Identifying and Investigating Difficult Concepts in Engineering Mechanics and Electric Circuits

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What important concepts do students find difficult to learn?

Engineering Mechanics

Concept	Understood?			Importance?		
	Round 1	Round 2	Round 3	Round 1	Round 2	Round 3
1. 3-D Visualization	3 (2.25, 5)	4 (3, 5)	4 (3.5, 5)	8 (7, 9)	8 (7.25, 9)	8 (7.5, 9)
2. Beam Deflection	6 (4, 7)	5.5 (5, 7)	6 (5, 6)	8 (7, 10)	9 (8, 9)	8 (7, 9)
3. Beam Shear Stress	5 (3, 6.5)	4 (3, 5)	4 (3, 5)	8 (5.75, 10)	6 (5, 9)	7 (6, 8)
4. Beams- Normal Stress	7 (6, 8)	7 (6, 8)	7 (6, 8)	10 (8, 10)	9 (8, 10)	9 (8.25, 10)
5. Combined Loading /Column Buckling	5 (4, 7)	5 (4.5, 6)	5 (4, 5)	9 (7.25, 9.75)	8.5 (7.75, 9)	8 (8, 9)
6. Conservation of Energy Thru Impact	3 (3, 5.75)	3 (3, 4.5)	3 (3, 4)	7.5 (3, 9.75)	8 (5.5, 8.5)	7 (7, 7.75)
7. Couple	5 (4, 7)	5 (3.25, 7)	5 (4.5, 7)	8 (4, 10)	8 (6.25, 9)	7 (6.5, 9)
8. Distributed Forces	7 (4, 8)	5 (5, 6.75)	5 (5, 6)	9 (8, 10)	9 (8.25, 9.75)	9 (8.5, 9)
9. Equilibrium – sum of forces = 0, sum of moments = 0 (Newton's 3rd Law)	7 (6, 8)	7.5 (6.25, 8)	7 (6.5, 8)	10 (10, 10)	10 (10, 10)	10 (10, 10)
10. External vs. Internal Forces	5 (4, 6.5)	5 (4, 6.75)	5 (4.5, 6)	9 (8, 10)	10 (9, 10)	10 (9, 10)
11. Importance of signs on forces	5 (4.25, 7.75)	6.5 (5, 7)	5 (5, 7)	7.5 (6, 10)	8.5 (7, 9.75)	8 (7, 9)
12. Isolating a body from surroundings	5 (4, 6.75)	5 (4, 6)	5 (4.5, 6.5)	9 (9, 10)	10 (9, 10)	10 (9, 10)
13. Linear vs. Circular Velocity and Acceleration	4.5 (3, 6)	5 (3, 5.5)	5 (3.5, 5)	7.5 (3.75, 10)	8 (7, 9)	8 (8, 8)
14. Mohr's Circle	6 (3. 7.5)	6 (5, 6.5)	5.5 (5, 6)	7 (6, 10)	6 (4, 8)	5.5 (2.75, 8)
15. Moment of Inertia	4 (3, 7)	4 (3, 7)	4 (4, 5)	9 (7, 10)	8 (8, 9)	9 (8, 9)
16. Moments	7 (5, 8)	7 (6, 7.75)	6 (6, 6.75)	10 (9, 10)	10 (9.25, 10)	10 (10, 10)
17. Momentum	7 (2, 8)	5 (3.5, 6.5)	5 (3.5, 5.5)	8.5 (6.75, 9.25)	9 (8, 9)	9 (8.5, 9.5)
18. Rolling/Kinetic Friction	3 (2, 6)	4 (2.75, 6)	4 (3, 4)	9 (5.25, 9.75)	8 (7, 9)	7.5 (7, 8)
19. Shear Force	5 (3.5, 7.5)	5 (4.5, 6)	5.5 (5, 6)	9 (7, 10)	9 (8, 9)	8 (7.25, 9)
20. Static Friction	5 (3, 6)	5.5 (4, 6)	5 (4.5, 6)	8 (7, 9)	8 (7.25, 9)	8 (8, 9)
21. Statically Indeterminant Members	3 (2, 5)	3.5 (2, 4.25)	3.5 (3, 4)	9 (8, 10)	10 (8, 10)	9 (8.5, 10)
22. Stress vs. Strain	6 (4.5, 7.5)	7 (5, 7)	6 (6, 7)	10 (9, 10)	10 (9, 10)	10 (9, 10)
23. Sum of Forces not equal to 0 in dynamics	6 (3, 8)	6 (4, 7)	5.5 (4, 6)	10 (9, 10)	10 (9, 10)	10 (9, 10)
24. Torsion	5 (4, 8)	6 (5, 7)	6 (5.5, 7)	9 (8, 10)	9 (8.75, 10)	9 (9, 9)
25. Translational & Rotational Motion	5.5 (3, 6)	4.5 (3.25, 5)	4 (3, 5)	9 (7.75, 10)	8.5 (8, 9)	8 (8, 9)
26. Truss Analysis	5.5 (5, 8)	6 (5, 7)	6 (5.5, 7)	8 (5.75, 10)	9 (5, 9)	9 (6, 9)
27. Two Force Members	5 (5, 8)	6 (5, 7)	6 (5, 6.5)	8 (6, 10)	8 (6, 9)	7 (6.5, 8.5)
28. Weight vs. Mass	7 (5, 8)	7 (6, 7)	7 (6, 7)	10 (6.5, 10)	9.5 (9, 10)	10 (9, 10)

Delphi Method

Understanding Scale	Importance Scale
1 = no one understands the concept	1 = not at all important to understand the concept
10 = everyone understands the concept	10 = extremely important to understand the concept

Resulting Main Topics
Force
stress and strain
friction
moment of inertia.

Resulting Main Topics
AC steady-state circuit analysis (including AC power)
the five fundamental electrical quantities (charge, current, voltage, power, and energy)
Kirchhoff's Laws
Thevenin/Norton equivalent circuits

Electric Circuits

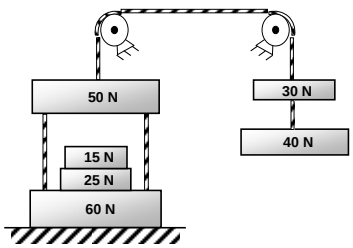
Concept	Understood?			Importance?		
	Round 1	Round 2	Round 3	Round 1	Round 2	Round 3
1. AC Power Concepts	6 (4.25, 6.25)	5 (4, 6)	5 (4, 6)	8 (6, 8)	7 (7, 8)	8 (7, 8)
2. AC Steady-State Circuit Analysis (Phasors and Impedance)	6 (4.75, 8)	6 (4, 7)	5.5 (5, 6.25)	9 (7.5, 10)	9 (8, 10)	9.5 (8, 10)
3. Active-Passive Power Sign Convention	8 (8, 9)	9 (8, 9)	9 (9, 9)	8 (5, 10)	10 (7, 10)	10 (9, 10)
4. Charge vs. Voltage vs. Current	7 (7, 9)	8 (7, 9)	8 (7, 8.25)	10 (5, 10)	10 (6, 10)	8 (7.5, 10)
5. Complex Numbers	8 (5, 9)	8 (5, 9)	7 (5, 8.25)	9 (5.75, 10)	9 (9, 10)	9 (8, 10)
6. Current Divider	6 (5, 8)	7 (5, 8)	6 (5, 7.25)	8 (7, 10)	8 (6, 10)	8 (6.75, 8.25)
7. Dependent Sources	5 (4, 8)	6 (4, 7)	5.5 (4, 7)	9 (7.75, 10)	9 (8, 10)	9 (7.75, 9)
8. Energy Storage Elements (Inductance and Capacitance)	7 (6, 9)	7 (6, 8)	7 (6.75, 8)	10 (8, 10)	10 (10, 10)	10 (9.75, 10)
9. Energy vs. Power	7 (4, 8)	7 (6, 7)	6 (6, 7)	10 (5, 10)	10 (7, 10)	9 (7.75, 10)
10. Equivalent Resistance	7 (4.5, 10)	7 (5, 8)	7 (5.75, 8)	8 (6.5, 9.25)	9 (8, 9.25)	9 (8, 9.25)
11. Frequency Response	6.5 (2.25, 8)	6 (4.5, 7)	5 (4.5, 6)	9 (7, 10)	9.5 (8, 10)	9 (8.5, 10)
12. Interpretation of Circuit Diagrams	6 (5, 8)	6 (5, 7)	6 (5.75, 6)	8 (6, 10)	10 (8, 10)	9 (8.75, 10)
13. I-V Characteristics of Current & Voltage Sources	6 (5, 8)	5 (5, 6)	5 (5, 6)	7 (5, 10)	7 (6, 9)	8.5 (6, 9)
14. Kirchhoff's Laws	9 (8, 10)	9 (8, 10)	8 (8, 9)	10 (10, 10)	10 (10, 10)	10 (10, 10)
15. Mesh vs. Node Method	5 (3, 7)	5 (5, 6)	5 (4, 5)	6 (5, 9)	6 (5, 7)	6 (5, 7)
16. Mess-Current Method	5 (4, 8)	6 (5, 7)	6 (5.75, 7)	7 (3, 9)	8 (5, 8)	7 (5, 8)
17. Node-Voltage Method	8 (6, 8)	7 (6, 8)	7.5 (6, 8)	9 (6, 10)	10 (8, 10)	9.5 (8, 10)
18. Operational Amplifiers	6 (6, 8)	6 (6, 7)	6 (6, 7)	8 (7, 10)	8.5 (8, 9)	9 (8, 9)
19. Reactive Power	4 (2, 5)	4 (2, 4)	3 (2, 4.5)	7 (6, 7)	6 (6, 7)	6 (5, 6.5)
20. RLC Circuits	6 (4, 7)	5 (5, 6)	5.5 (5, 6)	7 (6, 9)	8 (7, 9)	8.5 (8, 9)
21. Series and Parallel Circuit Elements	8 (6, 10)	9 (7, 9)	9 (7, 9)	9 (8, 10)	10 (8, 10)	9.5 (8.75, 10)
22. Superposition Method of Circuit Analysis	7 (4, 8)	8 (6, 8)	7 (6, 8)	5 (5, 8)	8 (5, 8)	7.5 (7, 8)
23. Thevenin/Norton Equivalent Circuits	4 (3, 8)	6 (4, 7)	6 (4.75, 6.2)	8 (7, 10)	10 (8, 10)	10 (9, 10)
24. Three Phase System	4 (3, 7)	5 (2.75, 5.2)	5 (2.5, 5)	5 (3.75, 6)	5 (4, 5.25)	5 (4, 5)
25. Transient Analysis (RC & RL Circuits)	5 (4, 7)	5 (5, 7)	5.5 (5, 6)	8(5, 9)	9 (8, 9)	9 (8, 9)
26. Two Port Networks	3 (3, 7)	3 (2.75, 4.2)	3 (2, 3)	5 (2, 6.5)	5 (3.75, 5.25)	5 (3.5, 5)
27. Voltage Divider	7 (5, 9)	8 (7, 8)	8 (7, 8)	10 (7, 10)	10 (9, 10)	10 (8, 10)

How can we describe students' mental models of these concepts?

Models link to substance based thinking

"force"

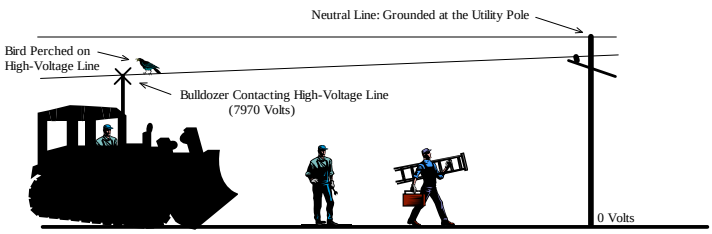
Consider the system of blocks connected by cords which wrap around pulleys. The 60 Newton (N) block rests on a table. Draw the FBD(s) required to determine the force of the table on the 60 N block. What is this force?



"…you've got cords that are connecting the 50N block to the 60N block. And then you have the 15N and 25 N sitting on top of the 60N block. I think you can write force equations and tension equations. [I don't know] exactly how you do that, but… I'm pretty sure you can write force equations and I'm pretty sure you can write tension equations. Not necessarily an equation that describes what tension is. But, there's a force on each of the cords here that makes it so they don't tear apart."

"voltage"

A bulldozer operator working in some muddy soil inadvertently contacts an energized overhead 7970 Volt power line. Students were asked to explain why the bulldozer operator was unhurt, while a worker on the ground was electrocuted when he took a step. The students were told that the worker was not shocked as long as he stood still.



"I would think initially that if he's standing in the same muddy soil as this machine, as soon as this machine contacts the wire, he should feel the shock. So, it should like, the voltage should like pass through his legs. I would think that if he's just standing that he should feel a shock also."

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