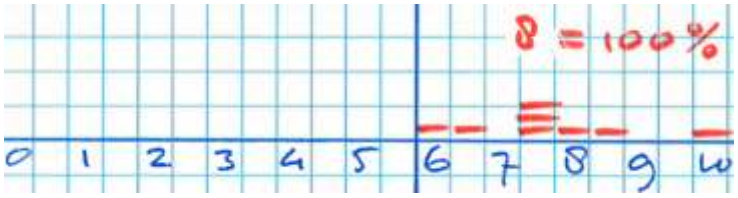
$$> \ eq1 := 0 = a + b \cdot \frac{29}{4} :$$

$$> \ eq2 := 10 = a + b \cdot 30 :$$

$$> \ opl := solve(\{eq1, eq2\}, \{a, b\}) : assign(opl) :$$

$$> \ g;$$

$$\frac{40\,s}{91} - \frac{290}{91}$$



[1] Question by Michael Middelkoop, November 2025
[2] Question by Daniele Casperetti, November 2025
[3] Question by Menno Marissen, November 2025
[4] Question by Bart van Dijk, November 2025
[5] Question by Elisa Lomazzi, November 2025
[6] Question by Nigel Wiesemann, November 2025