(Updated: 5/30/08)

MEEG 2003 Meeting #1

Prior Basic Mathematics and Fundamental Concepts

Check list:

1. Review the prior basic mathematics in App. B.

2. Solve and choose the correct answer to each of the 50 multiple-choice questions in App. A.

3. Define the following *key terms*:

- Scalar
- Vector
- Force
- Mechanics
- Statics
- Equilibrium
- Dynamics
- Kinematics
- Kinetics
- Particle
- Rigid body
- Continuum
- Concentrated force
- Dimension
- Unit
- Length
- Mass
- Time

4. Know and use the **scientific notation**, the **engineering notation**, and the **rounding rule**.

5. Know and use the following basic relations in converting units:

- 1 mi = 5280 ft
- 1 yd = 3 ft
- 1 ft = 12 in.
- 1 ft = 0.3048 m
- 1 d = 24 h
- 1 h = 60 min
- 1 min = 60 s
- π rad = 180°
- 1 ton = 2000 lb
- 1 kip = 1000 lb
- 1 lb = 16 oz
- 1 hp = 550 ft·lb/s

6. Know the following units:

- 1 Pa = 1 N/m^2
- 1 psi = 1 lb/in^2
- 1 lbm = 1 pound-mass
- 1 lb = 1 slug·ft/s^2 = 1 lbm (9.80665 m/s^2) ≈ 32.2 lbm·ft/s^2 ≠ 1 lbm

7. Solve problems involving conversion of units using the strategy of **chain-link conversions**, the given data, and the basic relations listed above.

MEEG 2003 Meeting #2

Fundamental Laws

Check list:

1. Describe the following **fundamental laws** and *key terms*:

- Newton's first law
- Newton's second law
- Newton's third law
- Newton's law of gravitation
- Parallelogram law
- Rigid-body principle
- Principle of transmissibility
- 1 kg
- 1 N
- 1 lbm
- 1 lb
- 1 slug

2. Know the *Standard gravitational acceleration* on earth

$$g = 9.806\ 65 \text{ m/s}^2$$

3. Use the approximate values

$$g = 9.81 \text{ m/s}^2 \qquad \text{or} \qquad g = 32.2 \text{ ft/s}^2$$

4. Distinguish *weight* (in N or lb) from *mass* (in kg or slug) in mechanics, and apply $W = mg$ as needed.

5. Solve problems using the strategy of **chain-link conversions**, the given data, and the basic relations in converting units (see page 12 of textbook).

MEEG 2003 Meeting #3

Addition & Resolution of Forces in 2D

Check list:

1. Review the basic relations in geometry in Sect. B2 (in App. B).
2. Review the following laws:
   - Parallelogram law and its extensions:
     - Triangle rule
     - Polygon rule
   - Law of sines
   - Law cosines
3. Define the following *key terms*:
   - Directional angle
   - Slope triangle
   - Zero vector
   - Parallel vectors
   - Couple
   - Unit vector
   - Scalar components
   - Vector components
   - Analytical expression of a vector
   - Magnitude of a vector
4. Add or resolve forces in a plane using the **parallelogram law** (the geometric method).
5. Add or resolve forces in a plane using **vector algebra** (the analytic method).

MEEG 2003 Meeting #4

Addition & Resolution of Forces in 3D

Check list:

1. Review the following *key terms*, which are used for **forces in space** as well as forces in a plane:

- Unit vectors
- Scalar components
- Vector components
- Magnitude of a vector
- Analytical expression of a vector

2. Define the following *key terms*:

- Direction angles
- Direction cosines
- Position vector

3. Determine the analytical expression of a vector in a specified direction using

$$\mathbf{F} = F\,\boldsymbol{\lambda}_F$$

$$\boldsymbol{\lambda}_{AB} = \frac{\overrightarrow{AB}}{\overline{AB}}$$

$$\mathbf{F}_{AB} = F_{AB}\,\boldsymbol{\lambda}_{AB}$$

4. Add or resolve forces in space using **vector algebra** (the analytic method).

MEEG 2003 Meeting #5

FBD & Equilibrium of Particles

Check list:

1. Define the following *key terms*:
- Inertial reference frame
- Concurrent force system
- Action of a body
- Reaction
- Internal force in a body
- External force to a body
- Space diagram
- Free-body diagram
- Equilibrium of a particle

2. Include the **free-body diagram** (FBD) as part of the solution for an equilibrium problem.

3. Show all **reactions** (i.e., external forces) exerted *on* (not *by*) the **isolated body** in the **FBD**.

4. Know the *necessary and sufficient condition* of **equilibrium of a particle**:

$$\Sigma \mathbf{F} = \mathbf{0}$$

5. For equilibrium of any particle *in a plane*, apply

$$\Sigma F_x = 0 \qquad \Sigma F_y = 0$$

6. Solve problems involving **equilibrium of particles in a plane** as assigned.

MEEG 2003 Meeting #6

Equilibrium of Particles in Space

Check list:

1. Review the following *key terms*:

- Action of a body
- Reaction
- Internal force in a body
- External force to a body
- Space diagram
- Free-body diagram
- Equilibrium of a particle

2. Show all forces acting *on* (not *by*) the isolated body in the **free-body diagram** as part of the solution for an equilibrium problem.

3. Recall the *necessary and sufficient condition* of **equilibrium of a particle**:

$$\Sigma \mathbf{F} = \mathbf{0}$$

4. For equilibrium of any particle *in space*, apply

$$\Sigma F_x = 0 \qquad \Sigma F_y = 0 \qquad \Sigma F_z = 0$$

5. Solve problems involving **equilibrium of particles in space** as assigned.

MEEG 2003 Meeting #7

Moments of Forces

Check list:

1. Define the following *key terms*:

- Moment of a force about an axis
  (*Special case: The force and the axis are perpendicular to each other.*)
- Moment arm
- Moment of a force about a point
- Moment center
- Right-hand rule for moment vectors
- Varignon's theorem
- Cross product: $\mathbf{P} \times \mathbf{Q}$
- Moment of a couple: torque, free vector
- Dot product: $\mathbf{P} \cdot \mathbf{Q}$

2. Compute **moment** of a force **F** about a **perpendicular axis** *AB* using

$$M_{AB} = d_s F$$

3. Compute **moment** of a force **F** about **a point** *Q* using

$$M_Q = d_s F \qquad \mathbf{M}_Q = \mathbf{r} \times \mathbf{F}$$

4. Compute **moment of a couple F** and –**F** using

$$M = d_s F \qquad \mathbf{M} = \mathbf{r} \times \mathbf{F}$$

where **r** is a vector drawn from *anywhere* on the line of action of –**F** to *anywhere* on the line of action of **F**.

5. Apply **cross product** and **dot product** to compute *areas* and *angles*.

MEEG 2003 Meeting #8

Moments of Forces
(Cont'd)

Check list:

1. Review the following *key terms*:

- Moment of a force about an axis
  *(**Special** case: The force and the axis are perpendicular to each other.)*
- Cross product: $\mathbf{P} \times \mathbf{Q}$
- Dot product: $\mathbf{P} \cdot \mathbf{Q}$

2. Define the following *key terms*:

- Scalar triple product: $\mathbf{A} \cdot (\mathbf{P} \times \mathbf{Q})$
- Moment of a force about an axis
  *(**General** case: The force and the axis are **not** perpendicular to each other.)*

3. Compute moment of a force about an axis in the *general* case using

$$M_{BC} = \boldsymbol{\lambda}_{BC} \cdot (\mathbf{r} \times \mathbf{F})$$

4. Compute the **shortest distance** d_s between the line of action of *a force* **F** and *a point Q* using

$$M_Q = d_s F$$

5. Compute the **shortest distance** d_s between the line of action of *a force* **F** and *an axis BC* using

$$\left| M_{BC} \right| = d_s F_{\perp} \qquad F_{\perp} = \left| \boldsymbol{\lambda}_{BC} \times \mathbf{F} \right|$$

MEEG 2003 Meeting #9

Review: Chaps. 1 $\rightarrow$ 3

Check list:

1. Review the *key terms* covered in Chaps. 1 $\rightarrow$ 4.

2. Review the laws, principles, and theorem covered in Chaps. 1 $\rightarrow$ 4:

- Newton's first law
- Newton's second law
- Newton's third law
- Newton's law of gravitation
- Parallelogram law and its extensions:
  - Triangle rule
  - Polygon rule
- Rigid-body principle
- Principle of transmissibility
- Varignon's theorem

3. Add or resolve forces using the **parallelogram law**.

4. Add or resolve forces using **vector algebra**.

5. Solve problems of **equilibrium of particles**.

6. Compute **moments** of forces and couples about *a point* or *an axis*.

7. Compute the **shortest distance** between the line of action of *a force* and *a point* or *an axis* using

$$M_Q = d_s F$$

$$\left| M_{BC} \right| = d_s F_\perp \qquad F_\perp = \left| \boldsymbol{\lambda}_{BC} \times \mathbf{F} \right|$$

MEEG 2003 Meeting #10

Test I (Covering Chaps. 1 $\rightarrow$ 3)

MEEG 2003 Meeting #11

Rigid-Body Equilibrium in a Plane

Check list:

1. Define the following *key terms*:

- Wrench
- Equipollent systems of forces
- Two-force body
- Statically indeterminate
- Partially constrained
- Equivalent systems of forces
- Equilibrium of a rigid-body
- Three-force body
- Degree of statical indeterminacy
- Improperly constrained

2. Identify the **reactions** exerted on a rigid body by the following types of supports and connections *in a plane*:

- Roller
- Smooth surface
- Cordlike element
- Collar on smooth rod
- Slider in smooth slot
- Hinge, pin, or pivot
- Rocker
- Rough surface
- Short link
- Pin in smooth slot
- Smooth corner
- Fixed support

3. Resolve a given force **F** at *A* into a **force-moment system** at another point *B*, consisting of $\mathbf{F}_B$ and $\mathbf{M}_B$, where

$$\mathbf{F}_B = \mathbf{F} \qquad \mathbf{M}_B = \overrightarrow{AB} \times \mathbf{F}$$

4. Solve problems involving **equivalent systems of forces** using

$$\mathbf{R} = \mathbf{R}' \qquad \mathbf{M}_P^R = (\mathbf{M}_P^R)'$$

5. Solve problems involving **equilibrium of simple rigid bodies** *in a plane* using

$$\Sigma F_x = 0 \qquad \Sigma F_y = 0 \qquad \Sigma M_P = 0$$

MEEG 2003 Meeting #12

Rigid-Body Equilibrium in Space

Check list:

1. Identify the **reactions** at the following types of supports and connections *in space*:

- Ball
- Cable
- Smooth surface
- Rough surface
- Narrow bearing
- Short link
- Ball and socket
- Universal joint
- Wide hinge
- Wide bearing
- Pin and bracket
- Eyebolt
- Smooth corner
- Fixed support
- Wide hinge with stop
- Wide bearing with stop
- Narrow bearing with stop
- Ball and socket on a slider

2. Solve the assigned problems involving **equilibrium of simple rigid bodies** *in space* using

$\Sigma \mathbf{F} = \mathbf{0}$**:**

$$\Sigma F_x = 0 \qquad \Sigma F_y = 0 \qquad \Sigma F_z = 0$$

$\Sigma \mathbf{M}_P = \mathbf{0}$**:**

$$\Sigma (M_P)_x = 0$$

$$\Sigma (M_P)_y = 0$$

$$\Sigma (M_P)_z = 0$$

MEEG 2003 Meeting #13

Centroids of Lines & Areas

Check list:

1. Define the following *key terms*:

- First moment of a quantity
- Geographic center
- Population center
- Centroid of a line
- Centroid of an area
- Center of gravity of a body

2. Describe the **principle of moments**:

Resultant = Sum of the *Components*

Moment of the *Resultant*
= Sum of the Moments of the *Components*

where the *moment* may be taken with respect to any point, axis, or plane, as appropriate.

3. Use it as a **formula** that the distance between the centroid of a *triangular area* and its base is equal to one third of the corresponding height; i.e.,

$$\bar{y} = \frac{h}{3}$$

4. Apply the **principle of moments** as a key to solving problems involving **centroids** of lines and areas, as well as **centers of gravity** of slender members and laminas.

MEEG 2003 Meeting #14

Distributed Loads & Volumes

Check list:

1. Define the following *key terms*:

- A load
- Distributed load on a beam
- Surface of revolution
- Body of revolution
- Centroid of a volume
- Center of mass

2. Describe **first theorem of Peppus-Guldinus**:

$$A = \theta \overline{y} L$$

3. Describe **second theorem of Peppus-Guldinus**:

$$V = \theta \overline{y} A$$

4. Review the **principle of moments**:

Resultant = Sum of the *Components*

Moment of the *Resultant*
= Sum of the Moments of the *Components*

where the *moment* may be taken with respect to any point, axis, or plane, as appropriate.

5. Apply the **principle of moments** as a key to solving problems involving **centroids** of volumes, as well as **centers of gravity** of bodies.

MEEG 2003 Meeting #15

Work, Displacement Center, & Virtual Work

Check list:

1. Define the following *key terms*:

- Displacement
  - Linear displacement
  - Angular displacement
- Work of a force
- Work of a couple
- Virtual displacement
- Displacement center
- Virtual work

2. Locate the **displacement center** of each member for a *given* virtual displacement of the system.

3. Compute components of linear virtual displacement in terms of angular virtual displacement using

$$\delta x_B = L_y\,\delta\theta \qquad \delta y_B = L_x\,\delta\theta$$

4. Describe the **principle of virtual work** in statics.

5. Apply the **principle of virtual work**, which uses

- Free-body diagram
- Virtual displacement diagram
- $\delta U = 0$

to solve equilibrium problems.

MEEG 2003 Meeting #16

Virtual Work Method

Check list:

1. Be prepared to use the **radian measure formula**

$$s = r\theta \qquad \text{or} \qquad \delta s = r\,\delta\theta$$

in computing first-order virtual displacements.

2. There are **three major steps** and **one strategy** in using the *virtual work method* to solve equilibrium problems. They are**:** †

Step 1: *Draw the free-body diagram* (FBD).
Step 2: *Draw the virtual-displacement diagram* (VDD) with a strategy.
Step 3: *Set to zero the total virtual work done* to find the unknown.

The **strategy** in step 2 is to give the free body a compatible virtual displacement in such a way that the *one* specified unknown, but *no other unknowns*, will be involved in the total virtual work done. That is it: three major steps and one strategy in the virtual work method!

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† In drawing the VDD, pay attention to the following:

- The virtual displacements drawn in the VDD are compatible virtual displacements, which are to be accurate only to the *first-order differential*.
- *Each member* in the system has its own **displacement center** and its own angular virtual displacement in the VDD.
- The end points of a member and the displacement center of this member form a rigid triangular plate. This plate rotates about the displacement center through an angular virtual displacement, and any side of the plate or any line drawn on the plate will undergo the *same* angular displacement.
- It is well to clearly indicate in the VDD the virtual displacements needed in computing the total virtual work done by the force system.

MEEG 2003 Meeting #17

Virtual Work (cont'd)

Check list:

1. Be prepared to use the **radian measure formula**

$$s = r\theta \qquad \text{or} \qquad \delta s = r\,\delta\theta$$

in computing first-order virtual displacements.

2. There are **three major steps** and **one strategy** in using the *virtual work method* to solve equilibrium problems. They are**:** †

Step 1: *Draw the free-body diagram* (FBD).
Step 2: *Draw the virtual-displacement diagram* (VDD) with a strategy.
Step 3: *Set to zero the total virtual work done* to find the unknown.

The **strategy** in step 2 is to give the free body a compatible virtual displacement in such a way that the *one* specified unknown, but *no other unknowns*, will be involved in the total virtual work done. That is it: three major steps and one strategy in the virtual work method!

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† In drawing the VDD, pay attention to the following:

- The virtual displacements drawn in the VDD are compatible virtual displacements, which are to be accurate only to the *first-order differential*.
- *Each member* in the system has its own **displacement center** and its own angular virtual displacement in the VDD.
- The end points of a member and the displacement center of this member form a rigid triangular plate. This plate rotates about the displacement center through an angular virtual displacement, and any side of the plate or any line drawn on the plate will undergo the *same* angular displacement.
- It is well to clearly indicate in the VDD the virtual displacements needed in computing the total virtual work done by the force system.

MEEG 2003 Meeting #18

Review: Chaps. 5, 6, & 10

Check list:

1. Review the *key terms* covered in Chaps. 5, 6, & 10.

2. Review the following principles and theorems:

- Principle of moments
- First theorem of Peppus-Guldinus
- Second theorem of Peppus-Guldinus
- Principle of virtual work

3. Solve problems involving **equilibrium of rigid bodies** using, as appropriate,

$\Sigma \mathbf{F} = \mathbf{0}$**:**

$$\Sigma F_x = 0 \qquad \Sigma F_y = 0 \qquad \Sigma F_z = 0$$

$\Sigma \mathbf{M}_P = \mathbf{0}$**:**

$$\Sigma\,(M_P)_x = 0 \qquad \Sigma\,(M_P)_y = 0 \qquad \Sigma\,(M_P)_z = 0$$

4. Apply the **principle of moments** as a key to solving problems involving **centroids** as well as **centers of gravity**.

5. Apply the **virtual work method**, which involves

- ❑ drawing the free-body diagram (FBD)
- ❑ drawing the virtual displacement diagram (VDD)
- ❑ setting $\delta U = 0$

in solving equilibrium problems.

MEEG 2003 Meeting #19

Test II (Covering Chaps. 5, 6, & 10)

MEEG 2003 Meeting #20

Area Moments of Inertia

Check list:

1. Define the following *key terms*:

- Second moment of a quantity
- Area moment of inertia
- Polar moment of inertia
- Radius of gyration
- Product of inertia

2. **Centroidal moments of inertia** of a rectangular area of base b and height h:

$$I = \frac{1}{12} b h^3$$

3. Determine the **area moments of inertia** by integration.

4. Determine the **radius of gyration**.

5. Describe the **parallel-axis theorem**:

$$I = \bar{I} + A d^2$$

or

$$I_x = \bar{I}_{x'} + A \bar{y}^2$$

$$I_y = \bar{I}_{y'} + A \bar{x}^2$$

$$J_O = \bar{J}_C + A \bar{r}^2$$

6. Solve problems involving **area moments of inertia** and the parallel-axis theorem.

MEEG 2003 Meeting #21

Moments of Inertia of Composites Areas

Check list:

1. Review the following *key terms*:

- Area moment of inertia
- Polar moment of inertia
- Radius of gyration

2. Review the **parallel-axis theorem**:

$$I = \bar{I} + A\,d^2$$

or

$$I_x = \bar{I}_{x'} + A\,\bar{y}^2$$

$$I_y = \bar{I}_{y'} + A\bar{x}^2$$

$$J_O = \bar{J}_C + A\bar{r}^2$$

3. Be able to look up from a table the pertinent properties of certain **rolled-steel structural sections** (e.g., W shapes, S shapes, C shapes, and L shapes).

4. Solve problems involving *area moments of inertia* and *radius of gyration* of **composite areas**.

MEEG 2003 Meeting #22

Trusses: Method of Joints

Checklist:

1. Define the following *key terms*:
   - Structure
   - Truss
   - Pin-connected truss
   - Rigid truss
   - Compound truss
   - Tensile member
   - Joint
   - Rigidly connected truss
   - Idealized truss
   - Simple truss
   - Complex truss
   - Compressive member

2. Identify **zero-force members** at T and V joints, if any.

3. Determine the forces in truss members using the **method of joints**.

4. Determine the forces in truss members using the **method of sections**.

5. Determine the forces in a truss containing X joints, where the forces are applied to joints other than the X joints.

6. Determine the forces in truss members using a **computer software package**; e.g., *WINTRUSS*.

MEEG 2003 Meeting #23

Trusses: Method of Sections

Checklist:

1. Define the following *key terms*:
   - Structure
   - Joint
   - Truss
   - Rigidly connected truss
   - Pin-connected truss
   - Idealized truss
   - Rigid truss
   - Simple truss
   - Compound truss
   - Complex truss
   - Tensile member
   - Compressive member
2. Identify **zero-force members** at T joints, if any.
3. Identify **zero-force members** at V joints, if any.
4. Determine the forces in truss members using the **method of joints**.
5. Determine the forces in truss members using the **method of sections**.
6. Determine the forces in a truss containing X joints, where the forces are applied to joints other than the X joints.
7. Determine the forces in truss members using a **computer software package**; e.g., *WINTRUSS*.

MEEG 2003 Meeting #24

Frames & Machines

Checklist:

1. Review the following *key terms* and fundamental law:

- Two-force body
- Free-body diagram
- Newton's third law

2. Define the following *key terms*:

- Multiforce member
- Frame
- Machine

3. Adopt the graphical notations: (*a*) a *dot* to represent a **pin**, (*b*) a *hole* to represent a **pinhole**.

4. Determine the forces in a **frame** using

- Free-body diagrams
- Newton's third law
- Equations of equilibrium

5. Determine the forces in a **machine** using

- Free-body diagrams
- Newton's third law
- Equations of equilibrium

MEEG 2003 Meeting #25

Frames & Machines (cont'd)

Checklist:

1. Review the following *key terms* and fundamental law:

- Two-force body
- Multiforce member
- Frame
- Machine
- Free-body diagram
- Newton's third law

2. Recall the graphical notations: (*a*) a *dot* to represent a **pin**, (*b*) a *hole* to represent a **pinhole**.

3. Determine the forces in a **frame** using

- Free-body diagrams
- Newton's third law
- Equations of equilibrium

4. Determine the forces in a **machine** using

- Free-body diagrams
- Newton's third law
- Equations of equilibrium

MEEG 2003 Meeting #26

Friction between Rigid Bodies

Checklist:

1. Define the following *key terms*:

- Friction
- Full film lubrication
- Boundary lubrication
- Dry friction
- Coulomb friction
- Friction force
- Coefficient of static friction
- Coefficient of kinetic friction
- Angle of static friction
- Angle of kinetic friction

2. Give a brief summary of the **laws of dry friction**; i.e.,

$$F \leq F_m$$

$$F_m = \mu_s N$$

$$F_k = \mu_k N$$

$$\mu_s > \mu_k$$

3. Solve problems involving *friction between rigid bodies*.

MEEG 2003 Meeting #27

Belt Friction

Checklist:

1. Review the following *key terms*:

- Friction
- Dry friction
- Coulomb friction
- Friction force
- Coefficient of static friction
- Coefficient of kinetic friction
- Angle of static friction
- Angle of kinetic friction

2. Review the laws of dry friction; i.e.,

$$F \leq F_m \qquad F_m = \mu_s N$$

$$F_k = \mu_k N \qquad \mu_s > \mu$$

3. Apply, as appropriate, the flat-belt friction formulas:

$$T_2 = T_1 e^{\mu_s \beta} \qquad T_2 = T_1 e^{\mu_k \beta}$$

4. Apply, as appropriate, the V-belt friction formulas:

$$T_2 = T_1 e^{\mu_s \beta / \sin(\alpha/2)} \qquad T_2 = T_1 e^{\mu_k \beta / \sin(\alpha/2)}$$

MEEG 2003 Meeting #28

Review: Chaps. 7, 8, & 9

Checklist:

1. Review the *key terms* covered in Chaps. 7, 8, & 9.

2. Review the **parallel-axis theorem** for moments of inertia:

$$I = \overline{I} + Ad^2$$

3. Determine the **moments of inertia** and **radius of gyration** of an area about an axis.

4. Determine the forces in truss members using (*a*) the **method of joints**, (*b*) the **method of sections**.

5. Determine the forces in frames and machines using

- Free-body diagrams
- Newton's third law
- Equations of equilibrium

6. Solve problems involving **friction between rigid bodies** using, as appropriate,

$$F \leq F_m \qquad F_m = \mu_s N \qquad F_k = \mu_k N$$

7. Solve problems involving **belt friction** using, as appropriate,

$$T_2 = T_1 e^{\mu_s \beta} \qquad T_2 = T_1 e^{\mu_k \beta}$$

$$T_2 = T_1 e^{\mu_s \beta / \sin(\alpha/2)} \qquad T_2 = T_1 e^{\mu_k \beta / \sin(\alpha/2)}$$

MEEG 2003 Meeting #29

Test III (Covering Chaps. 7 → 9)

MEEG 2003 Meeting #30

General Review

MEEG 2003 Meeting #31

Final Exam