MAE 3405-001, Flight Dynamics
Fall 2014

Instructor(s): Baxter R. Mullins, Jr., Ph.D., P.E.

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GTA: TBD

GTA Office Number: TBD

GTA Office Hours: TBD

Section Information: MAE 3405-001

Time and Place of Class Meetings: General Academic Classroom Building (GACB) #105
MoWe 4:00-5:50 PM

Emergency Exits: Do not use elevators. Straight out the door and nearest exit.

Description of Course Content: MAE 3405 FLIGHT DYNAMICS (4-0) Derivation of equation of motion (EOM) of a flight vehicle. Trimmed flight condition analysis based on the nonlinear EOM. Linearization of EOM for a given trimmed flight condition. State-space and transfer-function representations of the linear EOM. Aircraft stability and dynamic performance analysis based on the linear EOM.

Student Learning Outcomes: With the successful completion of this course, the student shall have basic understanding of how to develop models for aerospace vehicles, the short falls of such models, and basic understanding of analysis techniques commonly used.

Reference Textbook and Other Course Materials:

- Mechanics of Flight – 2nd Edition by Warren F. Phillips, John Wiley & Sons, Inc. 2010, ISBN 978-0-470-53975-0
- Software: MATLAB Student Edition by Mathworks Inc.

References:

- McRuer, D., Ashkenas, I., and Graham, D., "***Aircraft Dynamics and Automatic Control***," Princeton University Press, 1990, ISBN 069102024405
- Cook, Michael V., "***Flight Dynamics Principals: A Linear Systems Approach To Aircraft Stability And Control, 3rd ed.***," Elsevier, Waltham, MA, 2013.
- Bretscher, Otto, "***Linear Algebra with Application, 5th ed.***," Pearson, Boston, 2013.

- Hibbeler, R.C., "***Engineering Mechanics: Statics and Dynamics, 13th ed***.," Pearson, Boston,2013.
- Roskam, J., "***Airplane Flight Dynamics and Automatic Flight Controls, Part 1 & 2***," DarCorp; 6th ed. (2011), ISBN 1884885179
- Anon, "***USAF Stability and Control DATCOM (DATa COMpendium)***," ADB072483 is a downloadable pdf file – called the "Yellow Books" - over 3,000 pages (Public Domain)
- MIL-F-8785C, MILITARY SPECIFICATION: FLYING QUALITIES OF PILOTED AIRPLANES (05 NOV 1980)
- Federal Aviation Regulation: Part 23 & Part 25
- MIL-C-005011B (USAF)
- AS-5263 (USNAVY)

Descriptions of major assignments and examinations:

Exams:

- Mid Term (2-hr)
- Comprehensive Final Exam (2½-hr)
- Unannounced quizzes

Project(s):

- Individual project(s) may be assigned. Assigned projects may vary from student-to-student but be of equivalent status.

Homework:

- Homework will be assigned on a class-by-class basis
- Assigned homework is due one week from the assigned date at the beginning of the class
- Use Engineering Paper for assigned homework problems – See example
- Each problem will start on a new page
- Late homework is accepted only with approval of the instructor and will incur a 10% penalty
- All homework handed in for grade shall include a statement of the problem, a free body diagram (as appropriate), and an organized solution to the problem.

Other Requirements:

- Modeling software such as MATLAB® and SIMULNK® will be useful in working some homework problems and the project. Student version is available at the UTA Bookstore. Freeware SciLab® is an acceptable substitute and is available for download.

Attendance: Students taking this course are expected to attend every class, to **arrive on time**, and to stay in class until they are dismissed. Students who fail to adhere to the attendance policy can expect an impact on their grade. Students will not be penalized in the case of an emergency, or an incident beyond the student's control.

Other Requirements: Prerequisite: MAE 3306 (or concurrent enrollment), C or better in MATH 3330.

Grading:

- Final Grade Weighting:

Homework and Pop Quizzes	20%
Mid Term	25%
Project(s):	25%
Final Examination (Comprehensive)	30%

- Grade Allocation: Course grades will be assigned

  A (90-100), B (80-89), C (70-79), D (60-69), F (less than 60)

  In order to receive a passing grade, the weighted average of the scheduled exams, homework, Pop Quizzes, and the final examination must be 60 or above.

  Students are expected to keep track of their performance throughout the semester and seek guidance from available sources (including the instructor) if their performance drops below satisfactory levels.

Homework Policy:

- Assigned homework is due at the beginning of the following class meeting.
- Use Engineering Paper for assigned homework problems.
- One problem per page.
- Late homework is accepted only with approval of the instructor.
- All homework handed in for grade will include a statement of the problem, a free body diagram of the mechanism (as appropriate), and an organized solution to the problem.

Exam Policy:

- Midterm (two-hour exam) and a Comprehensive Final (two and one-half hour exam) are planned for the course. Unannounced Pop Quizzes will also be given.
- All problems stated in the exams will be weighted equally unless otherwise specified.
- There will be **NO** make-up exams for unexcused absences.
- Missed exams will receive a grade of zero unless the student has an excused absence.
- A student having an **UNEXCUSED** absence from the final exam will receive the course grade earned. A student having an **EXCUSED** absence from the final exam has two options:
  a. The student may elect to receive the course grade earned with the final exam grade equal to zero, or
  b. The student may elect to receive the grade of "I" (incomplete) and make arrangements to complete the course by taking the final examination at the end of the next semester.

  If the student chooses the second option, it is the student's responsibility to consult with the instructor regarding completion of the course requirements.

NOTE: Excuses for absences from the final exam must be in writing with appropriate verification; e.g., note from your doctor, dentist, etc.

Expectations for Out-of-Class Study: Beyond the time required to attend each class meeting, students enrolled MAE 3405, a 4-credit hour course, should expect to spend at least an additional 12 hours per week of their own time in course-related activities, including reading required materials, completing assignments, preparing for exams, etc. (The general rule of thumb is for every credit hour earned, a student should expect to spend 3-hours per week working outside of class.)

Grade Grievances: Any appeal of a grade in this course must follow the procedures and deadlines for grade-related grievances as published in the current undergraduate catalog.

Drop Policy: Students may drop or swap (adding and dropping a class concurrently) classes through self-service in MyMav from the beginning of the registration period through the late registration period. After the late registration period, students must see their academic advisor to drop a class or withdraw. Undeclared students must see an advisor in the University Advising Center. Drops can continue through a point two-thirds of the way through the term or session. It is the student's responsibility to officially withdraw if they do not plan to attend after registering. **Students will not be automatically dropped for non-attendance**. Repayment of certain types of financial aid administered through the University may be required as the result of dropping classes or withdrawing. For more information, contact the Office of Financial Aid and Scholarships (http://wweb.uta.edu/ses/fao).

Americans with Disabilities Act: The University of Texas at Arlington is on record as being committed to both the spirit and letter of all federal equal opportunity legislation, including the *Americans with Disabilities Act (ADA)*. All instructors at UT Arlington are required by law to provide "reasonable accommodations" to students with disabilities, so as not to discriminate on the basis of that disability. Any student requiring an accommodation for this course must provide the instructor with official documentation in the form of a letter certified by the staff in the Office for Students with Disabilities, University Hall 102. Only those students who have officially documented a need for an accommodation will have their request honored. Information regarding diagnostic criteria and policies for obtaining disability-based academic accommodations can be found at www.uta.edu/disability or by calling the Office for Students with Disabilities at (817) 272-3364.

Academic Integrity: All students enrolled in this course are expected to adhere to the UT Arlington Honor Code:

> *I pledge, on my honor, to uphold UT Arlington's tradition of academic integrity, a tradition that values hard work and honest effort in the pursuit of academic excellence.*
>
> *I promise that I will submit only work that I personally create or contribute to group collaborations, and I will appropriately reference any work from other sources. I will follow the highest standards of integrity and uphold the spirit of the Honor Code.*

Instructors may employ the Honor Code as they see fit in their courses, including (but not limited to) having students acknowledge the honor code as part of an examination or requiring students to incorporate the honor code into any work submitted. Per UT System *Regents' Rule* 50101, §2.2,

suspected violations of university's standards for academic integrity (including the Honor Code) will be referred to the Office of Student Conduct. Violators will be disciplined in accordance with University policy, which may result in the student's suspension or expulsion from the University.

Student Support Services: UT Arlington provides a variety of resources and programs designed to help students develop academic skills, deal with personal situations, and better understand concepts and information related to their courses. Resources include tutoring, major-based learning centers, developmental education, advising and mentoring, personal counseling, and federally funded programs. For individualized referrals, students may visit the reception desk at University College (Ransom Hall), call the Maverick Resource Hotline at 817-272-6107, send a message to resources@uta.edu, or view the information at www.uta.edu/resources.

Electronic Communication: UT Arlington has adopted MavMail as its official means to communicate with students about important deadlines and events, as well as to transact university-related business regarding financial aid, tuition, grades, graduation, etc. All students are assigned a MavMail account and are responsible for checking the inbox regularly. There is no additional charge to students for using this account, which remains active even after graduation. Information about activating and using MavMail is available at http://www.uta.edu/oit/cs/email/mavmail.php.

Student Feedback Survey: At the end of each term, students enrolled in classes categorized as lecture, seminar, or laboratory shall be directed to complete a Student Feedback Survey (SFS). Instructions on how to access the SFS for this course will be sent directly to each student through MavMail approximately 10 days before the end of the term. Each student's feedback enters the SFS database anonymously and is aggregated with that of other students enrolled in the course. UT Arlington's effort to solicit, gather, tabulate, and publish student feedback is required by state law; students are strongly urged to participate. For more information, visit http://www.uta.edu/sfs.

Final Review Week: A period of five class days prior to the first day of final examinations in the long sessions shall be designated as Final Review Week. The purpose of this week is to allow students sufficient time to prepare for final examinations. During this week, there shall be no scheduled activities such as required field trips or performances; and no instructor shall assign any themes, research problems or exercises of similar scope that have a completion date during or following this week *unless specified in the class syllabus*. During Final Review Week, an instructor shall not give any examinations constituting 10% or more of the final grade, except makeup tests and laboratory examinations. In addition, no instructor shall give any portion of the final examination during Final Review Week. During this week, classes are held as scheduled. In addition, instructors are not required to limit content to topics that have been previously covered; they may introduce new concepts as appropriate.

Course Schedule

Spring Term - Regular Session, 2014 (16 meeting weeks: 15 instructional weeks + 1 final exam week)

First day of classes:	August 21, 2014
Labor Day Holiday:	September 1, 2014
Census Date:	September 8, 2014

Last day to drop classes:	October 29, 2014
Thanksgiving Holidays	November 27-28, 2014
Last day of classes:	December 3, 2014
Final Exam	December 10, 2014 (Wednesday) 2:00 PM – 4:30 PM

In your course schedule, be sure to indicate (to the extent possible) dates for all major work to be completed. (The definition of "major" is left to the discretion of each instructor.)

"As the instructor for this course, I reserve the right to adjust this schedule in any way that serves the educational needs of the students enrolled in this course. – Baxter R. Mullins, Jr."

Topics covered:

- Review
  - Subject of Flight Mechanics
  - Static Stability and Control
  - Flying Qualities and the Human Pilot
  - Axes and Notation
- General Equations of Motion
  - Rules and Assumptions
  - Kinematic Equations
  - Rigid-body Equations of Motion
  - Evaluation of Angular Momentum
  - Elastic Degrees of Freedom
  - Effect of Spinning Rotors
- Stability Derivatives
  - Longitudinal Derivatives
  - Lateral Derivatives
- Stability of Controls-Fixed Motion
  - Longitudinal Stick-Fixed
  - Lateral Stick-Fixed
- Stability of Controls-Free Motion
  - Longitudinal Controls-Free Motion
  - Lateral Controls-Free Motion
- Mathematical Tools
  - Small-Disturbance Theory
  - Linear System Theory
  - Laplace Transforms
  - Block Diagram Algebra
  - State-Space Formulation
- Actuation of Controls (Open Loop)
- Closed-Loop Control (Introduction to Feedback Control)
- Every day "Rules of Thumb"

MAE 4305.001 FLIGHT DYNAMICS								
						MW 4:00 PM - 5:50 PM	GACB105	8/18/2014
WEEK	DATE		CLASS		ASSIGNMENTS			
					READING			Notes
#1								
#2	M	08/25/14	#	1	CHAP #7	Sect. 7.1 - 7.3	pp. 715 - 740	
	W	08/27/14	#	2	CHAP #7	Sect. 7.3 - 7.5	pp. 740 - 766	
#3	M	09/01/14				Labor Day Holiday		
	W	09/03/14	#	3	CHAP #7	Sect. 7.5 - 7.7	pp. 766 - 791	
#4	M	09/08/14	#	4	CHAP #7	Sect. 7.7 -7.9	pp. 791 - 806	
	W	09/10/14	#	5	CHAP #4	Sect. 4.1 - 4.3	pp. 377 - 400	
#5	M	09/15/14	#	6	CHAP #4	Sect. 4.4 - 4.6	pp. 401 - 427	
	W	09/17/14	#	7	CHAP #4	Sect. 4.4 - 4.7	pp. 427 - 458	
#6	M	09/22/14	#	8	CHAP #4	Sect. 4.8 - 4.11	pp. 458 - 486	
	W	09/24/14	#	9	CHAP #8	Sect. 8.1 - 8.2	pp. 813 - 838	
#7	M	09/29/14	#	10	CHAP #8	Sect. 8.2 - 8.4	pp. 838 - 864	
	W	10/01/14	#	11	CHAP #8	Sect. 8.4 - 8.6	pp. 864 - 877	
#8	M	10/06/14	#	12	CHAP #5	Sect. 5.1 - 5.3	pp. 497 - 522	
	W	10/08/14	#	13		Mid Term Exam		
#9	M	10/13/14	#	14	CHAP # 5	Sect. 5.3 - 5.5	pp. 523 - 547	
	W	10/15/14	#	15	CHAP #5	Sect. 5.5 - 5.7	pp. 547 - 574	
#10	M	10/20/14	#	16	CHAP #5	Sect. 5.8 - 5.12	pp. 575 - 597	
	W	10/22/14	#	17	CHAP #9	Sect. 9.1 - 9.5	pp. 885 - 910	
#11	M	10/27/14	#	18	CHAP #9	Sect. 9.5 - 9.8	pp. 910 - 936	
	W	10/29/14	#	19	CHAP #9	Sect. 9.8 -9.10	pp. 936 - 945	
#12	M	11/03/14	#	20	CHAP #10	Sect. 10.1 - 10.5	pp. 953 - 987	
	W	11/05/14	#	21	CHAP #6	Sect. 6.1 - 6.2	pp. 605 - 630	
#13	M	11/10/14	#	22	CHAP #6	Sect. 6.2 - 6.5	pp. 630 - 656	
	W	11/12/14	#	23	CHAP #6	Sect. 6.5 - 6.8	pp. 656 - 682	
#14	M	11/17/14	#	24	CHAP #6	Sect. 6.9 - 6.10	pp. 682 - 706	
	W	11/19/14	#	25	CHAP #11	Sect. 11.1 - 11.7	pp. 989 - 1012	
#15	M	11/24/14	#	26	CHAP #11	Sect. 11.8 - 11.10	pp. 1012 - 1036	
	W	11/26/14				Thanksgiving Holiday		
#16	M	12/01/14	#	27	CHAP #11	Sect. 11.11 - 11.12	pp. 1037 - 1063	
	W	12/03/14	#	28		REVIEW		
#17	W	12/10/14				FINAL	2:00 PM - 4:30 PM	

Homework Requirement

Page No. # / ##

Last Name, First Name (No Student Numbers)

Course Number

Date

Problem Statement

Problem "Givens"

Problem Requirements

Solution

Show all equations and work

Free Body Diagram

Last Name, First Name MAE 1312.001 STATICS MM/DD/YYYY 1/2

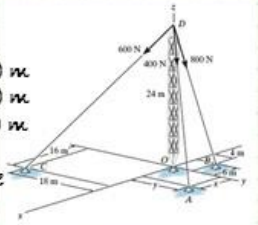
Problem 2-94. The tower is held by three cables. If the force of each cable acting on the tower is shown, determine the magnitude and coordinates direction angles α, β, γ of the resultant force. Take $x = 20$ m, $y = 15$ m.

Given:

$F_{DA} = 400\text{N}$ $\bar{L}_{DA} = (20\,i + 15\,j - 24\,k)$ m

$F_{DB} = 800\text{N}$ $\bar{L}_{DB} = (-6\,i + 4\,j - 24\,k)$ m

$F_{DC} = 600\text{N}$ $\bar{L}_{DC} = (16\,i - 18\,j - 24\,k)$ m



Find:

Resultant force magnitude and coordinate direction cosines.

Solution:

$\bar{F}_R = \bar{F}_{DA} + \bar{F}_{DB} + \bar{F}_{DC}$ (Resultant force is the vector sum of all the forces acting on the tower.)

Find the lengths of each wire.

$l_{DA} = |\bar{L}_{DA}| = \sqrt{(\bar{L}_{DA} \cdot \bar{L}_{DA})} = \sqrt{20x20+15x15+(-24)x(-24)} = 34.66$ m

$l_{DB} = |\bar{L}_{DB}| = \sqrt{(\bar{L}_{DB} \cdot \bar{L}_{DB})} = \sqrt{(-6)x(-6)+4x4+(-24)x(-24)} = 25.06$ m

$l_{DC} = |\bar{L}_{DC}| = \sqrt{(\bar{L}_{DC} \cdot \bar{L}_{DC})} = \sqrt{16x16+(-18)x(-18)+(-24)x(-24)} = 34$m

Determine the direction cosines for each force

$$\hat{\ell}_{DA} = \frac{\bar{L}_{DA}}{|\bar{L}_{DA}|} = \frac{20}{34.66}\hat{i} + \frac{15}{34.66}\hat{j} - \frac{24}{34.66}\hat{k}$$

$$\hat{\ell}_{DB} = \frac{\bar{L}_{DB}}{|\bar{L}_{DB}|} = \frac{-6}{25.06}\hat{i} + \frac{4}{25.06}\hat{j} - \frac{24}{25.06}\hat{k}$$

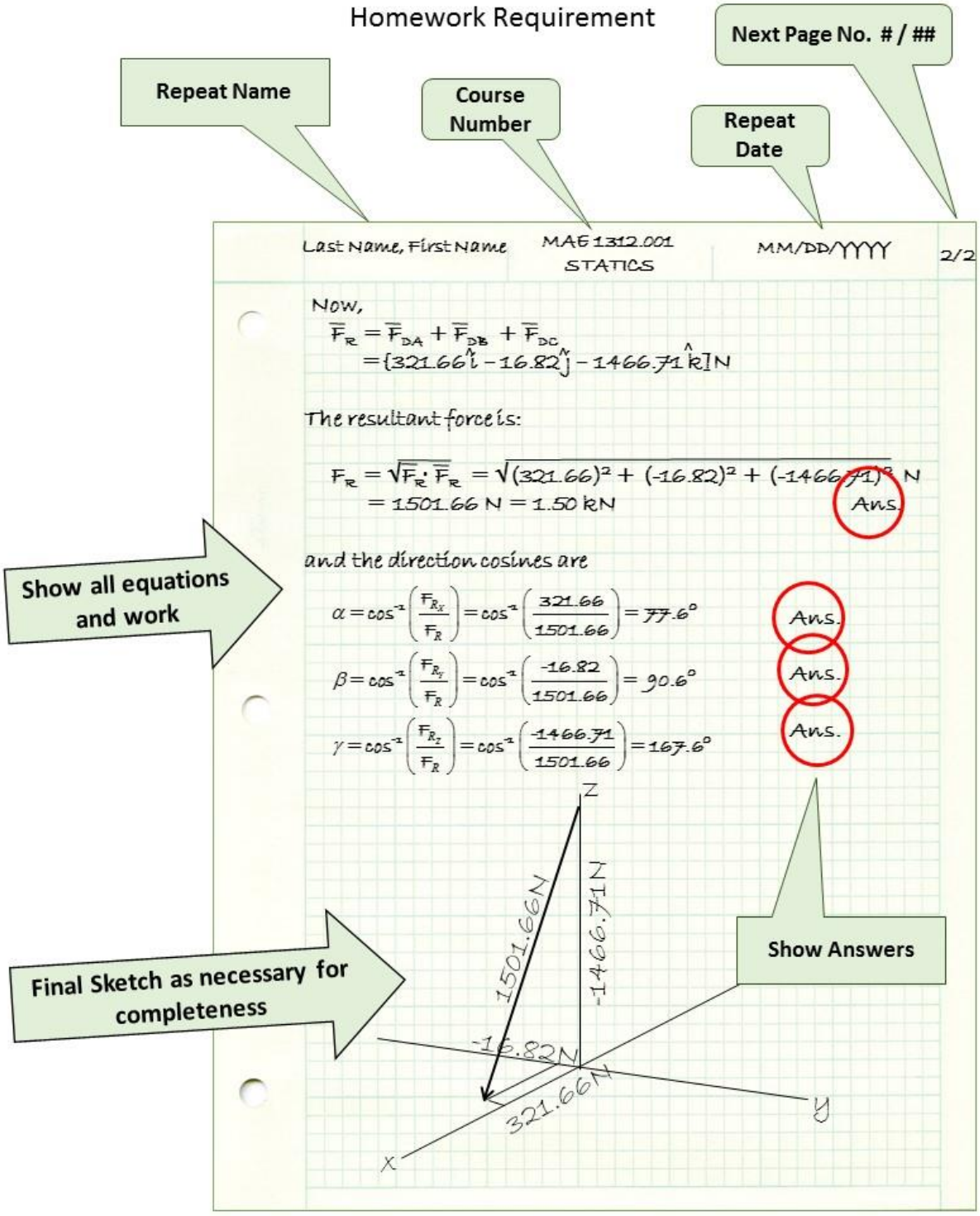
$$\hat{\ell}_{DC} = \frac{\bar{L}_{DC}}{|\bar{L}_{DC}|} = \frac{16}{34}\hat{i} - \frac{18}{34}\hat{j} - \frac{24}{34}\hat{k}$$

Determine the force vectors: $\bar{F}_i = F_i \hat{\ell}_i$

$$F_{DA} = 400\left(\frac{20}{34.66}\hat{i} + \frac{15}{34.66}\hat{j} - \frac{24}{34.66}\hat{k}\right) N = \left(230.81\hat{i} + 173.11\hat{j} - 276.98\hat{k}\right) N$$

$$F_{DB} = 800\left(\frac{-6}{25.06}\hat{i} + \frac{4}{25.06}\hat{j} - \frac{24}{25.06}\hat{k}\right) N = \left(-191.54\hat{i} + 127.69\hat{j} - 766.16\hat{k}\right) N$$

$$F_{DC} = 600\left(\frac{16}{34}\hat{i} - \frac{18}{34}\hat{j} - \frac{24}{34}\hat{k}\right) N = \left(282.35\hat{i} - 317.65\hat{j} - 423.53\hat{k}\right) N$$



Now,

$$\bar{F}_R = \bar{F}_{DA} + \bar{F}_{DB} + \bar{F}_{DC}$$
$$= \{321.66\hat{i} - 16.82\hat{j} - 1466.71\hat{k}\}\ N$$

The resultant force is:

$$F_R = \sqrt{\bar{F}_R \cdot \bar{F}_R} = \sqrt{(321.66)^2 + (-16.82)^2 + (-1466.71)^2}\ N$$
$$= 1501.66\ N = 1.50\ kN$$

Ans.

and the direction cosines are

$$\alpha = \cos^{-1}\left(\frac{F_{R_X}}{F_R}\right) = \cos^{-1}\left(\frac{321.66}{1501.66}\right) = 77.6^\circ$$

Ans.

$$\beta = \cos^{-1}\left(\frac{F_{R_Y}}{F_R}\right) = \cos^{-1}\left(\frac{-16.82}{1501.66}\right) = 90.6^\circ$$

Ans.

$$\gamma = \cos^{-1}\left(\frac{F_{R_Z}}{F_R}\right) = \cos^{-1}\left(\frac{-1466.71}{1501.66}\right) = 167.6^\circ$$

Ans.