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WORKSHEETS
ATTEMPT | CHECK | CORRECT | IMPROVE

OCR A A Level Physics | Young modulus worksheet

35-40 minutes independent practice + 15-20 minutes review | 40 marks

Specification points covered

- 3.4.2(c) Define and use stress, strain and ultimate tensile strength. This worksheet focuses on stress and strain; ultimate tensile strength is reserved for a later worksheet.
- 3.4.2(d)(i) Define Young modulus, E = stress / strain.
- 3.4.2(d)(ii) Use techniques and procedures to determine the Young modulus for a metal.

How to use this worksheet

Show numerical working in the blank spaces. Convert mm to m, kN to N, MPa to Pa and GPa to Pa before substituting. Stress and Young modulus have unit Pa; strain has no unit.

1. Building the Young modulus equation chain [4 marks]

Begin with the definitions that connect the load on a component to its deformation.

(a) Write expressions for tensile stress σ and tensile strain ε. Define every symbol that you use. **[2 marks]**

(b) Starting from E = σ / ε, derive ΔL = FL / (AE) for a uniform component in tension. **[2 marks]**

2. Checking a trial bolt [4 marks]

A trial bolt has original gauge length 0.180 m and diameter 12.0 mm. A tensile force of 18.0 kN produces an extension of 0.140 mm.

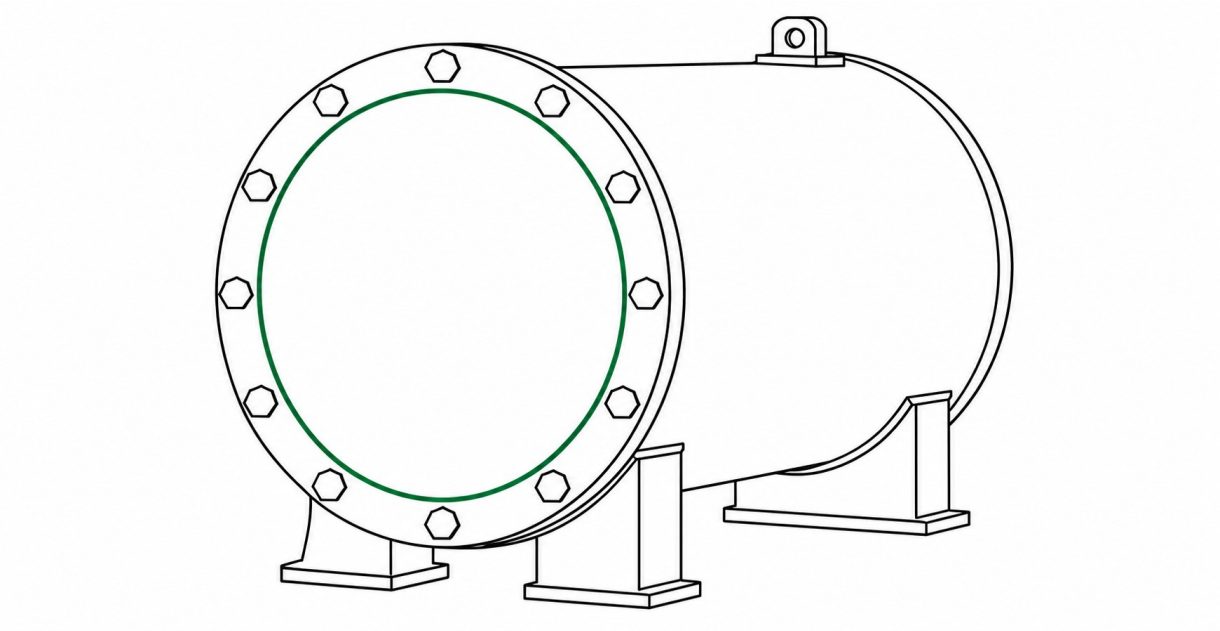
(a) Calculate the tensile stress in the bolt. **[2 marks]**

(b) Calculate the tensile strain in the bolt. **[1 mark]**

(c) Determine the Young modulus of the bolt material. **[1 mark]**

Scenario: the Helix composite-curing pressure chamber

An automated manufacturing line cures composite components inside a pressure chamber. A circular access plate is retained by twelve identical bolts. Treat the pressure as uniform, the external atmospheric pressure as already accounted for, and the load as shared equally between the bolts.



Chamber quantity	Value
Internal pressure above external pressure	1.80 MPa
Circular plate diameter	0.620 m
Number of identical bolts	12
Bolt shank diameter	18.0 mm
Effective bolt length	95.0 mm
Young modulus of bolt material	205 GPa

3. From chamber pressure to bolt tension [3 marks]

Use the pressure difference across the circular access plate and assume that the separating force is shared equally by all twelve bolts.

(a) Calculate the area of the circular access plate. **[1 mark]**

(b) Calculate the resultant separating force exerted on the plate by the pressure difference. **[1 mark]**

(c) Calculate the tensile force carried by each bolt. **[1 mark]**

4. Stress, strain and extension of one chamber bolt [5 marks]

The bolts are within the elastic region and each carries the force calculated in Question 3(c).

(a) Calculate the cross-sectional area of one bolt shank. **[1 mark]**

(b) Calculate the tensile stress in one bolt. Give the answer in MPa. **[1 mark]**

(c) Calculate the tensile strain in one bolt. **[1 mark]**

(d) Calculate the extension of one bolt in mm. **[2 marks]**

5. Verifying Young modulus using gap sensors [4 marks]

Four sensors measure the increase in the plate-to-chamber gap as 0.081 mm, 0.084 mm, 0.083 mm and 0.082 mm. Treat the chamber and plate as rigid, so the mean increase in the gap equals the bolt extension.

(a) Calculate the mean measured extension. **[1 mark]**

(b) Use the mean extension to calculate the experimental strain in a bolt. **[1 mark]**

(c) Use the stress from Question 4(b) to determine an experimental value for Young modulus. **[1 mark]**

(d) Calculate the percentage difference between the experimental value and 205 GPa. **[1 mark]**

6. One bolt is not carrying load [4 marks]

An automated inspection finds that one bolt is incorrectly seated. Model the same separating force as being shared equally by the remaining eleven bolts.

(a) Calculate the new tensile force and tensile stress in each load-carrying bolt. **[2 marks]**

(b) Calculate the new extension of each load-carrying bolt. **[1 mark]**

(c) Explain why the stress and extension have both increased by the same factor compared with the twelve-bolt case. **[1 mark]**

7. Redesigning the bolt diameter [5 marks]

A redesigned access plate uses eight identical bolts. The same separating force acts on the plate. Each bolt has effective length 110 mm and Young modulus 205 GPa. The extension of each bolt must not exceed 0.100 mm.

(a) Calculate the minimum cross-sectional area required for each bolt. **[3 marks]**

(b) Calculate the corresponding minimum bolt diameter. **[1 mark]**

(c) Available standard diameters are 18.0 mm, 20.0 mm, 22.0 mm and 24.0 mm. Select the smallest suitable diameter. **[1 mark]**

8. Quality-control tensile test [6 marks]

A sample from a new bolt batch has original gauge length 0.250 m. Five diameter readings are 6.01 mm, 5.99 mm, 6.00 mm, 6.02 mm and 5.98 mm. The force-extension data are shown below.

Force F / kN	Extension ΔL / mm
0	0
4.0	0.177
8.0	0.354
12.0	0.531
16.0	0.708
20.0	0.884

(a) Calculate the mean diameter of the sample. **[1 mark]**

(b) Calculate the cross-sectional area of the sample. **[1 mark]**

(c) Use the first and last data points to determine the gradient ΔF / ΔL in N m^{-1}. **[2 marks]**

(d) Use E = (L / A)(ΔF / ΔL) to determine the Young modulus of the sample. **[2 marks]**

9. Planning the production Young modulus check [5 marks]

A technician must determine Young modulus for a metal sample from each production batch using a tensile test machine.

(a) Describe the measurements, procedure and analysis required to obtain a reliable value for Young modulus. State how the load should be limited during the test. **[5 marks]**

Review and improve

- ☐ I can calculate tensile stress and tensile strain using SI units.
- ☐ I can use Young modulus to link force, area, length and extension.
- ☐ I can use measurements and a graph to determine Young modulus experimentally.