Moduel 1

ENGR 141
Engineering Mechanics

Introduction and Basic Concepts, and Definitions

Instructor: **Mohsen Akbari**, *Ph.D., Assistant* Professor

Structure of the Lions gates
(Vancouver BC)

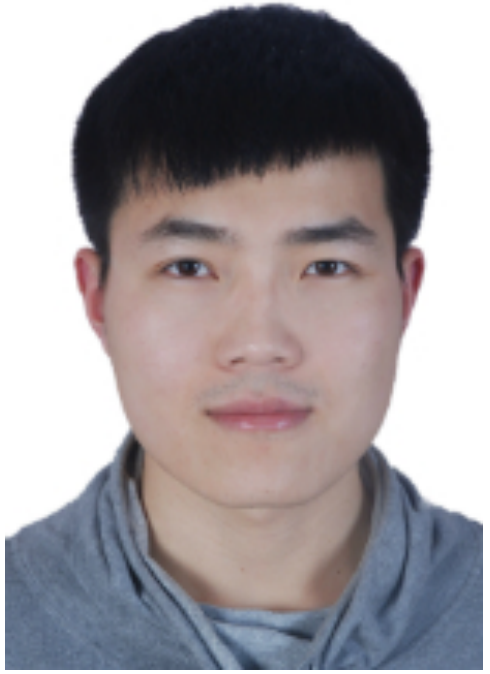
University of Victoria

Space frame
system

House Keeping

TAs

Majid Soleimani Nia
majids@uvic.ca



Wei Henglai
henglaiwei@uvic.ca

House Keeping

Office Hours

Days: Open door. Best way to find me is to email.
E-mail: makbari@uvic.ca
Location: EOW 553

House Keeping

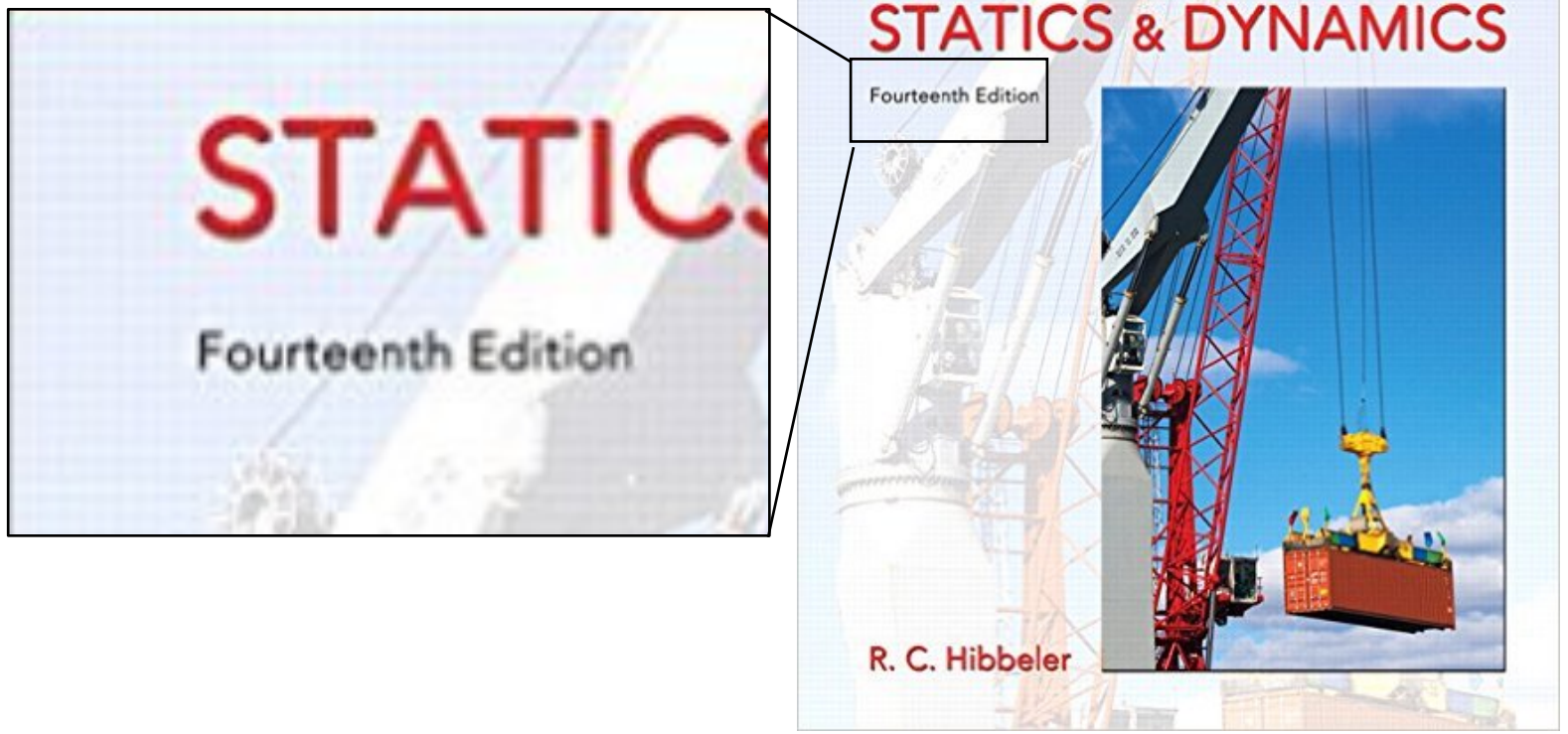
Course Objectives

- This course deals with the concept of equilibrium as applied to rigid bodies- the case in which the forces and moments acting on a body do not result in an acceleration of the body.
- The course will define a methodology, the method of statics, used to determine certain forces and moments acting on and within rigid bodies, and structures and machines composed of rigid components, that are in equilibrium.

House Keeping

Recommended Texts and References

Required: RC Hibbeler, Engineering Mechanics – Statics & Dynamics, 14th Edition, Pearson, 2016.



House Keeping

Tutorials

- T01: Tuesdays, 11:30 AM – 12:20 AM, Engineering Comp Science Bldg 108

- T02: Tuesdays, 14:30 AM – 15:20 AM, Engineering Comp Science Bldg 104.

- Few problems will be solved during the tutorials by your TAs.

- Attendance will be taken and will be accounted as part of your final grade of the course (see the evaluation).

House Keeping

Assignments

- There will be 10 assignments which will be given to you on Mondays (starting May 14th) every week. You will have one week to solve the problems.
- Assignments are worth 20% of your final grade.
- You MUST return your assignments on the following Monday by the end of the lecture. For example, Assignment#2 will be posted online on May 21st, thus, you MUST submit it by the end of the lecture on May 28th to me in the class.
- No late submissions will be accepted.

House Keeping

Assignments

- Two random problems will be selected and graded. The solutions to the assignments will be uploaded as well for your review.
- Each assignment will be graded out of 100% (50% for submitting the assignment and 50% for correct solutions)
- You can solve the assignments with the help of your friends but please DO NOT copy from each other or the solution manual.
- You can download the assignments from CourseSpaces or from https://makbari-lime.weebly.com/engineering-mechanics.html

House Keeping

Suggested problems

- Few suggested problems will be posted online every week for those who want to practice more.
- Solving these problems is optional but highly recommended.

House Keeping

Quizzes

- There will be 3 quizzes, each worth 5% of the final grade.
- Tentative dates are

Quizz#1: June 19th

Quizz#2: July 10th

Quizz#3: July 24th

- Quizzes will be closed-book and similar to the assignments, suggested problems, examples solved during the lectures and problems that will be solved in the tutorials.

House Keeping

Tests

- There will be 4 tests, each worth 15% of the final grade.
- The tests will be taken during the lectures. The tentative dates are:

Test #1: May 24th

Test #2: June 11th

Test #3: June 28th

Test #4: July 26th

House Keeping

Tests

- The tests will be closed-book. I will provide you with whatever you need for the tests.
- If you miss one of these tests for medical reasons, I will consider the average of the other three tests for the missed test. Please be advised that you should provide me with an original doctors note.

House Keeping

Evaluation

Tutorials attendance:	5%
Assignments:	20%
Pop quizzes:	15%
Test 1:	15%
Test 2:	15%
Test 3:	15%
Test 4:	15%
Total:	**100%**

House Keeping

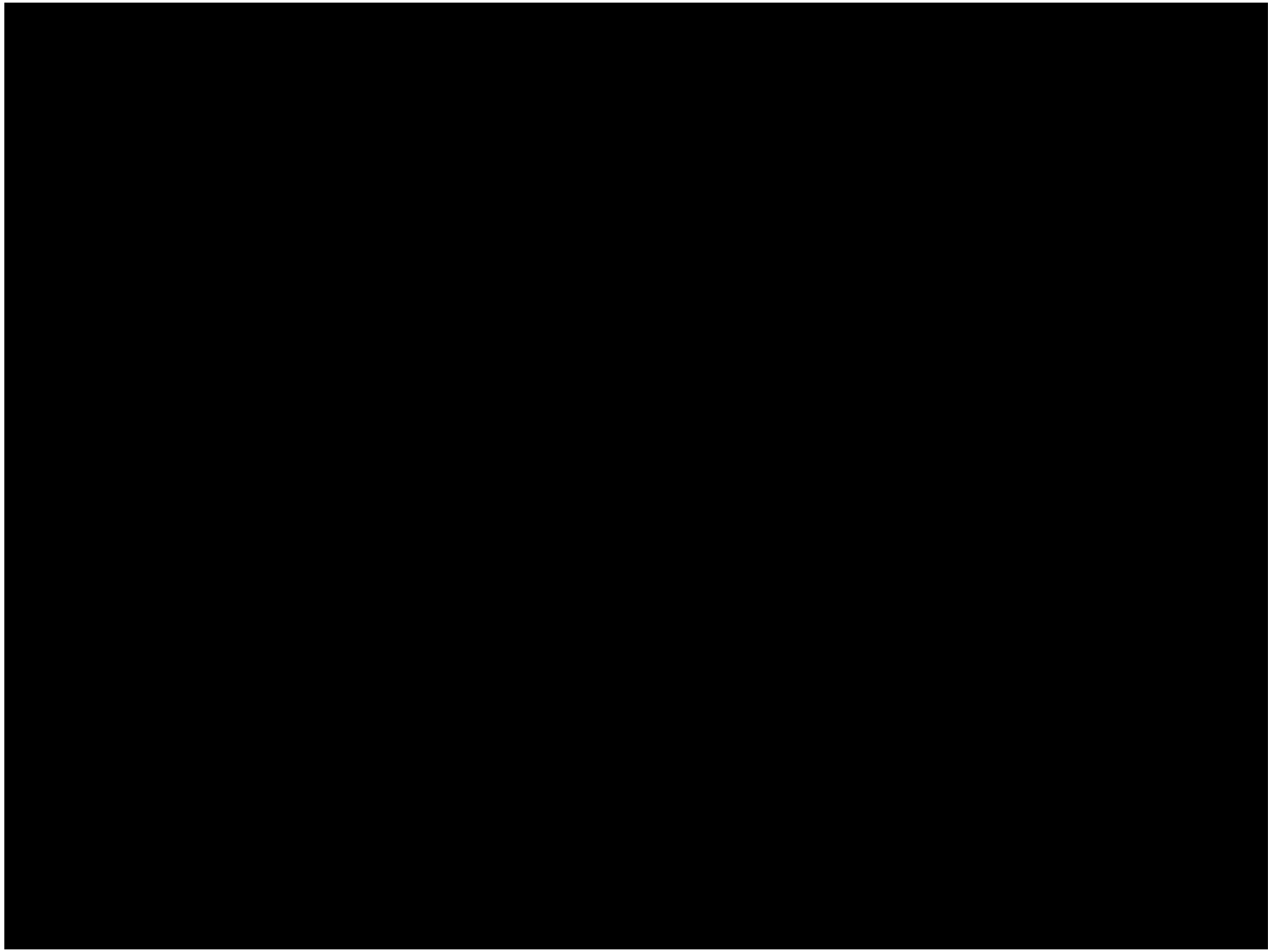
- Please switch-off electronic communication devices in my lectures.
- Please do not talk in my lectures.

5 minutes break

Why This Course?

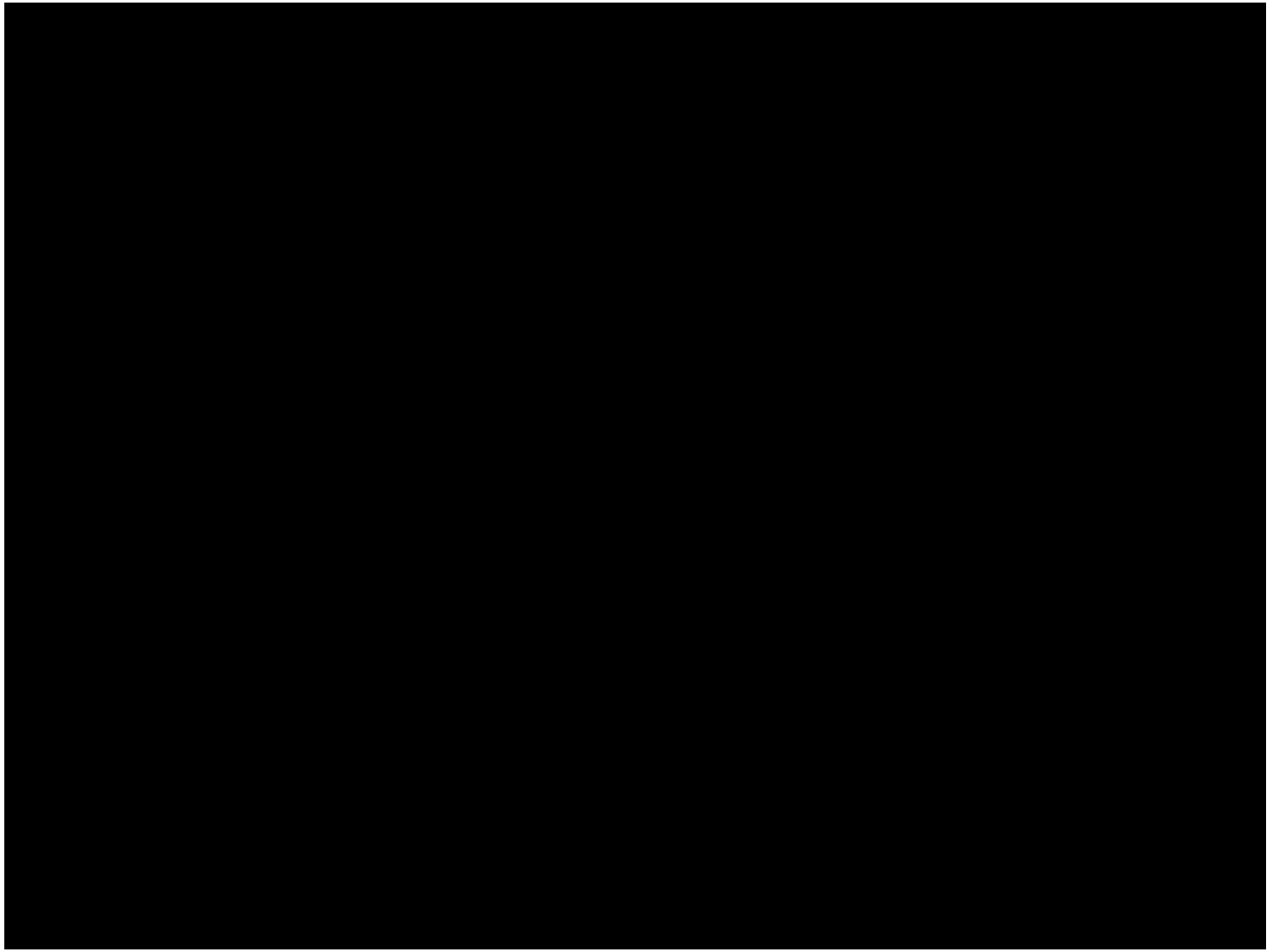
Engineering Mistakes (Crane Tips Over)

University of Victoria



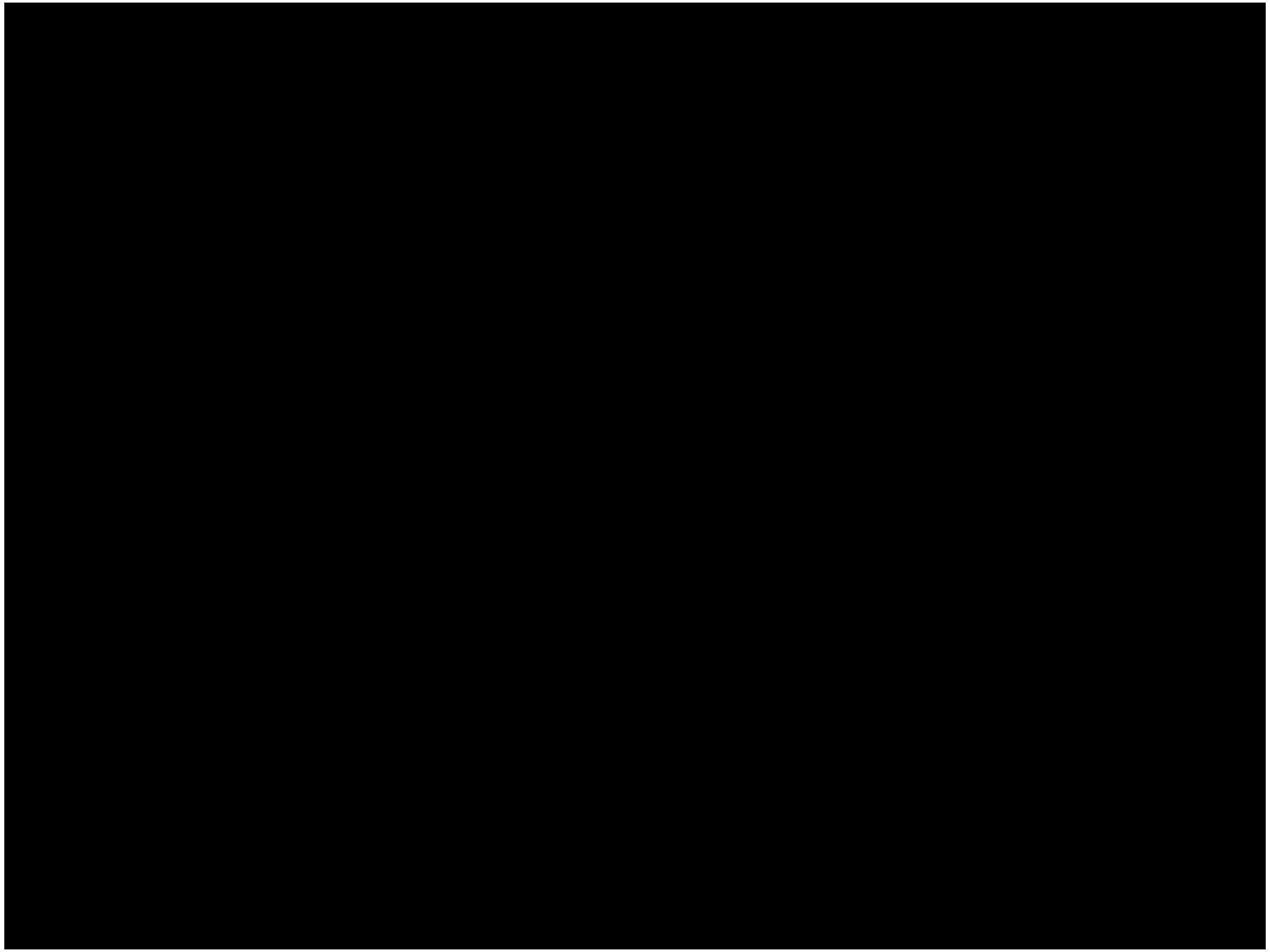
Engineering Mistakes (Crane Tips Over)

University of Victoria



Engineering Mistakes (Indianapolis Stage Collapse in 2011)

University of Victoria



Engineering Mistakes (Indianapolis Stage Collapse)

University of Victoria

Investigators say **the rigging had no cross bracing but was tethered to "Jersey barriers."** Those barriers began to slide under 33-mph winds - well below expected standards and before the tarp blew off.

Investigators said the tarp created "a parachuting effect. It did add a significant amount of drag to the structure. By the time that released, the other elements had already failed."

Jersey barriers
Photo from Wikipedia

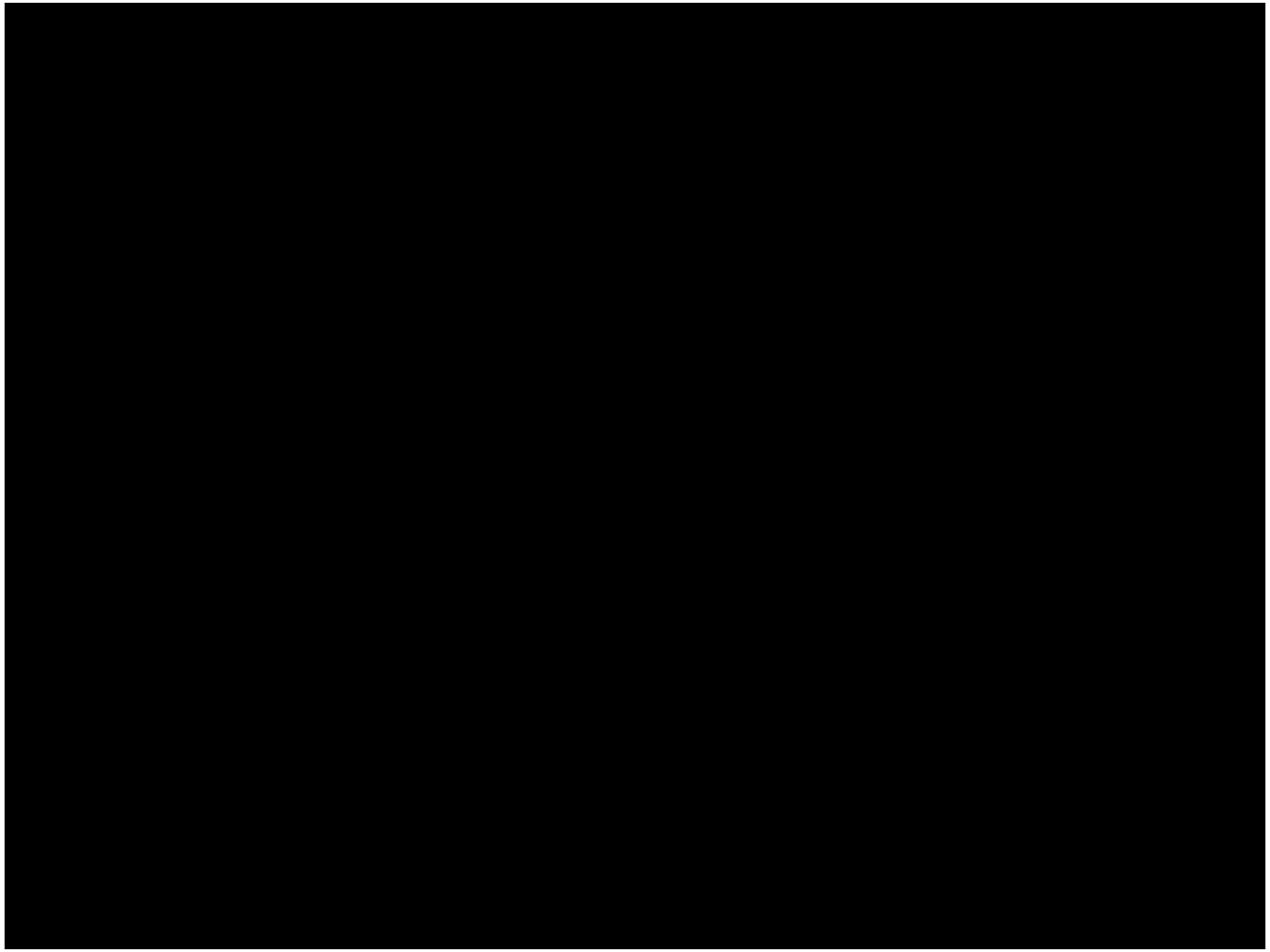
Engineering Mistakes (Indianapolis Stage Collapse)

University of Victoria

The report also stated that even if the ballast system had provided sufficient resistance, the synthetic webbing ratchet straps and wire rope guy lines used did not have sufficient strength to resist the wind gust - although it was actually less magnitude than code-specified requirements.

In 2014, the State of Indiana and other defendants settled these cases for $50,000,000.

Engineering Mistakes (Tacoma Narrows Bridge Collapse



Engineering Mistakes (Tacoma Narrows Bridge Collapse

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Shortly after construction finished at the end of June (opened to traffic on July 1, 1940), it was discovered that the bridge would sway and buckle dangerously in relatively mild windy conditions that are common for the area, and worse during severe winds. This **vibration** was transverse, one-half of the central span rising while the other lowered.

Engineering Mistakes (Tacoma Narrows Bridge Collapse

University of Victoria

The failure of the bridge occurred when a never-before-seen twisting mode occurred, from winds at a mild 40 miles per hour (64 km/h). This is a so-called **torsional vibration mode** (which is different from the transversal or longitudinal vibration mode), whereby when the left side of the roadway went down, the right side would rise, and vice versa, with the center line of the road remaining still.

Engineering Mechanics

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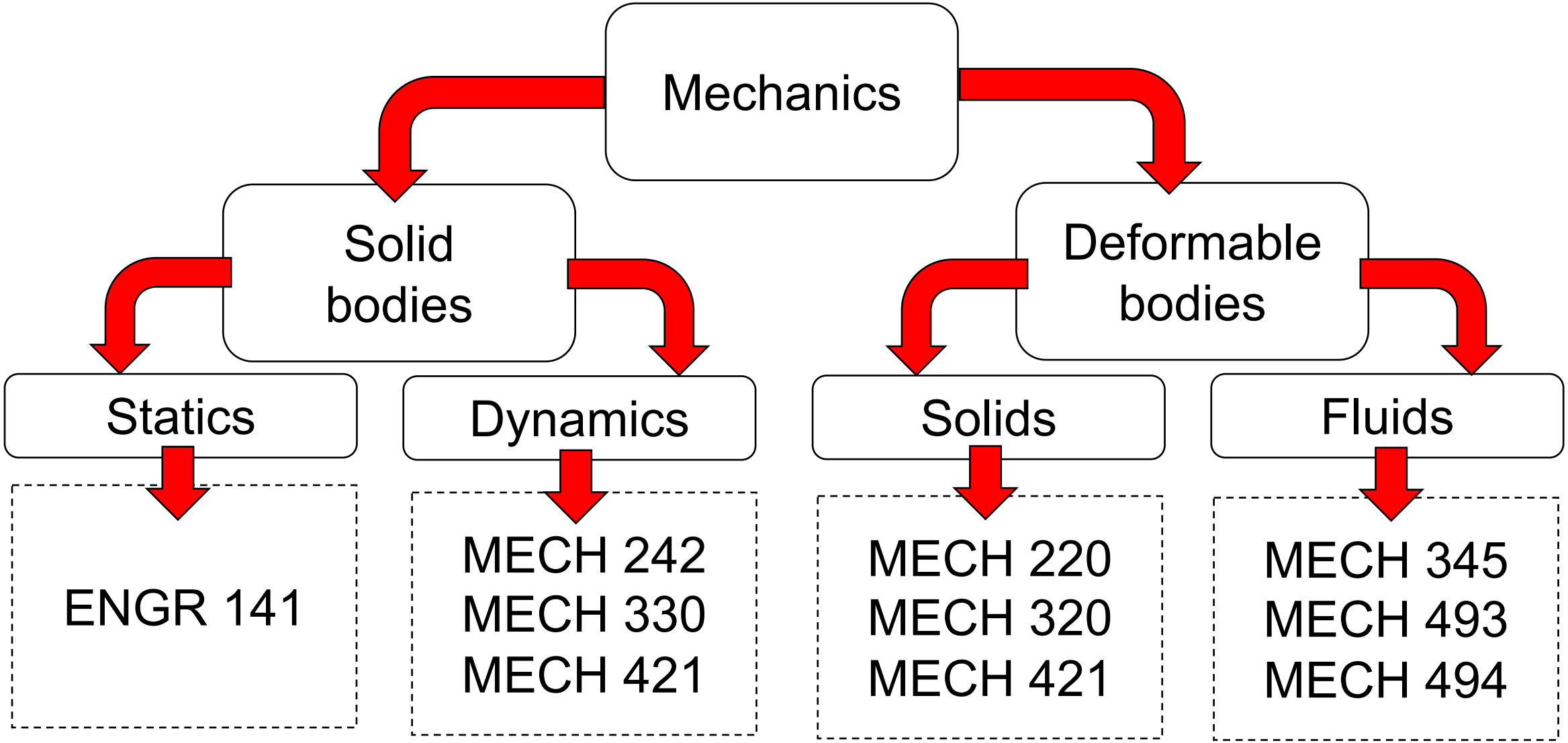
Mechanics: A branch of the physical sciences that is concerned with the state of rest or motion of bodies that are subjected to the action of forces.

Engineering Mechanics



Engineering Mechanics

University of Victoria

Statics deals with the equilibrium of bodies that are either at rest or move with a constant velocity.

Dynamics is concerned with the accelerated motion of bodies.

Statics is a special case of dynamics in which the acceleration is zero.

What Will be Covered?

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SECTION	TOPICS COVERED
1.1 – 1.6	Introduction: Course Overview, SI units, analysis procedure
2.1 - 2.9	Vectors: forces and positions, vector algebra, inner (dot) product
3.1 – 3.4	Particle equilibrium, equilibrium equations
4.1 – 4.3	Force system resultants: moment of a force
4.3-4.8	Cross product, principle of moments, reduction to equivalent loads
5.1 – 5.7	Equilibrium of rigid bodies: Equilibrium equations, FREE-BODY DIAGRAMS, Interconnections (constraints)
6.1 – 6.4	Truss analysis: methods of joints and sections
6.6	Frames and Machines.
4.9	Internal forces: distributed loads, shear and bending moment diagrams, method of sections.
7.1 – 7.2	Internal forces: distributed loads, shear and bending moment diagrams, method of sections.
7.3	Shear and bending moment diagrams: differential relations.
8.1, 8.2, 8.3,8.4	Friction: dry friction s crew forces, wedges
9.1 – 9.2	Centroids: center of gravity, composite bodies, integral methods.

Fundamental Concepts

Length is used to locate the position of a point in space so it describes the size of a physical system.

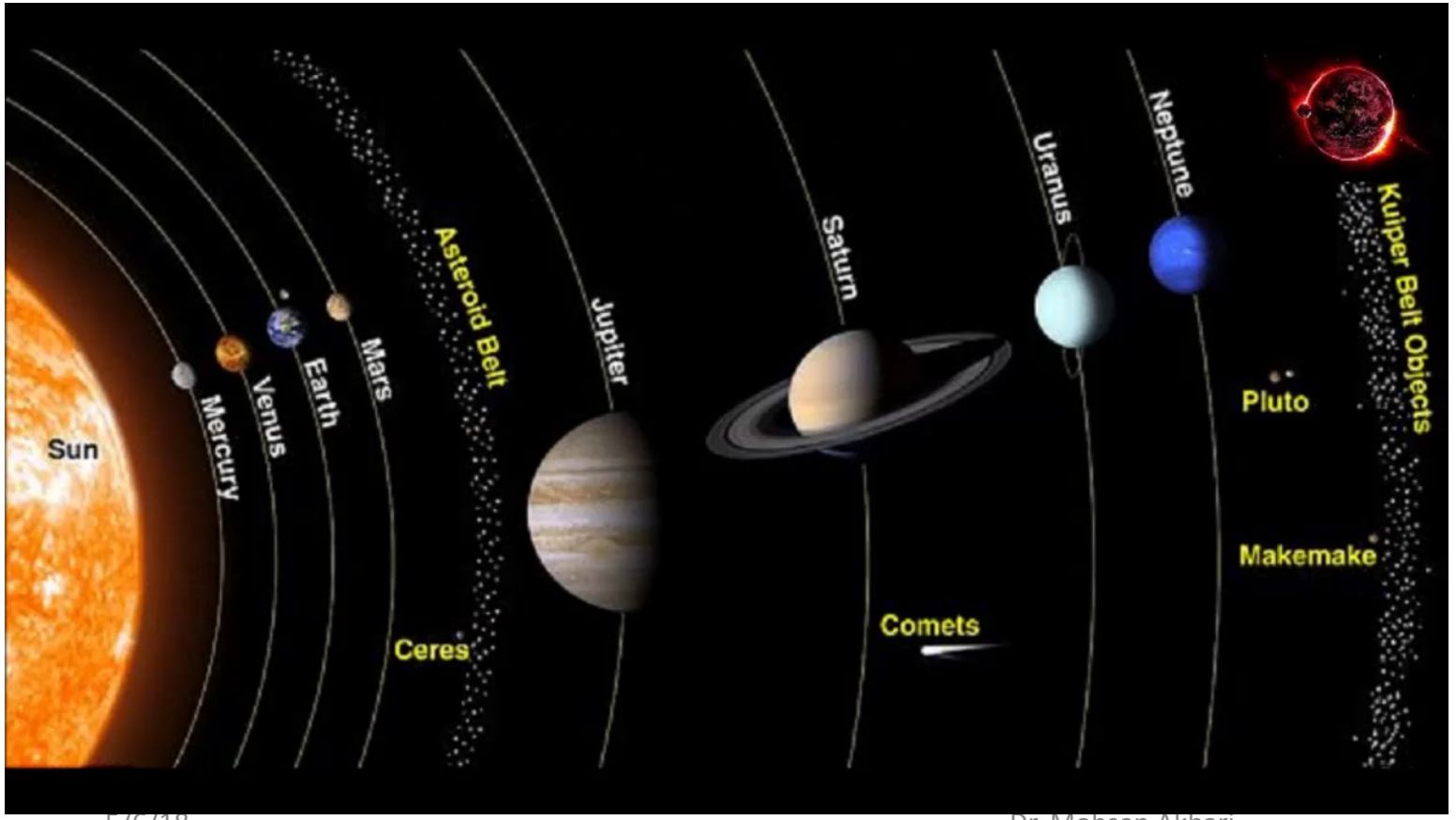
Mass is the property of matter that measures its resistance to acceleration. Roughly, the mass of an object is a measure of the number of atoms in it.

Force is any interaction (push or pull) that, when unopposed, will change the motion of an object. In other words, a force can cause an object with mass to change its velocity

Fundamental Concepts

Idealization is used to simplify the theory.

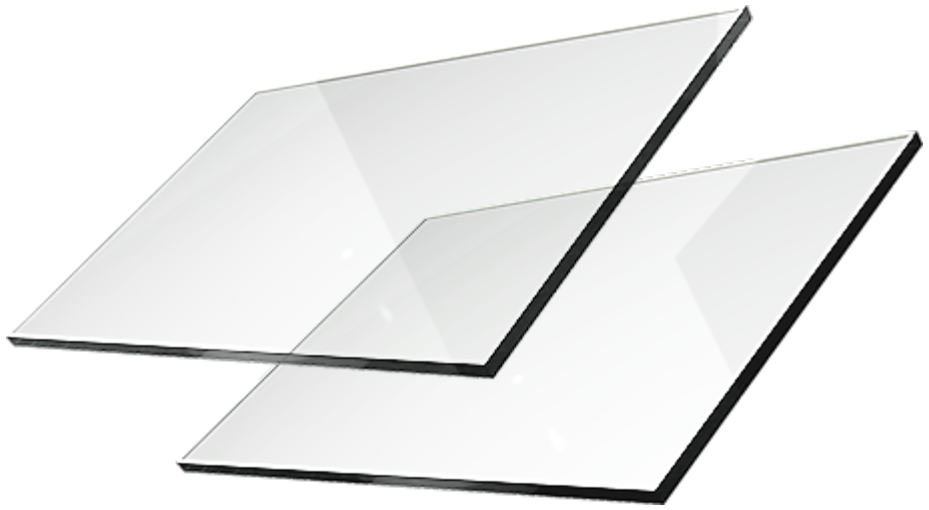
Particle has a mass, but the size is neglected.



The ratio of the Sun's radius to the Earth's radius is 110. Therefore, earth can be considered as a particle.

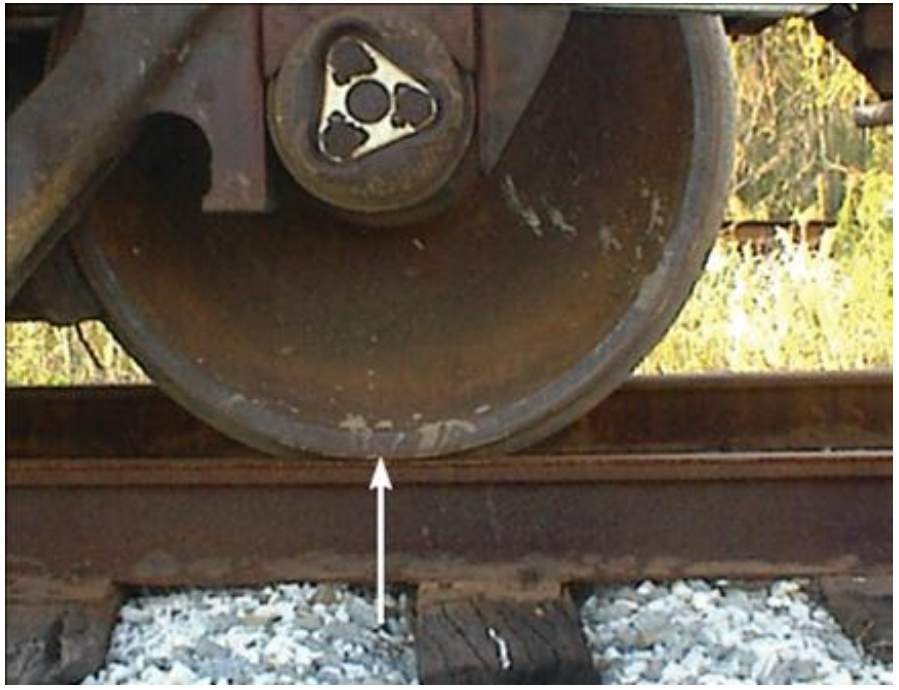
Fundamental Concepts

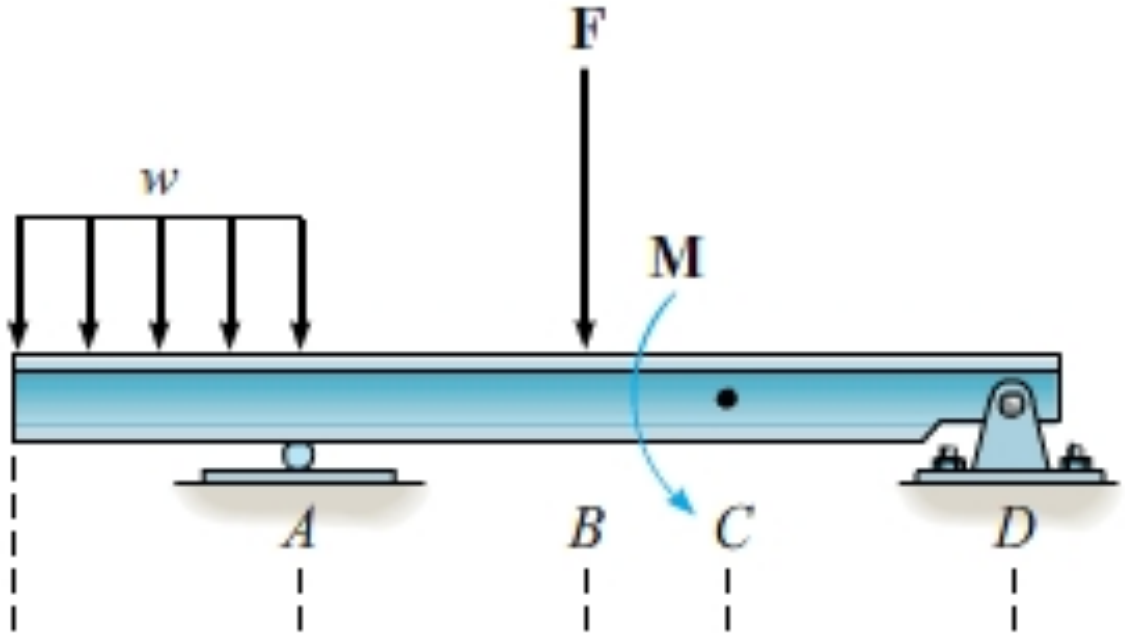
Rigid body can be considered as a combination of a large number of particles in which all particles remain at a fixed distance from each other.



Fundamental Concepts

Concentrated forces represent the effect of a loading which is assumed to act at a point on a body.





Administrative

- We do not use Mastering Engineering this summer.
- Tutorials will start next week on Tuesday 15th.

Fundamental Concepts

Newton's Three Laws of Motion

First law: a particle will remain at rest or moving in a straight line with a constant velocity if it is NOT acted upon by an unbalanced external force,

Second law: The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object. $\mathbf{F} = m\mathbf{a}$,

Third law: Forces of action and reaction between two particles are equal, opposite and collinear.

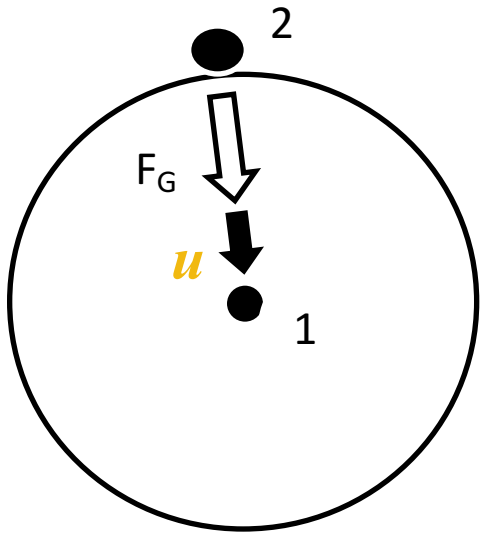
Netwon's three laws apply to particles, not rigid bodies.

Fundamental Concepts

Newton's Law of Attraction

A particle exerts a gravitational force on another particle that is proportional to the mass of each particle.

In ENGR 141, the Earth is one "particle" for which this attractive force significantly affects static and dynamic analyses of rigid bodies.



$$F_G = m_2\left(\frac{GM_1}{R_E^{\,2}}\right)\boldsymbol{u} = m_2\boldsymbol{g} \quad \Leftarrow \quad G = 66.73\times10^{-12}\ \frac{m^3}{kg\cdot s^2}$$

$$|\boldsymbol{g}| = 9.81\ \frac{\text{m}}{\text{s}^2} \qquad R_E \approx 6.37\times10^{6}\ \text{m}$$

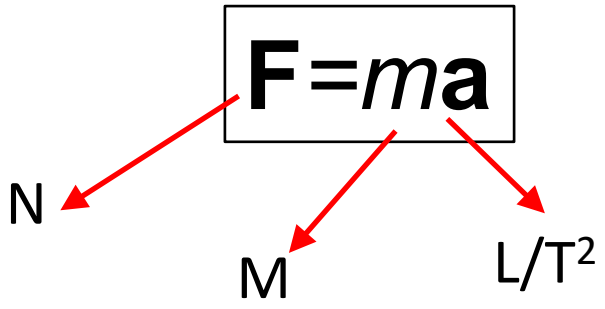
or

$$|\boldsymbol{g}| = 32.2\ \frac{\text{ft}}{\text{s}^2}$$

Fundamental Concepts

Newton's Law of Attraction

- Newton's Law of Gravitational Attraction is a special case of the Second Law.
- The Earth will cause a particle to accelerate at 9.81 m/s^2, independent of the mass of the particle.
- The force exerted by the Earth adheres to the Second Law.
- The Second Law relates the four physical quantities that govern mechanics.



Fundamental Concepts

SI ("International System") system of units:

Mass (kg), length (m), and time (s) are the independent quantities.

A unit of force, the "Newton" (N), is that required to create a unit acceleration (1 m/s^2) of a unit mass (1 kg).

FPS ("U.S. Customary") system of units:

Force (lbf), length (ft), time (s) are the independent quantities.

A unit of mass (the "slug") is the amount of mass that is accelerated at a unit amount (1 ft/s^2) when acted upon by a unit force (1 lbf).

A misleading term that is sometimes used is the "pound mass" (lbm).

Fundamental Concepts

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Work problems in the units given unless otherwise instructed!

TABLE 1–2 Conversion Factors

Quantity	Unit of Measurement (FPS)	Equals	Unit of Measurement (SI)
Force	lb		4.448 N
Mass	slug		14.59 kg
Length	ft		0.3048 m

Can you convert a force value of 47 lb into SI units?

Answer is 209.06 N

Fundamental Concepts

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Some rules

- No plurals (e.g., m = 5 kg, not kgs)
- Separate units with a • (e.g., meter second = m • s)
- Most symbols are in lowercase.
  - Key exceptions are N, Pa, M and G.
- Exponential powers apply to units, e.g., cm • cm = cm^2

Fundamental Concepts

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Prefixes

• We use prefixes when a numerical quantity is either very large or very small.

Example:

4000000 N = 4000 kN (kilo-newton) = 4 MN (mega-newton)

0.000001 m = 0.001 mm (milli-meter) = 1 μm (micro-meter)

Fundamental Concepts

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TABLE 1–3 Prefixes

	Exponential Form	Prefix	SI Symbol
Multiple			
1 000 000 000	10^9	giga	G
1 000 000	10^6	mega	M
1 000	10^3	kilo	k
Submultiple			
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n

Fundamental Concepts

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How to solve problems?

1. **Interpret:** Read carefully and determine what is given and what is to be found/ delivered. Ask, if not clear. If necessary, make assumptions and indicate them.

2. **Plan:** Think about major steps (or a road map) that you will take to solve a given problem. Think of alternative/creative solutions and choose the best one.

3. **Execute:** Carry out your steps. Use appropriate diagrams and equations. Estimate your answers. Avoid simple calculation mistakes. Reflect on and then revise your work, if necessary.

Example # 1

Convert 2 km/h to m/s and ft/s.

TABLE 1–2 Conversion Factors

Quantity	Unit of Measurement (FPS)	Equals	Unit of Measurement (SI)
Force	lb		4.448 N
Mass	slug		14.59 kg
Length	ft		0.3048 m

Example # 2

Convert the quantities 300 lb • s and 52 slugs/ft^3 to appropriate SI unites.

TABLE 1–2 Conversion Factors

Quantity	Unit of Measurement (FPS)	Equals	Unit of Measurement (SI)
Force	lb		4.448 N
Mass	slug		14.59 kg
Length	ft		0.3048 m

Example # 3

Evaluate each of the following and express with SI units having an appropriate prefix: (a) (50 mN)(6 GN), (b) (400 mm)(0.6 MN)^2, (c) 45 MN^3/900 Gg.

TABLE 1–3 Prefixes

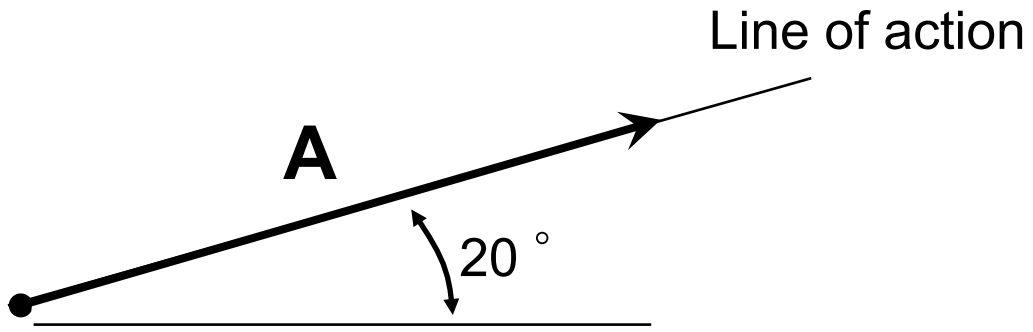
	Exponential Form	Prefix	SI Symbol
Multiple			
1 000 000 000	10^9	giga	G
1 000 000	10^6	mega	M
1 000	10^3	kilo	k
Submultiple			
0.001	10^{-3}	milli	m
0.000 001	10^{-6}	micro	μ
0.000 000 001	10^{-9}	nano	n

Force Vectors

University of Victoria

Scalars and Vectors

- A scalar is a quantity with positive or negative magnitude.
- A vector is a quantity with magnitude and direction.



Force Vectors

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	Scalars	***Vectors***
Examples:	Mass, Volume	Force, Velocity
Characteristics:	It has a magnitude (positive or negative)	It has a magnitude and direction

Force Vectors

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Vector operations

- Addition, subtraction and products.
- Vector operations must not only account for magnitudes of a vector but how each vector is oriented in space.
- All vector operations have a geometric interpretation but vector operations are not generally executed using geometric techniques (sine and cosine law).

Force Vectors

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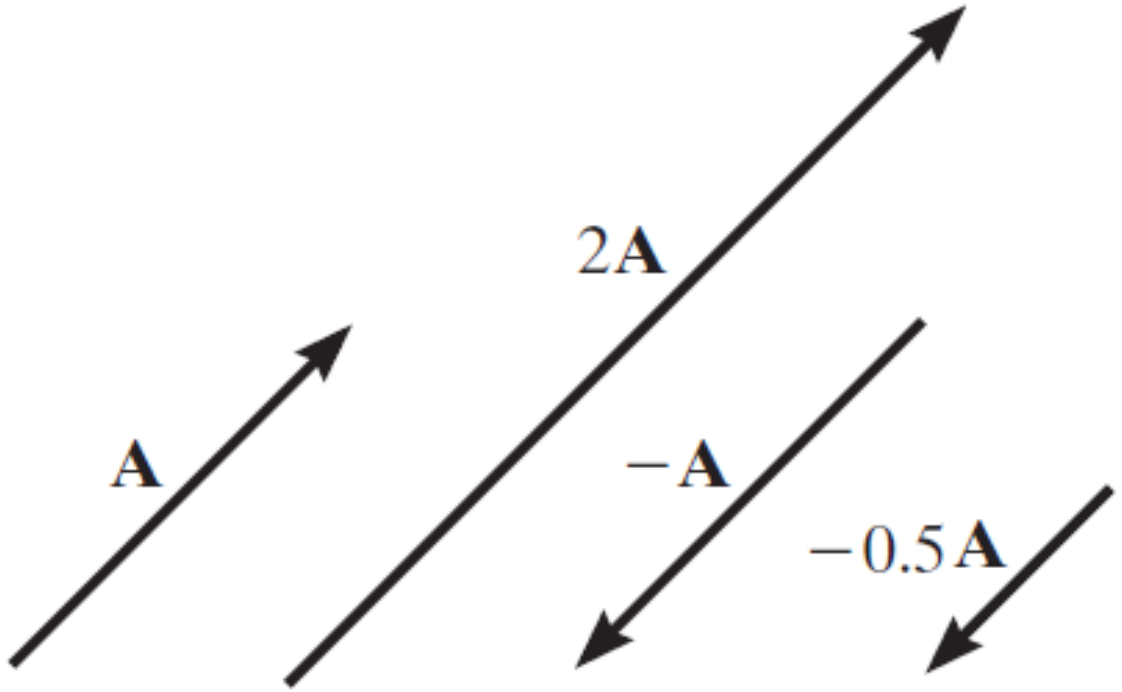
Scalar Multiplication

and Division



Force Vectors

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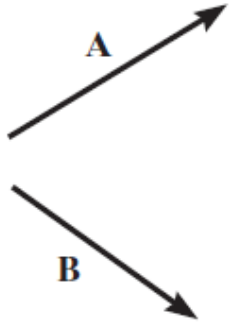
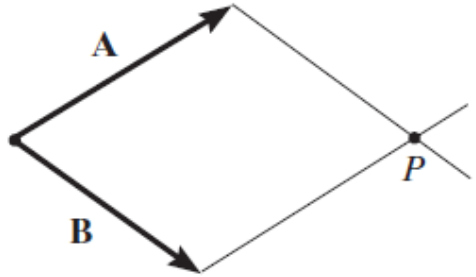
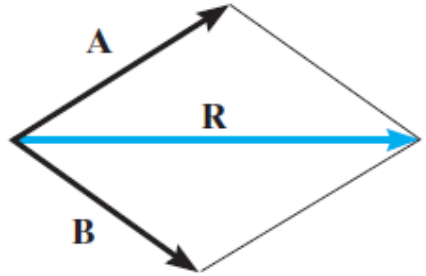
Parallelogram Law:



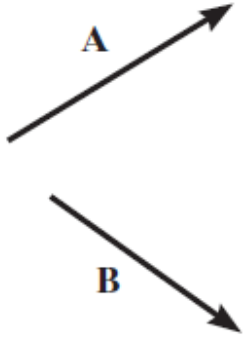


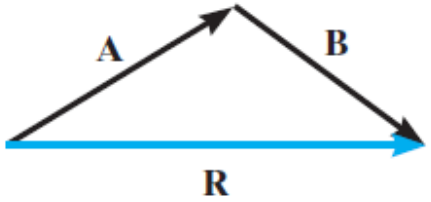


R = A + B

Parallelogram law

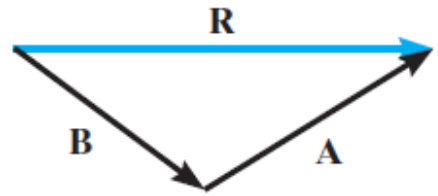
Triangle method (always 'tip to tail'):





R = A + B

Triangle rule



R = B + A

Triangle rule

How do you subtract a vector?

How can you add more than two collinear vectors graphically?

Force Vectors

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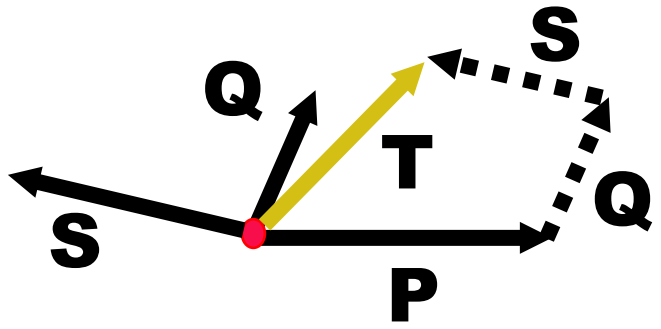
- The addition/subtraction of vectors is independent of magnitude calculations.
- **P** + **Q** = **R** but |P| + |Q| ≠ |R|
  - |R|=R is the magnitude of the vector **R**= $\vec{R}$ =$\underline{R}$
  - |R| is a scalar quantity.
- The sum of 3 or more vectors is simply the sequential application of the vector triangle - the VECTOR POLYGON!

$$\mathbf{P} + \mathbf{Q} + \mathbf{S} = (\mathbf{P} + \mathbf{Q}) + \mathbf{S} = \mathbf{R} + \mathbf{S} = \mathbf{T}$$



Force Vectors

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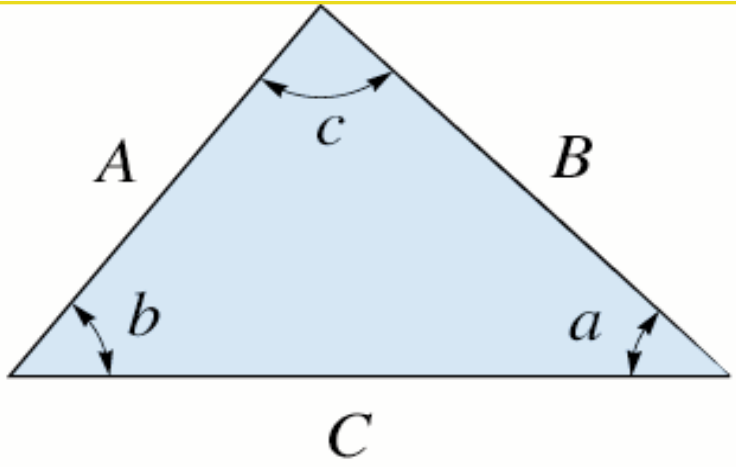
To perform vector operations using a geometric approach (That is by drawing the vector triangle) one can employ:

Sine Law:

Cosine Law:



Sine law:

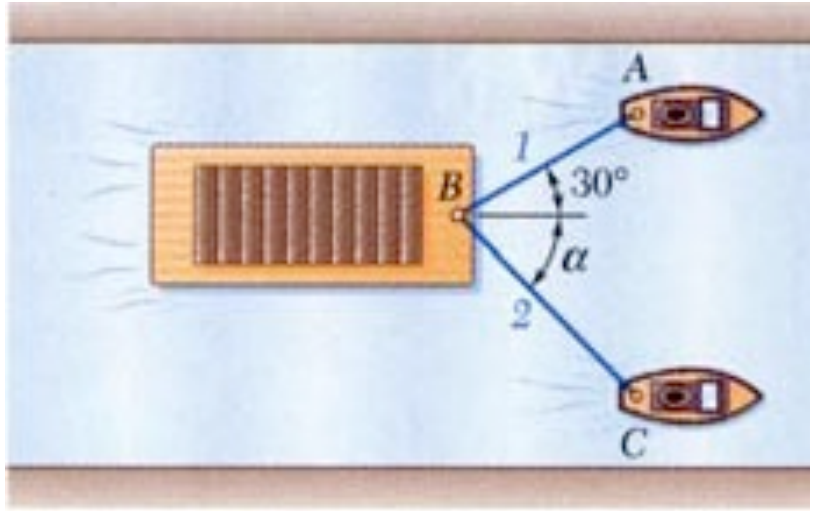
$$\frac{A}{\sin a} = \frac{B}{\sin b} = \frac{C}{\sin c}$$

Cosine law:

$$C = \sqrt{A^2 + B^2 - 2AB\cos c}$$

Example # 4

A barge is pulled by two tugboats. If the resultant of the forces exerted by the tugboats is 5000 lbf directed along the axis of the barge, determine the tension in each of the ropes for $\alpha = 45^{o}$.



Quiz: At what value of α would the tension in rope 2 be a minimum?