EVERYDAY EXAMPLES OF ENGINEERING CONCEPTS

S2: Control cable extension

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This is an extract from 'Real Life Examples in Mechanics of Solids: Lesson plans and solutions' edited by Eann A. Patterson, first published in 2006 (ISBN:978-0-615-20394-2) which can be obtained on-line at www.engineeringexamples.org and contains suggested exemplars within lesson plans for Sophomore Solids Courses. Prepared as part of the NSF-supported project (#0431756) entitled: "Enhancing Diversity in the Undergraduate Mechanical Engineering Population through Curriculum Change".

INTRODUCTION

(from *'Real Life Examples in Mechanics of Solids: Lesson plans and solutions'*)

These notes are designed to enhance the teaching of a sophomore course in mechanics of solids, increase the accessibility of the principles and raise the appeal of the subject to students from a diverse background[1]. The notes have been prepared as skeletal lesson plans using the principle of the 5Es: Engage, Explore, Explain, Elaborate and Evaluate. These are not original and were developed by the Biological Sciences Curriculum Study[2] in the 1980s from work by Atkin and Karplus[3] in 1962. Today they are considered to form part of the constructivist learning theory and a number of websites provide easy to follow explanations of them[4].

These notes are intended to be used by instructors and are written in a style that addresses the instructor, however this is not intended to exclude students who should find the notes and examples interesting, stimulating and hopefully illuminating, particularly when their instructor is not utilizing them. In the interest of brevity and clarity of presentation, standard derivations and definitions are not included since these are readily available in textbooks which these notes are not intended to replace but rather to supplement. Similarly, it is anticipated that these lessons plans can be used to generate lectures/lessons that supplement those covering the fundamentals of each topic.

Acknowledgements

Many of these examples have arisen through lively discussion in the consortium supported by the NSF grant (#0431756) on "Enhancing Diversity in the Undergraduate Mechanical Engineering Population through Curriculum Change" and the input of these colleagues is cheerfully acknowledged as is the support of NSF. The influence of the editor's mentors and peers at the University of Sheffield is substantial and is gratefully acknowledged since many of the ideas for these examples originate from tutorial questions developed and used in the Department of Mechanical Engineering in Sheffield over many years.

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[1] Patterson, E.A., Campbell, P.B., Busch-Vishniac, I., Guillaume, D.W., 2011, The effect of context on student engagement in engineering, *European J. Engng Education*, 36(3):211-224.
[2] http://www.bscs.org/library/BSCS_5E_Instructional_Approach_July_06.pdf
[3] Atkin, J. M. and Karplus, R. (1962). Discovery of invention? *Science Teacher* 29(5): 45.
[4] e.g. http://www.science.org.au/primaryconnections/constructivist.htm

ELEMENTARY STRESS SYSTEMS

2. Principle: **Control cable extension**

Engage:

Ride a bike into class changing gear in front of the students.

Explore:

Upturn the bike on the bench or floor. Invite a student to help you by turning pedals. Change gear to demonstrate mechanism for those who have never thought about it. Release the tension in the derailleur cable and try to change gear.

Explain:

Explain that with the tension released the motion of the gear lever is being used to take up slack resulting in no motion at derailleur. Tension is required in the cable to transmit the motion of the gear lever to the derailleur arm. The cable acts against the spring in the derailleur system, so force in the cable is higher in hill-climbing gears.

Elaborate:

Work through the example below:

Assume the cable to be 1.2mm in diameter and of length 1.8m. If the spring force exerted when shifting one gear is 100N then estimate the linear motion required at the handle bars when the derailleur needs to move 4mm.

Solution:

Displacement at handle-bars, $\partial_h = \partial_d + \delta$ where ∂_d is the displacement required at the derailleur and δ is the extension of the cable.

Deflection of the cable, $\delta = \varepsilon L = \dfrac{\sigma L}{E} = \dfrac{FL}{AE} = \dfrac{100 \times 1.8}{\left(\pi \times 0.0012^2 / 4\right)\left(210 \times 10^9\right)} = 7.6 \times 10^{-4}\,\text{m}$

So the movement required at the handle-bars is $\partial_h = 4 + 0.76 = 4.76\,\text{mm}$.

Evaluate:

Ask the students to complete the following examples:

Example 2.1

A cable of diameter 3mm and length 3.5m connects the rudder to the wheel on a yacht. Assuming the force exerted on the cable by the rudder is approximately 20kN find the displacement that must be applied at the wheel to achieve a displacement of 10cm at the rudder.

Solution:

The extension, δ of the cable is the difference in the displacements of the two ends, so for the unknown displacement at the wheel, ∂_w

$\delta = (\partial_w - \partial_r)$ where ∂_r is the displacement at the rudder,

now the longitudinal strain, $\varepsilon = \dfrac{e}{L} = \dfrac{(\partial_w - \partial_r)}{L}$ where L is the length of the cable.

Also we can define longitudinal strain in terms of stress, σ; i.e.

$$\varepsilon = \frac{\sigma}{E} = \frac{P}{AE} = \frac{P}{E\pi d^2/4}$$

where E is the Young's modulus, A is the cable cross-section area and d is the diameter. Hence equating these two definitions gives:

$$\frac{(\partial_w - \partial_r)}{L} = \frac{P}{E\pi d^2/4}$$

thus $$\partial_w = \frac{PL}{E\pi d^2/4} + \partial_r = \frac{(20\times10^3)(3.5)}{\pi(210\times10^9)(3\times10^{-3})^2/4} + 0.1 = 0.147\,\text{m}$$

The required displacement at the wheel is 14.7cm.

Example 2.2

Ask students to look for two other examples in their everyday life and explain how the above principles apply to each example.