College of Integrative Sciences and Arts
Science and Mathematics Faculty
Tenure-Track Faculty Annual Report Form

Tenured and Tenure Track Faculty Annual Report Form for January 1, 2021 – December 31, 2021. Reference: CISA bylaws/Appendix A

Please use this Annual Report Form to report your accomplishments in research/creative activity, teaching, and service. Use the category and subcategory headings. On those lines of the form where there is no activity to report, leave the line blank. Provide an explanation or clarification wherever you think it may be useful, including contributions to diversity and inclusion.

For the evaluation of faculty performance in 2019, please submit your report as a single pdf file by **January 15, 2022 at 5:00pm**. Name the report using the format LastName_annual_report_2021.pdf. Please add syllabi, representative assignments, CV and any other materials, **in that order**, as appendices at the end of the document. Information on where to send your file will be sent out in a separate message.

Name: Michael Dugger

Rank: Associate Professor

Faculty Head to complete this section.
Evaluation Summary for 2021 based on evidence in categories 1, 2, and 3 below:
Numerical ranking [unsatisfactory (1), satisfactory (2), merit (3), high merit (4)]:

Research	_____	X Research Weight	_____	= _____
Instruction	_____	X Instruction Weight	_____	= _____
Service	_____	X Service Weight	_____	= _____

Overall numerical ranking = _____

Faculty Head signature _____ Date _____

I have read this review and it has been discussed with me. I understand my signature does not necessarily indicate agreement.
Faculty signature _____ Date _____

Category 1: Research (provide information in the following categories as applicable)

ABOR mandates that research be evaluated in three-calendar-year increments.

1. Books (including monographs, edited volumes, and textbooks)

2. Articles, chapters, essays, poems, and short stories in refereed venues

Response: I was a coauthor on 6 articles [1-6]

[1] S. Adhikari *et al*.(GlueX Collaboration), "*Measurement of beam asymmetry for π−Δ++ photoproduction on the proton at Eγ=8.5 GeV*, Phys.Rev.C **103**, L022201 (2021)

[2] M. Carver *et al*.(CLAS Collaboration), "*Photoproduction of the f2(1270) meson using the CLAS detector*", Phys.Rev.Lett. **126** (2021) 8, 082002

[3] T.B. Hayward *et al*.(CLAS12 Collaboration), "*Observation of Beam Spin Asymmetries in the Process ep→e'π+π−X with CLAS12*", Phys.Rev.Lett. **126** (2021) 152501

[4] U. Shresha, *et al*.(CLAS Collaboration), "*Differential cross sections for Λ(1520) using photoproduction at CLAS*", Phys.Rev.C **103** (2021) 2, 025206

[5] N. Zachariou, *et al*.(CLAS Collaboration), "*Double polarisation observable G for single pion photoproduction from the proton*", Phys.Lett.B **817** (2021) 136304

[6] S. Adhikari *et al*., for the GlueX collaboration, *The GlueX beamline and detector*, Nucl. Inst. Meth. A **987** (2021) 164897

3. Invited publications

4. Grants (both internal and external; specify amount and role)

Proposals funded. Include funding agency, amount funded, degree of involvement (%, PI, Co-PI, etc.), and dates.

Response:

- 2019-2022: Department of Energy grant "Experimental Medium Energy Physics at Arizona State University" (PI: M. Dugger, 100%, award number DE-SC0020404, total award amount: $450,000, award amount received thus far: $450,000).

- Design Aspirations Grant from CISA for undergraduates (from the underrepresented group of female STEM) in my research group to present posters at the American Physics Society Four Corners Meeting (PI: M. Dugger, 100%). The amount awarded was $1000.

5. Proposals submitted. Include funding agency, amount requested, degree of involvement (%, PI, Co-PI, etc.), and dates.

Response:

- Withdrawn: 2022-2025: Renewal for Department of Energy grant "Experimental Medium Energy Physics at Arizona State University". The grant renewal was withdrawn because I sent it in too early (I was used to NSF renewal timeframe). I am resubmitting

the renewal application when it is appropriate to do so (March 2022).

6. Invited addresses, such as keynotes
7. Conference presentations and papers
8. Professional-development workshops attended
9. Travel to collections for research purposes
10. Book reviews, review essays, and research notes
11. Honors and awards for scholarship
12. Sabbatical report
13. Shows, performances and exhibits

14. Other contributions

Response:

I have given presentations at various meetings over the past year [7-11]. A bulleted list of my presentations is given below.

- Presentations related to the ASU designed and constructed photon polarimeter (TPOL) [7-10]
- Presentation related to $K\,K\,\pi$ photoproduction [11]

[7] https://userweb.jlab.org/~dugger/triPol/makePolVals75V10.pdf, Update on polarizations values for 2018 fall and spring (75-micron) data, GlueX Beamline Working Group meeting 1-5-2021
[8] https://userweb.jlab.org/~dugger/triPol/tpolFileIssuesSp20.pdf, Data issues, GlueX Beamline Working Group meeting 7-17-2021
[9] https://userweb.jlab.org/~dugger/triPol/tpolFileIssuesSp20V2.pdf, Data issues (part 2), GlueX Beamline Working Group meeting 8-31-2021
[10] http://meson.hldsite.com/presentations/TPOL/tpolFileIssuesSp20batch5-8.pdf, Data issues (part 3), GlueX Beamline Working Group meeting 10-26-2021
[11] http://meson.hldsite.com/presentations/glueX/kkpi0V1.pdf, Mass dependent *t*-slopes at low invariant-mass $K^*\,K$ and use of sigmoid function for estimating background under $\varphi \rightarrow K^+\,K^-$ events, GlueX Vector-Psedoscalar Working Group Meeting 10-5-2021

Category 2: Instructional Contributions (provide information in the following categories as applicable)

ABOR mandates that teaching be evaluated in one-calendar-year increments.

Evaluation of teaching will include attention to SYLLABI AND OTHER COURSE MATERIALS, student evaluations, the number of students enrolled in a class, and the demonstrated relation between the classes offered and departmental needs.

1. List the courses you taught each semester. Explain any special circumstances that apply to these courses (e.g., a first-time prep; team-teaching; teaching early in the morning, at night, or on Saturday; teaching high-enrollment/multicultural content classes; or teaching online or web-enhanced courses).

List course, enrollment numbers, credits, and SCH (enrollment number x credit hours) in the order of S20, Su20, and F20 (add more lines as needed).

Semester/ Year	Prefix/ Number	Course Title	Enrollment number	Credit hours	SCH
S21	PHY321	Vector Mechanics and Vibration	26	3	78
S21	PHY456	Laser Optics	3	4	12
S21	PHY492	Honors Directed Study	1	3	3
S21	PHY495	Project Research	3	1 or 2	5
S21	PHY792	Research	1	9	9
S21	PHY 799	Dissertation	1	12	12
Su21	PHY792	Research	1	1	1
Su21	PHY795	Continuing Registration	1	1	1
F20	PHY321	Vector Mechanics and Vibration	23	3	69
F20	PHY321	Vector Mechanics and Vibration	36	3	108
F20	PHY495	Project Research	3	2	6
F20	PHY492	Honors Directed Study	1	3	3
F20	PHY792	Research	2	6 or 9	15
				Total SCH =	322

Special circumstances: PHY456 was first-time prep.

2. At the **end of the report** attach syllabi and other course documents. Please submit one syllabus for each unique course you taught (i.e., if you taught the same course two semesters in a row, only submit one syllabus for this course). Please also submit one representative assignment for each unique course taught.
3. For online and web-enhanced courses, faculty using My ASU are encouraged to enroll their head as an instructor so that the head can view password-protected materials; faculty using their homepages or other web pages should provide their head with URLs and access.

1. Course evaluations Please provide a **table** (see example below) that gives the evaluation score for Question 17 (All things considered, this instructor was a very effective university teacher) for **each course** taught.

Semester	Course number; SLN	Type of class	Score
Fall 21	PHY 321; 80853	lecture	2.5
Fall 21	PHY 321; 82235	lecture	1.0
Spring 21	PHY 321; 32646	lecture	2.0
Spring 21	PHY 456; 32186	lecture	1.0
Spring 21	PHY 456; 32191	lab	1.0

Produce a double-spaced narrative (at most 1 to 2 pages) that contextualizes your evaluation scores. Discuss areas in which you excel (such as your level of experience, effective teaching strategies, accessibility to students, your ability to produce an effective learning environment

for your students), as well as any pedagogical changes you would like to implement in becoming a more effective teacher**. Please include your contributions to diversity and inclusion in your teaching in this section.**

Response:

As seen in Table 1, my scores for PHY-321 ranged from 1.0 to 2.5. When I look at the evaluation comments, I see that some of the students would prefer a less theoretical exploration of the material. However, PHY-321 with less theory is PHY-121. Some engineering students do not want to understand the underlying physics. For students that just want a quick guide on how to guess equations, my teaching style can be frustrating. However, if I were to turn to a style of teaching that emphasized guessing the right equation, I would do a disservice to those students that want to choose equations based on physical understanding. There are also students that wish for me to immediately substitute numbers for symbols, and that is a horrible idea. I try to train them to put in numbers toward the end of the calculation. I tell them that removing the symbols early on makes it very difficult when trying to figure out possible errors in multiline calculations.

I have found a few lectures that can have a reduced theoretical discussion without harming the course. When the theoretical description requires summing an indeterminate number of particles, I can replace some of the theoretical material with example problems. The next time I teach PHY-321 I plan to change my lectures as described above.

The largest contributions I can make as a teacher and mentor towards making physics a more Diverse, Equitable and Inclusive (DEI) field of study, is in my efforts with those students that I spend the most time with. I am a strong advocate for my research students that come from underrepresented groups. I teach them to represent themselves to the wider physics community by utilizing opportunities designed to make physics a more equitable discipline. The underrepresented students need to take on forward-facing roles. When possible, I actively help my students find and exploit opportunities.

I obtained a Design Aspiration Grant at Poly for two undergraduate students to present results at an American Physical Society (APS) conference. I made sure to state in the grant proposal that the

students were from an underrepresented group (females). Since the APS conference was held remotely, the costs from the grant were far from depleted. As a way to deploy the remaining funds in a manner that fit within the intent of the grant, I encouraged those students (Emily Lamagna and Rebecca Osar) to apply to present at the Conferences for Undergraduate Women in Physics (CUWiP). Rebecca Osar had had her application accepted but could not attend. Ms. Lamagna did not submit her application in time for consideration.

For my Black PhD student, Brandon Sumner, I tried to obtain an ASU Presidential Postdoctoral Fellowship (PPF) that was established for underrepresented communities. My first step was to contact Dean Grabski to inquire as to how I could obtain an ASU PPF for Mr. Sumner. I was then invited into a group that was tasked with writing a PPF proposal for Poly. I aggressively tried to secure a PPF for my grad student until it was made very clear that Brandon was not going to fit within the direction that Poly wanted to go. I then switched gears and started looking for other DEI opportunities. Eventually I learned of the Mathematical and Physical Sciences Ascending Postdoctoral Research Fellowships (MPS-Ascend) from the NSF. The MPS-Ascend Fellowship has the intent to "broaden the participation of groups that are underrepresented in MPS fields". I then encouraged Brandon Sumner to apply for the MPS-Ascend Fellowship. Mr. Sumner asked if I would be his lead sponsor with Professor Barry Ritchie as a cosponsor and Physics Department Chair Patricia Rankin as a second cosponsor. The MPS-Ascend Fellowship proposal was sent out to the NSF and we are waiting for the decision.

Most of the students in my lecture courses are from engineering and there are many diversity organizations that may be of interest: Women engineering the future (https://engineering.asu.edu/women-in-engineering/), Society of Women Engineers (https://swe.engineering.asu.edu/), Desert WAVE (Women in Autonomous Vehicle Engineering) (https://www.desertwave.us/) (Placed 2nd in RoboSub 2019 and 3rd in RoboSub 2020), National Society of Black Engineers (https://studentorgs.engineering.asu.edu/nsbe/), Advancing Women in Construction (https://studentorgs.engineering.asu.edu/awic/), American Indian Science and Engineering Society

(https://studentorgs.engineering.asu.edu/aises/), Society of Asian Scientists and Engineers

https://studentorgs.engineering.asu.edu/sase/), Society of Hispanic Professional Engineers

(https://studentorgs.engineering.asu.edu/shpe/)

I will encourage the students in my lecture courses to look into what these organizations may be able to

offer them in terms of opportunities and activities.

5. Names of students supervised in independent study courses and names of students you are mentoring at the graduate level, indicating whether you are serving as chair or member of their committees.

Response:
For the undergraduates, my mentorship included weekly one-hour one-on-one sessions where I assist them in learning analysis techniques related to their projects. For the graduate students that I am the primary mentor (Cole, Sumner, Gardner), the amount of one-on-one time can vary greatly and is determined by the student.

Students supervised (notable achievements are highlighted):

- Sebastian Cole (graduate student): I was the chair of his Ph.D. committee and supervised him for PHY 799. Sebastian presented his results at the GlueX Vector-Pseudoscalar meeting [12]. He successfully defended his Ph.D. on July 2, 2021 [13].
- Brandon Sumner (graduate student): I am the chair of his Ph.D. committee and supervised him for PHY 792. Brandon presented results at the GlueX Cross Section Working Group [14-18], GlueX Collaboration Meetings [19,20], the American Physical Society (APS) April meeting [21] and at the APS Division of Nuclear Physics (DNP) meeting [22].
- Alan Gardner (graduate student): I am Alan's advisor, supervised Alan for his research rotation (PHY 500) and research (792) and will be the chair of his committee when it has been formed. Alan gave a presentation at the GlueX Vector Pseudoscalar PWA Meeting [23] and at the APS Division of Nuclear Physics (DNP) meeting [24] .
- Glenn Randall (graduate student): I was on Glenn's Ph.D. committee. He successfully defended his Ph.D. on April 12, 2021 [25].
- Jesse Giron (graduate student): I am was on Jesse's Ph.D. committee. He successfully defended his Ph.D. on April 9, 2021.
- Rebecca Osar (undergraduate student): Rebecca took Honors Directed study (PHY492) with me and I am her Honors Thesis advisor. Ms. Osar has been analyzing the photoproduction of $K\Lambda$ states from the proton. She presented results at the 17th Annual Undergraduate Physics Symposium [26]. Rebecca also Presented at the Four Corners Section of the APS [27].
- Patrick Walker (undergraduate student): I was Patrick's advisor for his Honors Thesis. Patrick took Honors Directed study (PHY492) with me. Mr. Walker has analyzed K^*K final states, successfully defended his honors thesis [28], graduated with his B.S degree and

won the ASU Department of Physics Undergraduate Research Award for a presentation at the 17th Annual Undergraduate Physics Symposium [29].

- Emily Lamagna (undergraduate student): Emily took PHY-495 with me. Ms. Lamagna presented results at the 17th Annual Undergraduate Physics Symposium [30]. Emily also Presented at the Four Corners Section of the APS [31].
- Anna Costelle (undergraduate student): Anna took PHY-495 with me. Ms. Costelle won the ASU Women in Physics Award for Undergraduate Research for her presentation describing the development of an event generator for strangeness states at the 17th Annual Undergraduate Physics Symposium [32].
- Shane Watters (undergraduate student): Shane took PHY-495 with me and is working on an event generator for ground-state Λ photoproduction from the proton.

[12] S. Cole, "Partial Wave Analysis of K* K-bar events in GlueX",presentation at the GlueX Vector Pseudoscalar PWA Meeting, 2021-9-07, http://meson.hldsite.com/presentations/Cole/September7_VectorPseudoscalar_Meeting.pdf

[13] S. Cole, "Partial Wave Analysis of Meson Resonances that Decay K* K-bar Using Data from the GlueX Experiment", Dissertation, 7-2-2021, https://keep.lib.asu.edu/items/161902

[14] B. Sumner, "Cascade Update Ξ− 1530, Cross Section Update", Presentation at the GlueX Cross Section Working Group, 1-25-2021, http://meson.hldsite.com/presentations/others/CrossSection12521.pdf

[15] B. Sumner, "Cascade Update Ξ− 1530, Cross Section Update", Presentation at the GlueX Cross Section Working Group, 2-8-2021, http://lc.asu.edu/~testUser/CSM2-8-21.pdf

[16] B. Sumner, "Initial study of some new files", Presentation at the GlueX Cross Section Working Group, 3-22-2021, http://lc.asu.edu/~testUser/Cascade%20Update%203-22-21.pdf

[17] B. Sumner, "Cascade Update Ξ− 1530, Cross section meeting", Presentation at the GlueX Cross Section Working Group, 4-5-2021, http://lc.asu.edu/~testUser/FPR4-4-21.pdf

[18] B. Sumner, "Cascade Update Ξ−", Presentation at the GlueX Cross Section Working Group, 2-8-2021, http://lc.asu.edu/~testUser/Cross%20Section%208-23-2021.pdf

[19] B. Sumner, "Cascade Update Ξ− 1530 Collaboration Meeting", Presentation at the Fall GlueX Collaboration Meeting, 2-19-2021, http://meson.hldsite.com/presentations/Sumner/SumnerCollaborationMeeting2-19-2021.pdf

[20] B. Sumner, "*Search for excited Ξ^* states and preliminary cross section for Ξ^-(1530)*", Presentation at the Fall GlueX Collaboration Meeting, 9-23-2021, http://meson.hldsite.com/presentations/Sumner/bSumnerCollaborationMeetingFa21.pdf

[21] B. Sumner, *Search for excited Ξ^* states and preliminary cross section for Ξ^-(1530)*, Presentation at the American Physical Society April meeting, 4-20-2021, Online, http://meson.hldsite.com/presentations/Sumner/APSSumnerApril2021.pdf

[22] B. Sumner, *Search for excited Ξ^* states*, Presentation at the APS Division of Nuclear Physics meeting, 10-14-2021, Online, http://meson.hldsite.com/presentations/Sumner/SumnerDNP2021.pdf

[23] A. Gardner, $\gamma p \rightarrow p$ K-K+ $\gamma\gamma$ Background Analysis, presentation at the GlueX Vector Pseudoscalar PWA Meeting, 2021-10-05, http://meson.hldsite.com/presentations/Gardner/October-5th-2021.pdf

[24] A. Gardner, "Exploring photoproduced meson states that decay $K^+K^-\pi^0$ with an emphasis on

events where the K^+K^- pair are from a_0 decay", Presentation at the APS Division of Nuclear Physics meeting, 10-14-2021, Online, http://meson.hldsite.com/presentations/Gardner/GardnerDNP2021.pdf
[25] G. Randall, "Si Detector Timing Studies for the Nab Experiment", Dissertation, 4-12-2021, https://keep.lib.asu.edu/items/161587
[26] R. Osar, *Search for high-mass resonances decaying to K Λ**, presentation at the 17th Annual Undergraduate Physics Symposium, 4-29-2021, Tempe Campus, Arizona State University, https://youtu.be/Q2YhBCv1riE
[27] R. Osar, Efficiency-Corrected Yields of K+ Λ*1520 Channel , Presentation at the Four Corners Meeting of the APS, Online, http://meson.hldsite.com/presentations/rosar/Rosar4CS%20presentation10-9-2021.pdf
[28] P. Walker, Meson decay in $e\ p \rightarrow e\ p\ K^+\ K^-$ and $e\ p \rightarrow e\ p\ K^+\ K^-\ \pi^0$ events, Honors Thesis, 4-7-2021, Arizona State University, http://meson.hldsite.com/theses/Thesis_WalkerPatrick.pdf
[29] P. Walker, *Search for new states that decay K* K*, presentation at the 17th Annual Undergraduate Physics Symposium, 4-29-2021, Tempe Campus, Arizona State University, https://youtu.be/Buu2YDIrUK4
[30] E. Lamagna, *On the road to constructing events that decay φ π^0 using electroproduction with a proton target*, presentation at the 17th Annual Undergraduate Physics Symposium, 4-29-2021, Tempe Campus, Arizona State University, https://youtu.be/3AZP9fjStuc
[31] E. Lamagna, Invariant mass of the ϕ π0 System, Presentation at the Four Corners Meeting of the APS, Online, http://meson.hldsite.com/presentations/LaMagna/APS_Four_Corners_2021_Emily_LaMagna.pdf
[32] A. Costelle, *Construction of Event Generators for Strangeness-Containing Final States*, presentation at the 17th Annual Undergraduate Physics Symposium, 4-29-2021, Tempe Campus, Arizona State University, https://youtu.be/tKCB4t_G2yk

6. Any additional mentoring of undergraduate and/or graduate students (e.g., co-authoring with students or assisting them to make conference presentations; participating in professional-development workshops).

7. Names of undergraduate Barrett honors students you have mentored, 1) class honors contracts or 2) either as chair or member of their thesis committees.

Response:

- Patrick Walker (undergraduate student): I was Patrick's advisor for his honors thesis. As stated previously, Mr. Walker has analyzed K^*K final states, successfully defended his honors thesis [28], graduated with his B.S degree and won the ASU Department of Physics Research Award for a presentation at the 17th Annual Undergraduate Physics Symposium [29].
- Rebecca Osar (undergraduate student): I am the advisor for her honors thesis.

8. Teaching awards you have received.

9. Materials that provide evidence of curriculum development and/or significant course revision.
10. Evidence of course supervision, mentoring of teachers.

11. Other instructional contributions not listed above.

Response:

- I started working with Joshua Grumski-Flores in the fall of 2021. Joshua is a very talented freshman. Joshua has joined an effort to create simulations of a detector that we hope will be constructed in the future.

Category 3: Service (provide information in the following categories as applicable)

ABOR mandates that service be evaluated in three-calendar-year increments. For each of the four service categories please indicate the year 2019, 2020, 2021.

Service to the Profession:
1. Academic activities (e.g., editorships; boards of directors; consulting editor; occasional reviewer of proposals, manuscripts; conference sessions organized and/or chaired). Specify journal or agency, role, and time period.

Response:
I have performed journal reviews of an article and two proceedings:

- Article review for Physical Review C (8-12-2019 to 10-11-2019).
- Proceedings reviews (two) for the MENU (Meson Nucleon) conference (10-22-2019 to 11-22-2019).

2. Service (e.g., committee work for professional organizations). Specify organization, role and time period.

Response:
I was a chair for the nuclear physics session of the American Physical Society Four Corners Meeting held on October 24, 2020.

Service to the University:
1. Membership on university-level committees. Indicate with an asterisk those committees you chair(ed).

Response:
Member of the Graduate College review committee for the ARCS (Achievement Rewards for College Scientists) Fellowship, 2018, 2019 and 2020.

2. Work with other departments (e.g., serving on search committees, coordinating joint programs).
3. Lectures, seminars given specifically to other departments.

4. Other service to the university (e.g., faculty senator).

Service to the College of Integrative Sciences and Arts:
1. School committees on which you have served and/or are serving. Indicate with an asterisk those committees you chair(ed).

Response:
Member of PSM Safety Committee 2021

2. School activities you organize(d), beyond assigned committee work.
3. School administrative position(s) you have held/currently hold.

Service to the Community:
1. Consultation and membership on community committees and boards. List the agency, duties and time period that you served.
2. Lectures, talks, workshops, and other public relations.

Other Professional Activities:
Please provide information not covered in previous headings, such as being the subject of interviews.

To faculty with course releases: If you have non-research-related course releases, please specify what you are doing for that course release.

Category 4: Professional Goals for 2021 Calendar Year

Please list goals for each of the three evaluative categories (research, teaching and service) for the next year.

Response:
Research goals: During the 2022 year, my goal is to assist my graduate students in discovering new baryonic Ξ states and hybrid mesons. I also plan to submit a continuing grant proposal to the DOE.

Teaching goals: During the 2022 year, my goal is to improve my course evaluations to be closer to the optimal values. I also plan to put more diversity and inclusion material into my regular lecture classes.

Service activity goals: My goal for service work is to maintain good standing with the collaborations I participate in. I also plan to provide service work to the academic and general physics communities by agreeing to any reasonable requests of my time made by those entities.

Tenured/Tenure-track faculty member to complete this section.

Three Year Workload Distribution (%)

Area	2019	2020	2021	2022 (projected)
Teaching	30%	40%	40%	40%
Research/Creative Activity	30%	40%	40%	40%
Service	15%	20%	20%	20%

PHY 321

Polytechnic campus | TTH | 9:00-10:15am | SANCA bldg., room 360
ASU Sync

Course and Faculty Information

Course Description: Vector based formulation of Newtonian mechanics of particles and rigid bodies, including oscillatory systems

Credits: 3

Prerequisites: None

Instructor: Dr. Michael Dugger

Contact Info: Office: Wanner Hall 340B. Email: dugger@asu.edu

Office Hours: Zoom session by appointment only

College Contact: This course is offered by the College of Integrative Sciences and Arts (CISA). For more information about the college, visit our website: https://cisa.asu.edu. If you have questions about this course, please speak with your instructor. If your instructor is unable to address your questions, please send your inquiry to cisa@asu.edu.

Course Format: Lecture TTH from 9:00 am to 10:15 am.

Required Textbook:

1. ***Vector Mechanics for Engineers, Dynamics*** (11th edition) by Ferdinand Beer, E. Russell Johnston Jr., Philip J. Cornwell and Brian Self.

Assignments, Exams and Grading

Tentative schedule: The exact schedule for lectures, quizzes and examinations will depend on how long it takes to cover the material. The following is a tentative schedule:

Chapter 11:	Starts January 12
Chapter 12:	Starts January 26
Chapter 13:	Starts February 9
Chapter 14:	Starts February 16
Chapter 15:	Starts March 2
Chapter 16:	Starts March 11
Chapter 17:	Starts March 18
Chapter 19:	Starts April 1

Tentative exam dates:

February 4:	Chapter 11 and 12
February 25:	Chapter 13 and 14
March 30:	Chapter 15, 16, 17
April 20:	Chapter 19
April 29:	Comprehensive final

ASU Sync

This course is scheduled as an in-person (face-to-face) course. You will attend some class sessions in-person and be remote for other sessions to ensure we keep the room occupancy below 50%.

For the remote option, this course uses Sync. ASU Sync is a technology-enhanced approach designed to meet the dynamic needs of the class. During Sync classes, students learn remotely through live class lectures, discussions, study groups, and/or tutoring. You can find out more information about ASU Sync for students here: https://provost.asu.edu/sync/students.

To access live sessions of this class, go to MyASU and click the Attend via Sync button next to this class on your schedule.

Face Coverings

Everyone is required to wear a face cover while in ASU buildings and community spaces, regardless of distance. Face covers help prevent pre-symptomatic and asymptomatic individuals from inadvertently spreading COVID-19 to others. They are meant to protect others in case you are sick. Students will be required to wear a face cover in the classroom. For more information about face coverings, please visit the FAQ page.

Course Access

Your ASU courses can be accessed by both my.asu.edu and asu.instructure.com; bookmark both in the event that one site is down.

Computer Access Requirements

ASU Sync classes can be live streamed anywhere with the proper technology. We encourage you to use a PC or Apple laptop or desktop equipped with a built-in or standalone webcam. You will need an internet connection that can effectively stream live broadcasts. It is recommended that your internet download speed is at least 5.0 mbps. You can use this tool to test your current connection.

We do not recommend the use of iPads or Chromebooks for ASU Sync because these devices do not work for class exams that may be proctored remotely.

If you are not able to personally finance the equipment that you need to attend class via ASU Sync, ASU has a laptop and WiFi hotspot checkout program available through ASU Library.

Who is eligible?

- Any currently enrolled ASU student is eligible to checkout a laptop or WiFi hotspot. The current availability of laptops can be found here.

Borrowing and returning laptop rules

- Laptops are lent on a first-come, first-serve basis, and cannot be reserved in advance. They can be returned at any time, but will be due at the conclusion of the fall 2020 semester.
- Rentals are limited to one laptop per student.
- Laptops are available for checkout at the following libraries on all four campuses: (Please check online for current library hours)
    - Downtown Phoenix campus Library
    - Polytechnic campus Library
    - Tempe: Hayden and Noble Libraries
    - West campus: Fletcher Library
- Return laptops to any ASU Library Information Desk (not at the drop box or other location)
- Refer to ASU Library Computer Use Policy and ASU Computer, Internet, and Electronic Communications Policy.
- Borrowers are responsible for loss, damage, and theft of the laptop while in their possession. Borrowers should verify the condition of the laptop at the time of check-out and upon check-in.

Student Success

To be successful:

- check the course daily
- read announcements
- read and respond to course email messages as needed
- complete assignments by the due dates specified
- communicate regularly with your instructor and peers
- create a study and/or assignment schedule to stay on track
- access ASU Online Student Resources or CISA Academic Resources

Assignments and Exams:

Percentage Distribution:	
Homework assignments	20%
Exams (4 out of 5)	80%
Total	**100%**

The lowest score from the five examination scores will be dropped in computing the semester average.

Course Grading System:

Grades will be determined by the percentage you accumulate:

A	90-100	Excellent
B	80-89.9	Good
C	70-79.9	Average
D	60-69.9	Passing
E	<60	Failure
XE		Failure due to Academic Dishonesty

For your own protection, you should keep a copy of everything you hand in, and you should keep your graded assignments at least until grades are finalized at the end of the semester, and in the event you wish to contest any grades.

Course Policies

Attendance is expected. Students are responsible for all material presented in class, all homework, and for all changes to the schedule or plans announced in class.

Homework: Late homework will **not** be accepted.

Extra Credit: There will be no extra credit opportunities assigned for this course.

Communicating with your Instructor and Classmates

Classroom Community

To build a course climate that is comfortable for all, it is important that students (1) display respect for all members of the class – including the instructor and students; (2) pay attention to and participate in all interactive student partner/instructor sessions and activities; and (3) observe the rules of appropriate online behavior (also known as *netiquette*). This term is defined by the instructor and includes keeping course discussion posts and oral communication with other students (or the instructor) focused on the assigned topics. Students must maintain a cordial atmosphere and use tact in expressing differences of opinion. In addition, they must avoid racist, sexist, homophobic, or other negative language that may unnecessarily exclude course members. This is not an exhaustive list of behaviors; rather, it represents examples of the types of things that can have a dramatic impact on the course environment. Your final grade may be reduced each time you engage in the types of negative behaviors indicated above.

Email

ASU email is an official means of communication among students, faculty, and staff. Students are expected to read and act upon email in a timely fashion. Students bear the responsibility of missed messages and should check their ASU-assigned email regularly.

All instructor correspondence will be sent to your ASU email account.

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All assignments, unless otherwise announced by the instructor, MUST be submitted to the designated area of Canvas. Do not submit an assignment via email.

Assignment due dates follow Arizona Standard time. Click the following link to access the Time Converter to ensure you account for the difference in time zones. Note: Arizona does not observe daylight savings time.

Course Time Commitment

Coursework includes all learning activities including reading, watching videos, studying, and completing assignments. Arizona Board of Regents (ABOR) requires 45 hours of coursework per credit for college-level courses, which translates to:

- 1 credit hour = 45 total hours
- 2 credit hours = 90 total hours
- 3 credit hours = 135 total hours
- 4 credit hours = 180 total hours
- 5 credit hours = 225 total hours

ASU courses range in length from 6 weeks to 15 weeks. Below is a breakdown of the 135-hour required time commitment for a three-credit course divided among weeks for courses of various lengths.

Course Length	**Time on Coursework per Week for a 3-credit course**	**Total Time Requirement for a 3-credit Course**
6 weeks	22.5 hours	135 hours
7.5 weeks	18 hours	135 hours
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Drop and Add Dates/Withdrawals

If you are unable to take this course for any reason, be aware that there is a limited timeline to drop or add the course. Consult with your advisor and notify your instructor to add or drop this course. If you are considering a withdrawal, review the following ASU policies: Withdrawal from Classes, Withdrawing as a Financial Aid Recipient, Medical/Compassionate Withdrawal, and a Grade of Incomplete.

Grade Appeals

Students must first speak with the instructor of the class to discuss any disputed grades. If, after review, a resolution is not achieved, students may proceed with the appeal process. Student grade appeals must be processed in the regular semester immediately following the issuance of the grade in dispute (by

commencement for fall or spring), regardless whether the student is enrolled at the university. Complete details are available in the CISA Grade Appeals policy.

Academic Integrity

Academic honesty is expected of all students in all examinations, papers, laboratory work, academic transactions and records. The possible sanctions include, but are not limited to, appropriate grade penalties, course failure (indicated on the transcript as a grade of E), course failure due to academic dishonesty (indicated on the transcript as a grade of XE), loss of registration privileges, disqualification and dismissal. For more information, see provost.asu.edu/academicintegrity.

If you fail to meet the standards of academic integrity in any of the criteria listed on the university policy website, sanctions will be imposed by the instructor, college, and/or dean. Academic dishonesty includes, but is not limited to, cheating on an academic evaluation or assignment, plagiarizing, academic deceit (such as fabricating data or information), or falsifying academic records. Turning in an assignment (all or in part) that you completed for a previous class is considered self-plagiarism and falls under these guidelines. Any infractions of self-plagiarism are subject to the same penalties as copying someone else's work without proper citations. Students who have taken this class previously and would like to use the work from previous assignments should contact the instructor for permission to do so.

If you have any questions about your work and the academic integrity policy, please discuss your assignment or concerns with your instructor, teaching assistant, or your college Academic Integrity Officer in advance of submitting an assignment. Student resources on Sun Devil Integrity and strategies for completing your work with integrity and avoiding plagiarism are available here: ASU Student Resources for Academic Integrity or provost.asu.edu/academicintegrity for more information.

Harassment Prohibited

ASU policy prohibits harassment on the basis of race, sex, gender identity, age, religion, national origin, disability, sexual orientation, Vietnam era veteran status, and other protected veteran status. Violations of this policy may result in disciplinary action, including termination of employees or expulsion of students. Students are encouraged to report harassment to instructors and the Dean of Students Office.

Student Conduct

ASU and the College of Integrative Sciences and Arts expects and requires its students to act with honesty, integrity, and respect. Required behavior standards are listed in the Student Code of Conduct and Student Disciplinary Procedures, Computer, Internet, and Electronic Communications policy, ASU Student Academic Integrity Policy, and outlined by the Office of Student Rights & Responsibilities. Anyone in violation of these policies is subject to sanctions. Students are entitled to receive instruction free from interference by other members of the class. An instructor may withdraw a student from the course when the student's behavior disrupts the educational process per Instructor Withdrawal of a Student for Disruptive Classroom Behavior. The Office of Student Rights and Responsibilities accepts incident reports from students, faculty, staff, or other persons who believe that a student or a student organization may have violated the Student Code of Conduct.

Students must refrain from uploading to any course shell, discussion board, or website used by the course instructor or other course forum, material that is not the student's original work, unless the students first

comply with all applicable copyright laws; faculty members reserve the right to delete materials on the grounds of suspected copyright infringement.

Title IX

Title IX is a federal law that provides that no person be excluded on the basis of sex from participation in, be denied benefits of, or be subjected to discrimination under any education program or activity. Both Title IX and university policy make clear that sexual violence and harassment based on sex is prohibited. An individual who believes they have been subjected to sexual violence or harassed on the basis of sex can seek support, including counseling and academic support, from the university. If you or someone you know has been harassed on the basis of sex or sexually assaulted, you can find information and resources at https://sexualviolenceprevention.asu.edu/faqs.

As a mandated reporter, I am obligated to report any information I become aware of regarding alleged acts of sexual discrimination, including sexual violence and dating violence. ASU Counseling Services, https://eoss.asu.edu/counseling, is available if you wish to discuss any concerns confidentially and privately.

Disability Accommodations

Qualified students with disabilities who will require disability accommodations in this class are encouraged to make their requests to the instructor at the beginning of the semester either during office hours or by appointment. Note: Prior to receiving disability accommodations, verification of eligibility from the Disability Resource Center (DRC) is required. Disability information is confidential.

Disability Resource Center (eoss.asu.edu/drc)
Email: DRC@asu.edu
DRC Phone: 480-965-1234
DRC FAX: 480-965-0441

Statement on Inclusion

Arizona State University is deeply committed to positioning itself as one of the great new universities by seeking to build excellence, enhance access, and have an impact on our community, state, nation, and the world. To do that requires our faculty and staff to reflect the intellectual, ethnic, and cultural diversity of our nation and world so that our students learn from the broadest perspectives, and we engage in the advancement of knowledge with the most inclusive understanding possible of the issues we are addressing through our scholarly activities. We recognize that race and gender historically have been markers of diversity in institutions of higher education. However, at ASU, we believe that diversity includes additional categories such as socioeconomic background, religion, sexual orientation, gender identity, age, disability, veteran status, nationality, and intellectual perspective.

Mental Health

As a student, like anyone else, you may experience a range of challenges that can interfere with learning, such as strained relationships, increased anxiety, substance use, feeling down, difficulty concentrating, and/or lack of motivation. These emotional health concerns or stressful events may diminish your academic performance and/or reduce your ability to participate in daily activities. ASU Counseling

Services provides counseling and crisis services for students who are experiencing a mental health concern. Any student may call or walk-in to any ASU counseling center for a same-day or future appointment to discuss any personal concern. Here is the website: eoss.asu.edu/counseling. After office hours and 24/7 ASU's dedicated crisis line is available for crisis consultation by calling 480-921-1006.

Establishing a Safe Environment

Learning takes place best when a safe environment is established in the classroom. In accordance with SSM 104-02 of the Student Services Manual, students enrolled in this course have a responsibility to support an environment that nurtures individual and group differences and encourages engaged, honest discussions. The success of the course rests on your ability to create a safe environment where everyone feels comfortable to share and explore ideas. We must also be willing to take risks and ask critical questions. Doing so will effectively contribute to our own and others' intellectual and personal growth and development. We welcome disagreements in the spirit of critical academic exchange, but please remember to be respectful of others' viewpoints, whether you agree with them or not.

All incidents and allegations of violent or threatening conduct by an ASU student (whether on- or off-campus) must be reported to the ASU Police Department (ASU PD) and the Office of the Dean of Students. If either office determines that the behavior poses or has posed a serious threat to personal safety or to the welfare of the campus, the student will not be permitted to return to campus or reside in any ASU residence hall until an appropriate threat assessment has been completed and, if necessary, conditions for return are imposed. ASU PD, the Office of the Dean of Students, and other appropriate offices will coordinate the assessment in light of the relevant circumstances.

Prohibition of Commercial Notetaking Services

In accordance with ACD 304-06 Commercial Note Taking Services, written permission must be secured from the official instructor of the class in order to sell the instructor's oral communication in the form of notes. Notes must have the note taker's name as well as the instructor's name, the course number, and the date.

Course Evaluation

Students are expected to complete the course evaluation. The feedback provides valuable information to the instructor and the college and is used to improve student learning. Students are notified when the online evaluation form is available. The results are always anonymous and cannot be reviewed by the instructor/department until after final grades have been posted.

Trigger Warning

Please note that some course content may be deemed offensive by some students, although it is not my intention to offend anyone. In addition, some materials that we link with online might also be considered offensive, troubling, or difficult to review in terms of language or graphics. I attempt to provide warnings when introducing this kind of material; yet, if I forget to do so, or if something else (in my materials or posts from fellow students) seems offensive, please contact me at **dugger@asu.edu**, or the faculty head.

Academic Affairs Manual

For a complete guide to Arizona State University course policies, please refer to the Academic Affairs Manual (ACD).

Syllabus Disclaimer

The syllabus is a statement of intent and serves as an implicit agreement between the instructor and the student. Every effort will be made to avoid changing the course schedule but the possibility exists that unforeseen events will make syllabus changes necessary. Remember to check your ASU email and the course site often.

Representative homework assignment (taken from textbook used in course):

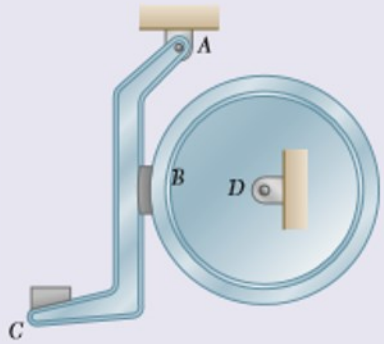

Fig. P15.1

15.1 The brake drum is attached to a larger flywheel that is not shown. The motion of the brake drum is defined by the relation $\theta = 36t - 1.6t^2$, where θ is expressed in radians and t in seconds. Determine (*a*) the angular velocity at $t = 2$ s, (*b*) the number of revolutions executed by the brake drum before coming to rest.

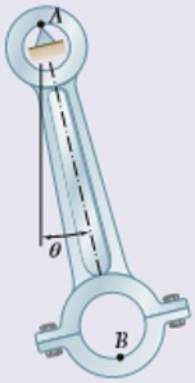

Fig. P15.6

15.6 A connecting rod is supported by a knife-edge at point *A*. For small oscillations the angular acceleration of the connecting rod is governed by the relation $\alpha = -6\theta$ where α is expressed in rad/s^2 and θ in radians. Knowing that the connecting rod is released from rest when $\theta = 20°$, determine (*a*) the maximum angular velocity, (*b*) the angular position when $t = 2$ s.

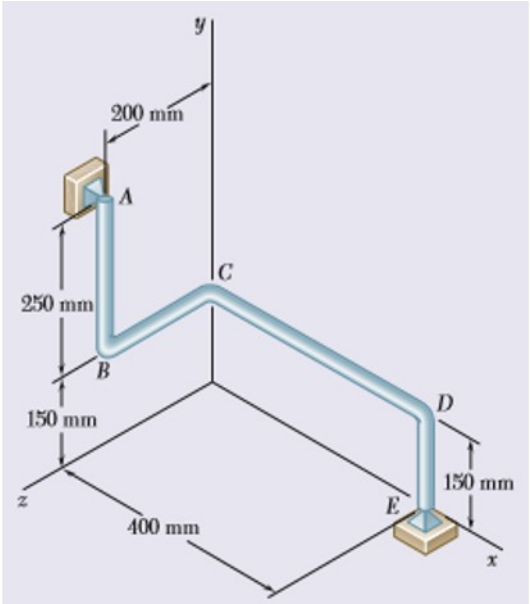

Fig. P15.10

15.10 The bent rod *ABCDE* rotates about a line joining points *A* and *E* with a constant angular velocity of 9 rad/s. Knowing that the rotation is clockwise as viewed from *E*, determine the velocity and acceleration of corner *C*.

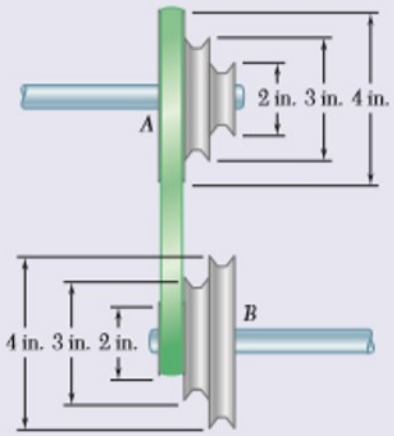

Fig. P15.22

15.22 The two pulleys shown may be operated with the V belt in any of three positions. If the angular acceleration of shaft *A* is 6 rad/s^2 and if the system is initially at rest, determine the time required for shaft *B* to reach a speed of 400 rpm with the belt in each of the three positions.

15.38 An automobile travels to the right at a constant speed of 48 mi/h. If the diameter of a wheel is 22 in., determine the velocities of points *B*, *C*, *D*, and *E* on the rim of the wheel.

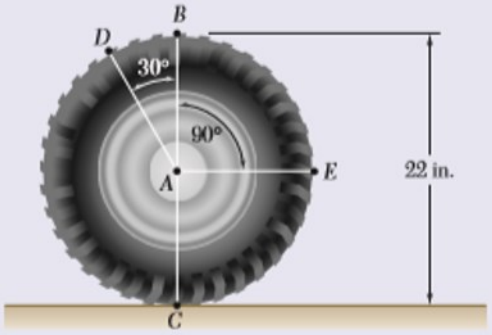

Fig. P15.38

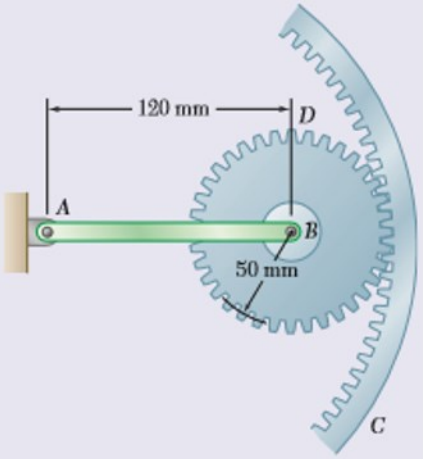

Fig. P15.50

15.50 Arm *AB* rotates with an angular velocity of 20 rad/s counterclockwise. Knowing that the outer gear *C* is stationary, determine (*a*) the angular velocity of gear *B*, (*b*) the velocity of the gear tooth located at point *D*.

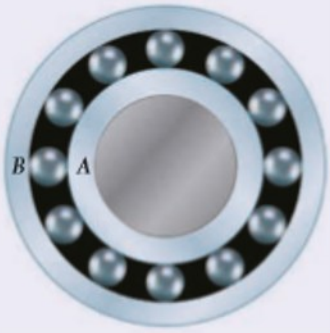

Fig. P15.51

15.51 In the simplified sketch of a ball bearing shown, the diameter of the inner race *A* is 60 mm and the diameter of each ball is 12 mm. The outer race *B* is stationary while the inner race has an angular velocity of 3600 rpm. Determine (*a*) the speed of the center of each ball, (*b*) the angular velocity of each ball, (*c*) the number of times per minute each ball describes a complete circle.

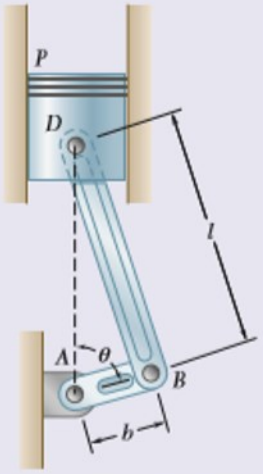

Fig. P15.61 and P15.62

15.62 In the engine system shown, $l = 160$ mm and $b = 60$ mm. Knowing that crank AB rotates with a constant angular velocity of 1000 rpm clockwise, determine the velocity of the piston P and the angular velocity of the connecting rod when $\theta = 60°$.

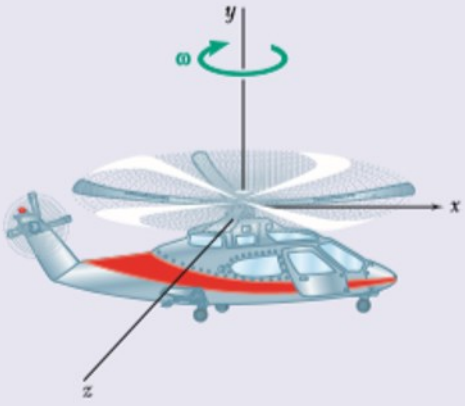

Fig. P15.75

15.75 A helicopter moves horizontally in the x direction at a speed of 120 mi/h. Knowing that the main blades rotate clockwise when viewed from above with an angular velocity of 180 rpm, determine the instantaneous axis of rotation of the main blades.

15.76 and ~~15.77~~ A 60-mm-radius drum is rigidly attached to a 100-mm-radius drum as shown. One of the drums rolls without sliding on the surface shown, and a cord is wound around the other drum. Knowing that end E of the cord is pulled to the left with a velocity of 120 mm/s, determine (*a*) the angular velocity of the drums, (*b*) the velocity of the center of the drums, (*c*) the length of cord wound or unwound per second.

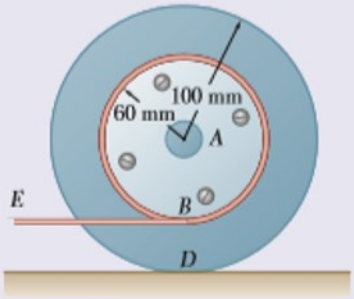

Fig. P15.76

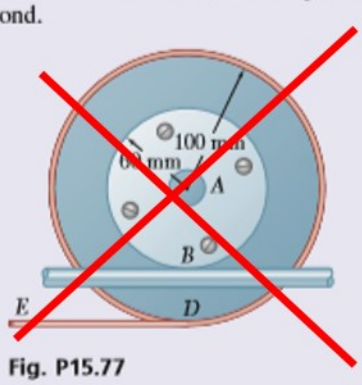

Fig. P15.77

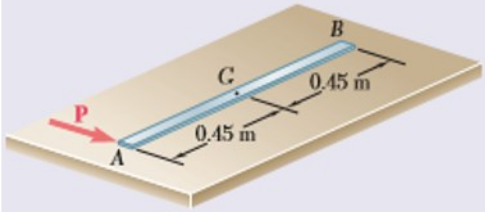

Fig. P15.107 and P15.108

15.107 A 900-mm rod rests on a horizontal table. A force **P** applied as shown produces the following accelerations: $\mathbf{a}_A = 3.6$ m/s^2 to the right, $\alpha = 6$ rad/s^2 counterclockwise as viewed from above. Determine the acceleration (*a*) of point G, (*b*) of point B.

15.111 An automobile travels to the left at a constant speed of 72 km/h. Knowing that the diameter of the wheel is 560 mm, determine the acceleration (*a*) of point B, (*b*) of point C, (*c*) of point D.

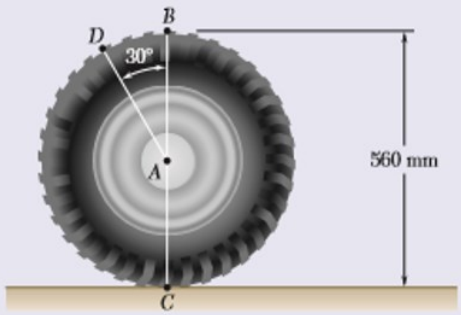

Fig. P15.111

15.112 The 18-in.-radius flywheel is rigidly attached to a 1.5-in.-radius shaft that can roll along parallel rails. Knowing that at the instant shown the center of the shaft has a velocity of 1.2 in./s and an acceleration of 0.5 in./s^2, both directed down to the left, determine the acceleration (*a*) of point A, (*b*) of point B.

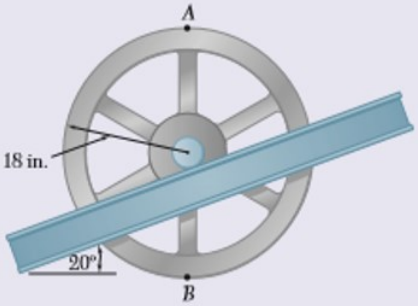

Fig. P15.112

PHY 456

Polytechnic campus | Lecture | TTH | 12:00-1:15pm | CLRB bldg., room 130
Lab | TH | 1:30-2:20pm | CLRB bldg., room 130
ASU Sync

Course and Faculty Information

Course Description: Vector based formulation of Newtonian mechanics of particles and rigid bodies, including oscillatory systems

Credits: 4

Prerequisites: PHY361

Instructor: Dr. Michael Dugger

Contact Info: Office: Wanner Hall 340B. Email: dugger@asu.edu

Office Hours: Zoom session by appointment only

College Contact: This course is offered by the College of Integrative Sciences and Arts (CISA). For more information about the college, visit our website: https://cisa.asu.edu. If you have questions about this course, please speak with your instructor. If your instructor is unable to address your questions, please send your inquiry to cisa@asu.edu.

Course Format: Lecture TTH from 9:00 am to 10:15 am.

Required Textbook:

1. ***Optics*** (5th edition) by Eugene Hecht.

ASU Sync

This course is scheduled as an in-person (face-to-face) course. You will attend some class sessions in-person and be remote for other sessions to ensure we keep the room occupancy below 50%.

For the remote option, this course uses Sync. ASU Sync is a technology-enhanced approach designed to meet the dynamic needs of the class. During Sync classes, students learn remotely through live class lectures, discussions, study groups, and/or tutoring. You can find out more information about ASU Sync for students here: https://provost.asu.edu/sync/students.

To access live sessions of this class, go to MyASU and click the Attend via Sync button next to this class on your schedule.

Face Coverings

Everyone is required to wear a face cover while in ASU buildings and community spaces, regardless of distance. Face covers help prevent pre-symptomatic and asymptomatic individuals from inadvertently spreading COVID-19 to others. They are meant to protect others in case you are sick. Students will be required to wear a face cover in the classroom. For more information about face coverings, please visit the FAQ page.

Course Access

Your ASU courses can be accessed by both my.asu.edu and asu.instructure.com; bookmark both in the event that one site is down.

Computer Access Requirements

ASU Sync classes can be live streamed anywhere with the proper technology. We encourage you to use a PC or Apple laptop or desktop equipped with a built-in or standalone webcam. You will need an internet connection that can effectively stream live broadcasts. It is recommended that your internet download speed is at least 5.0 mbps. You can use this tool to test your current connection.

We do not recommend the use of iPads or Chromebooks for ASU Sync because these devices do not work for class exams that may be proctored remotely.

If you are not able to personally finance the equipment that you need to attend class via ASU Sync, ASU has a laptop and WiFi hotspot checkout program available through ASU Library.

Who is eligible?

- Any currently enrolled ASU student is eligible to checkout a laptop or WiFi hotspot. The current availability of laptops can be found here.

Borrowing and returning laptop rules

- Laptops are lent on a first-come, first-serve basis, and cannot be reserved in advance. They can be returned at any time, but will be due at the conclusion of the fall 2020 semester.
- Rentals are limited to one laptop per student.
- Laptops are available for checkout at the following libraries on all four campuses: (Please check online for current library hours)
    - Downtown Phoenix campus Library
    - Polytechnic campus Library
    - Tempe: Hayden and Noble Libraries
    - West campus: Fletcher Library
- Return laptops to any ASU Library Information Desk (not at the drop box or other location)
- Refer to ASU Library Computer Use Policy and ASU Computer, Internet, and Electronic Communications Policy.
- Borrowers are responsible for loss, damage, and theft of the laptop while in their possession. Borrowers should verify the condition of the laptop at the time of check-out and upon check-in.

Student Success

To be successful:

- check the course daily
- read announcements
- read and respond to course email messages as needed
- complete assignments by the due dates specified
- communicate regularly with your instructor and peers
- create a study and/or assignment schedule to stay on track
- access ASU Online Student Resources or CISA Academic Resources

Assignments and Exams:

Percentage Distribution:	
Homework assignments	75%
Lab work	25%
Total	**100%**

Course Grading System:

Grades will be determined by the percentage you accumulate:

A	90-100	Excellent
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Students must first speak with the instructor of the class to discuss any disputed grades. If, after review, a resolution is not achieved, students may proceed with the appeal process. Student grade appeals must be processed in the regular semester immediately following the issuance of the grade in dispute (by commencement for fall or spring), regardless whether the student is enrolled at the university. Complete details are available in the CISA Grade Appeals policy.

Academic Integrity

Academic honesty is expected of all students in all examinations, papers, laboratory work, academic transactions and records. The possible sanctions include, but are not limited to, appropriate grade penalties, course failure (indicated on the transcript as a grade of E), course failure due to academic dishonesty (indicated on the transcript as a grade of XE), loss of registration privileges, disqualification and dismissal. For more information, see provost.asu.edu/academicintegrity.

If you fail to meet the standards of academic integrity in any of the criteria listed on the university policy website, sanctions will be imposed by the instructor, college, and/or dean. Academic dishonesty includes, but is not limited to, cheating on an academic evaluation or assignment, plagiarizing, academic deceit (such as fabricating data or information), or falsifying academic records. Turning in an assignment (all or in part) that you completed for a previous class is considered self-plagiarism and falls under these guidelines. Any infractions of self-plagiarism are subject to the same penalties as copying someone else's work without proper citations. Students who have taken this class previously and would like to use the work from previous assignments should contact the instructor for permission to do so.

If you have any questions about your work and the academic integrity policy, please discuss your assignment or concerns with your instructor, teaching assistant, or your college Academic Integrity Officer in advance of submitting an assignment. Student resources on Sun Devil Integrity and strategies for completing your work with integrity and avoiding plagiarism are available here: ASU Student Resources for Academic Integrity or provost.asu.edu/academicintegrity for more information.

Harassment Prohibited

ASU policy prohibits harassment on the basis of race, sex, gender identity, age, religion, national origin, disability, sexual orientation, Vietnam era veteran status, and other protected veteran status. Violations of this policy may result in disciplinary action, including termination of employees or expulsion of students. Students are encouraged to report harassment to instructors and the Dean of Students Office.

Student Conduct

ASU and the College of Integrative Sciences and Arts expects and requires its students to act with honesty, integrity, and respect. Required behavior standards are listed in the Student Code of Conduct and Student Disciplinary Procedures, Computer, Internet, and Electronic Communications policy, ASU Student Academic Integrity Policy, and outlined by the Office of Student Rights & Responsibilities. Anyone in violation of these policies is subject to sanctions. Students are entitled to receive instruction free from interference by other members of the class. An instructor may withdraw a student from the course when the student's behavior disrupts the educational process per Instructor Withdrawal of a Student for Disruptive Classroom Behavior. The Office of Student Rights and Responsibilities accepts incident reports from students, faculty, staff, or other persons who believe that a student or a student organization may have violated the Student Code of Conduct.

Students must refrain from uploading to any course shell, discussion board, or website used by the course instructor or other course forum, material that is not the student's original work, unless the students first comply with all applicable copyright laws; faculty members reserve the right to delete materials on the grounds of suspected copyright infringement.

Title IX

Title IX is a federal law that provides that no person be excluded on the basis of sex from participation in, be denied benefits of, or be subjected to discrimination under any education program or activity. Both Title IX and university policy make clear that sexual violence and harassment based on sex is prohibited. An individual who believes they have been subjected to sexual violence or harassed on the basis of sex can seek support, including counseling and academic support, from the university. If you or someone you know has been harassed on the basis of sex or sexually assaulted, you can find information and resources at https://sexualviolenceprevention.asu.edu/faqs.

As a mandated reporter, I am obligated to report any information I become aware of regarding alleged acts of sexual discrimination, including sexual violence and dating violence. ASU Counseling Services, https://eoss.asu.edu/counseling, is available if you wish to discuss any concerns confidentially and privately.

Disability Accommodations

Qualified students with disabilities who will require disability accommodations in this class are encouraged to make their requests to the instructor at the beginning of the semester either during office hours or by appointment. Note: Prior to receiving disability accommodations, verification of eligibility from the Disability Resource Center (DRC) is required. Disability information is confidential.

Disability Resource Center (eoss.asu.edu/drc)

Email: DRC@asu.edu
DRC Phone: 480-965-1234
DRC FAX: 480-965-0441

Statement on Inclusion

Arizona State University is deeply committed to positioning itself as one of the great new universities by seeking to build excellence, enhance access, and have an impact on our community, state, nation, and the world. To do that requires our faculty and staff to reflect the intellectual, ethnic, and cultural diversity of our nation and world so that our students learn from the broadest perspectives, and we engage in the advancement of knowledge with the most inclusive understanding possible of the issues we are addressing through our scholarly activities. We recognize that race and gender historically have been markers of diversity in institutions of higher education. However, at ASU, we believe that diversity includes additional categories such as socioeconomic background, religion, sexual orientation, gender identity, age, disability, veteran status, nationality, and intellectual perspective.

Mental Health

As a student, like anyone else, you may experience a range of challenges that can interfere with learning, such as strained relationships, increased anxiety, substance use, feeling down, difficulty concentrating, and/or lack of motivation. These emotional health concerns or stressful events may diminish your academic performance and/or reduce your ability to participate in daily activities. ASU Counseling Services provides counseling and crisis services for students who are experiencing a mental health concern. Any student may call or walk-in to any ASU counseling center for a same-day or future appointment to discuss any personal concern. Here is the website: eoss.asu.edu/counseling. After office hours and 24/7 ASU's dedicated crisis line is available for crisis consultation by calling 480-921-1006.

Establishing a Safe Environment

Learning takes place best when a safe environment is established in the classroom. In accordance with SSM 104-02 of the Student Services Manual, students enrolled in this course have a responsibility to support an environment that nurtures individual and group differences and encourages engaged, honest discussions. The success of the course rests on your ability to create a safe environment where everyone feels comfortable to share and explore ideas. We must also be willing to take risks and ask critical questions. Doing so will effectively contribute to our own and others' intellectual and personal growth and development. We welcome disagreements in the spirit of critical academic exchange, but please remember to be respectful of others' viewpoints, whether you agree with them or not.

All incidents and allegations of violent or threatening conduct by an ASU student (whether on- or off-campus) must be reported to the ASU Police Department (ASU PD) and the Office of the Dean of Students. If either office determines that the behavior poses or has posed a serious threat to personal safety or to the welfare of the campus, the student will not be permitted to return to campus or reside in any ASU residence hall until an appropriate threat assessment has been completed and, if necessary, conditions for return are imposed. ASU PD, the Office of the Dean of Students, and other appropriate offices will coordinate the assessment in light of the relevant circumstances.

Prohibition of Commercial Notetaking Services

In accordance with ACD 304-06 Commercial Note Taking Services, written permission must be secured from the official instructor of the class in order to sell the instructor's oral communication in the form of notes. Notes must have the note taker's name as well as the instructor's name, the course number, and the date.

Course Evaluation

Students are expected to complete the course evaluation. The feedback provides valuable information to the instructor and the college and is used to improve student learning. Students are notified when the online evaluation form is available. The results are always anonymous and cannot be reviewed by the instructor/department until after final grades have been posted.

Trigger Warning

Please note that some course content may be deemed offensive by some students, although it is not my intention to offend anyone. In addition, some materials that we link with online might also be considered offensive, troubling, or difficult to review in terms of language or graphics. I attempt to provide warnings when introducing this kind of material; yet, if I forget to do so, or if something else (in my materials or posts from fellow students) seems offensive, please contact me at **dugger@asu.edu**, or the faculty head.

Academic Affairs Manual

For a complete guide to Arizona State University course policies, please refer to the Academic Affairs Manual (ACD).

Syllabus Disclaimer

The syllabus is a statement of intent and serves as an implicit agreement between the instructor and the student. Every effort will be made to avoid changing the course schedule but the possibility exists that unforeseen events will make syllabus changes necessary. Remember to check your ASU email and the course site often.

momentum, or *spin*, that determines their grouping characteristics. Quantum Theory tells us that the desired field behavior can occur only if forces are mediated by messenger particles having angular momenta equal to integer multiples of $h/2\pi$ (i.e., $0, 1h/2\pi, 2h/2\pi, 3h/2\pi, \ldots$). The angular momentum of the virtual photon is $1(h/2\pi)$; it's a spin-1 particle. The exceedingly important class of interactions that have spin-1 messengers are known as **gauge forces**, and the electromagnetic force is the model for all the gauge forces. Today, the magic of action-at-a-distance is understood via the no less mysterious exchange of virtual particles, but at least now a highly predictive mathematical theory is in place that describes the phenomenon.

Assigned problems are highlighted

PROBLEMS

Complete solutions to all problems—except those with an asterisk—can be found in the back of the book.

3.1 Consider the plane electromagnetic wave in vacuum (in SI units) given by the expressions $E_x = 0, E_y = 2\cos[2\pi \times 10^{14}(t - x/c) + \pi/2]$, and $E_z = 0$.

(a) What are the frequency, wavelength, direction of motion, amplitude, initial phase angle, and polarization of the wave?

(b) Write an expression for the magnetic flux density.

3.2 Write an expression for the $\vec{\mathbf{E}}$- and $\vec{\mathbf{B}}$-fields that constitute a plane harmonic wave traveling in the $+z$-direction. The wave is linearly polarized with its plane of vibration at 45° to the yz-plane.

3.3* Considering Eq. (3.30), show that the expression

$$\vec{\mathbf{k}} \times \vec{\mathbf{E}} = \omega \vec{\mathbf{B}}$$

is correct as it applies to a plane wave for which the direction of the electric field is constant.

3.4* Imagine an electromagnetic wave with its $\vec{\mathbf{E}}$-field in the y-direction. Show that Eq. (3.27)

$$\frac{\partial E}{\partial x} = -\frac{\partial B}{\partial t}$$

applied to the harmonic wave $\vec{\mathbf{B}}$

$$\vec{\mathbf{E}} = \vec{\mathbf{E}}_0 \cos(kx - \omega t) \qquad \vec{\mathbf{B}} = \vec{\mathbf{B}}_0 \cos(kx - \omega t)$$

yields the fact that

$$E_0 = cB_0$$

in agreement with Eq. (3.30).

3.5* An electromagnetic wave is specified (in SI units) by the following function:

$$\vec{\mathbf{E}} = (-6\hat{\mathbf{i}} + 3\sqrt{5}\hat{\mathbf{j}})(10^4 \text{ V/m})\, e^{i\left[\frac{1}{3}(\sqrt{5}x + 2y)\pi \times 10^7 - 9.42 \times 10^{15} t\right]}$$

Remember that $\vec{\mathbf{E}}_0$ and $\vec{\mathbf{k}}$ are perpendicular to each other.

Find (a) the direction along which the electric field oscillates, (b) the scalar value of amplitude of the electric field, (c) the direction of propagation of the wave, (d) the propagation number and wavelength, (e) the frequency and angular frequency, and (f) the speed.

3.6 The electric field of an electromagnetic wave traveling in the positive x-direction is given by

$$\vec{\mathbf{E}} = E_0 \hat{\mathbf{j}} \sin\frac{\pi z}{z_0} \cos(kx - \omega t)$$

(a) Describe the field verbally. (b) Determine an expression for k. (c) Find the phase speed of the wave.

3.7* If the electric field $\vec{\mathbf{E}}(z, t)$ of an EM wave in vacuum is, at a certain location and time, given by $\vec{\mathbf{E}} = (10\,\text{V/m})(\cos 0.5\pi)\hat{\mathbf{i}}$, write an expression for the associated $\vec{\mathbf{B}}$-field.

3.8* A 550-nm harmonic EM wave whose electric field is in the z-direction is traveling in the y-direction in vacuum. (a) What is the frequency of the wave? (b) Determine both ω and k for this wave. (c) If the electric field amplitude is 600 V/m, what is the amplitude of the magnetic field? (d) Write an expression for both $E(t)$ and $B(t)$ given that each is zero at $x = 0$ and $t = 0$. Put in all the appropriate units.

3.9* The E-field of an electromagnetic wave is described by

$$\vec{\mathbf{E}} = (\hat{\mathbf{i}} + \hat{\mathbf{j}})E_0 \sin(kz - \omega t + \pi/6)$$

Write an expression for the B-field. Determine $\vec{\mathbf{B}}(0, 0)$.

3.10* Using the wave given in the previous problem, determine $\vec{\mathbf{E}}(-\lambda/2, 0)$ and draw a sketch of the vector representing it at that moment.

3.11* A plane electromagnetic wave traveling in the y-direction through vacuum is given by

$$\vec{\mathbf{E}}(x, y, z, t) = E_0 \hat{\mathbf{i}}\, e^{i(ky - \omega t)}$$

Determine an expression for the corresponding magnetic field of the electromagnetic wave. Draw a diagram showing $\vec{\mathbf{E}}_0$, $\vec{\mathbf{B}}_0$, and $\vec{\mathbf{k}}$, the propagation vector.

3.12* Given that the $\vec{\mathbf{B}}$-field of an electromagnetic wave in vacuum is

$$\vec{\mathbf{B}}(x, y, z, t) = B_0 \hat{\mathbf{j}}\, e^{i(kz + \omega t)}$$

write an expression for the associated $\vec{\mathbf{E}}$-field. What is the direction of propagation?

3.13* Calculate the energy input necessary to charge a parallel-plate capacitor by carrying charge from one plate to the other. Assume the

energy is stored in the field between the plates and compute the energy per unit volume, u_E, of that region, that is, Eq. (3.31). *Hint:* Since the electric field increases throughout the process, either integrate or use its average value $E/2$.

3.14* Starting with Eq. (3.32), prove that the energy densities of the electric and magnet fields are equal ($u_E = u_B$) for an electromagnetic wave.

3.15 The time average of some function $f(t)$ taken over an interval T is given by

$$\langle f(t)\rangle_T = \frac{1}{T}\int_t^{t+T} f(t')\,dt'$$

where t' is just a dummy variable. If $\tau = 2\pi/\omega$ is the period of a harmonic function, show that

$$\langle \sin^2(\vec{\mathbf{k}}\cdot\vec{\mathbf{r}} - \omega t)\rangle = \tfrac{1}{2}$$

$$\langle \cos^2(\vec{\mathbf{k}}\cdot\vec{\mathbf{r}} - \omega t)\rangle = \tfrac{1}{2}$$

and

$$\langle \sin(\vec{\mathbf{k}}\cdot\vec{\mathbf{r}} - \omega t)\cos(\vec{\mathbf{k}}\cdot\vec{\mathbf{r}} - \omega t)\rangle = 0$$

when $T = \tau$ and when $T >> \tau$.

3.16* Show that a more general formulation of the previous problem yields

$$\langle \cos^2\omega t\rangle_T = \tfrac{1}{2}[1 + \operatorname{sinc}\omega T\cos 2\omega t]$$

for any interval T.

3.17* With the previous problem in mind, prove that

$$\langle \sin^2\omega t\rangle_T = \tfrac{1}{2}[1 - \operatorname{sinc}\omega T\cos 2\omega t]$$

for any interval T.

3.18* Prove that the irradiance of a harmonic EM wave in vacuum is given by

$$I = \frac{1}{2c\mu_0}E_0^2$$

and then determine the average rate at which energy is transported per unit area by a plane wave having an amplitude of 15.0 V/m.

3.19* A 1.0-mW laser produces a nearly parallel beam 1.0 cm^2 in cross-sectional area at a wavelength of 650 nm. Determine the amplitude of the electric field in the beam, assuming the wavefronts are homogeneous and the light travels in vacuum.

3.20* A nearly cylindrical laserbeam impinges normally on a perfectly absorbing surface. The irradiance of the beam (assuming it to be uniform over its cross section) is 40 W/cm^2. If the diameter of the beam is $2.0/\sqrt{\pi}$ cm how much energy is absorbed per minute?

3.21* The following is the expression for the $\vec{\mathbf{E}}$-field of an electromagnetic wave traveling in a homogeneous dielectric:

$$\vec{\mathbf{E}} = (-100\ \text{V/m})\hat{\mathbf{i}}\,e^{i(kz-\omega t)}$$

Here $\omega = 1.80\times10^{15}$ rad/s and $k = 1.20\times10^{7}$ rad/m.

(a) Determine the associated $\vec{\mathbf{B}}$-field. (b) Find the index of refraction. (c) Compute the permittivity. (d) Find the irradiance. (e) Draw a diagram showing $\vec{\mathbf{E}}_0$, $\vec{\mathbf{B}}_0$, and $\vec{\mathbf{k}}$, the propagation vector.

3.22* A tungsten lightbulb puts out 20 W of radiant energy (most of it IR). Assume it to be a point source and calculate the irradiance 1.00 m away.

3.23* Consider a linearly polarized plane electromagnetic wave traveling in the $+x$-direction in free space having as its plane of vibration the xy-plane. Given that its frequency is 10 MHz and its amplitude is $E_0 = 0.08$ V/m,

(a) Find the period and wavelength of the wave.

(b) Write an expression for $E(t)$ and $B(t)$.

(c) Find the flux density, $\langle S\rangle$, of the wave.

3.24* On average, the net electromagnetic power radiated by the Sun, its so-called *luminosity* (L), is 3.9×10^{26} W. Determine the mean amplitude of the electric field due to all the radiant energy arriving at the top of Earth's atmosphere (1.5×10^{11} m from the Sun).

3.25 A linearly polarized harmonic plane wave with a scalar amplitude of 10 V/m is propagating along a line in the xy-plane at 45° to the x-axis with the xy-plane as its plane of vibration. Please write a vector expression describing the wave assuming both k_x and k_y are positive. Calculate the flux density, taking the wave to be in vacuum.

3.26 Pulses of UV lasting 2.00 ns each are emitted from a laser that has a beam of diameter 2.5 mm. Given that each burst carries an energy of 6.0 J, (a) determine the length in space of each wavetrain, and (b) find the average energy per unit volume for such a pulse.

3.27* A laser provides pulses of EM-radiation in vacuum lasting 10^{-12} s. If the radiant flux density is 10^{20} W/m^2, determine the amplitude of the electric field of the beam.

3.28 A 1.0-mW laser has a beam diameter of 2 mm. Assuming the divergence of the beam to be negligible, compute its energy density in the vicinity of the laser.

3.29* A cloud of locusts having a density of 100 insects per cubic meter is flying north at a rate of 6 m/min. What is the flux density of locusts? That is, how many cross an area of 1 m^2 perpendicular to their flight path per second?

3.30 Imagine that you are standing in the path of an antenna that is radiating plane waves of frequency 100 MHz and flux density 19.88×10^{-2} W/m^{-2}. Compute the photon flux density, that is, the number of photons per unit time per unit area. How many photons, on the average, will be found in a cubic meter of this region?

3.31* How many photons per second are emitted from a 100-W yellow lightbulb if we assume negligible thermal losses and a quasimonochromatic wavelength of 550 nm? In actuality only about 2.5% of the total dissipated power emerges as visible radiation in an ordinary 100-W incandescent lamp.

3.32 A 3.0-V incandescent flashlight bulb draws 0.25 A, converting about 1.0% of the dissipated power into light ($\lambda \approx 550$ nm). If the beam has a cross-sectional area of 10 cm^2 and is approximately cylindrical,

(a) How many photons are emitted per second?

(b) How many photons occupy each meter of the beam?

(c) What is the flux density of the beam as it leaves the flashlight?

3.33* An isotropic quasimonochromatic point source radiates at a rate of 100 W. What is the flux density at a distance of 1 m? What are the amplitudes of the $\vec{\mathbf{E}}$- and $\vec{\mathbf{B}}$-fields at that point?

3.34 Using energy arguments, show that the amplitude of a cylindrical wave must vary inversely with $\sqrt{r}$. Draw a diagram indicating what's happening.

3.35* What is the momentum of a 10^{19}-Hz X-ray photon?

3.36 Consider an electromagnetic wave impinging on an electron. It is easy to show kinematically that the average value of the time rate-of-change of the electron's momentum $\vec{\mathbf{p}}$ is proportional to the average value of the time rate-of-change of the work, W, done on it by the wave. In particular,

$$\left\langle \frac{d\vec{\mathbf{p}}}{dt} \right\rangle = \frac{1}{c}\left\langle \frac{dW}{dt} \right\rangle \hat{\mathbf{i}}$$

Accordingly, if this momentum change is imparted to some completely absorbing material, show that the pressure is given by Eq. (3.51).

3.37* A harmonic electromagnetic plane wave with a wavelength of 0.12 m travels in vacuum in the positive z-direction. It oscillates along the x-axis such that at $t = 0$ and $z = 0$, the E-field has a maximum value of $E(0, 0) = +6.0\,V/m$. (a) Write an expression for $\vec{\mathbf{E}}(z, t)$. (b) Write an expression for the magnetic field. (c) Write an expression for the vector momentum density of the wave.

3.38* Derive an expression for the radiation pressure when the normally incident beam of light is totally reflected. Generalize this result to the case of oblique incidence at an angle θ with the normal.

3.39 A completely absorbing screen receives 300 W of light for 100 s. Compute the total linear momentum transferred to the screen.

3.40 The average magnitude of the Poynting vector for sunlight arriving at the top of Earth's atmosphere (1.5×10^{11} m from the Sun) is about 1.4 kW/m^2.

(a) Compute the average radiation pressure exerted on a metal reflector facing the Sun.

(b) Approximate the average radiation pressure at the surface of the Sun whose diameter is 1.4×10^9 m.

3.41* A surface is placed perpendicular to a beam of light of constant irradiance (I). Suppose that the fraction of the irradiance absorbed by the surface is α. Show that the pressure on the surface is given by

$$\mathcal{P} = (2 - \alpha)I/c$$

3.42* A light beam with an irradiance of $2.00 \times 10^6\ W/m^2$ impinges normally on a surface that reflects 70.0% and absorbs 30.0%. Compute the resulting radiation pressure on the surface.

3.43 What force on the average will be exerted on the (40 m × 50 m) flat, highly reflecting side of a space station wall if it's facing the Sun while orbiting Earth?

3.44 A parabolic radar antenna with a 2-m diameter transmits 200-kW pulses of energy. If its repetition rate is 500 pulses per second, each lasting 2 μs, determine the average reaction force on the antenna.

3.45 Consider the plight of an astronaut floating in free space with only a 10-W lantern (inexhaustibly supplied with power). How long will it take to reach a speed of 10 m/s using the radiation as propulsion? The astronaut's total mass is 100 kg.

3.46 Consider the uniformly moving charge depicted in Fig. 3.26*b*. Draw a sphere surrounding it and show via the Poynting vector that the charge does not radiate.

3.47* A plane, harmonic, linearly polarized lightwave has an electric field intensity given by

$$E_z = E_0 \cos\pi\, 10^{15}\left(t - \frac{x}{0.65c}\right)$$

while traveling in a piece of glass. Find

(a) The frequency of the light.

(b) Its wavelength.

(c) The index of refraction of the glass.

3.48* What is the speed of light in diamond if the index of refraction is 2.42?

3.49* Given that the wavelength of a lightwave in vacuum is 540 nm, what will it be in water, where $n = 1.33$?

3.50* Determine the index of refraction of a medium if it is to reduce the speed of light by 10% as compared to its speed in vacuum.

3.51 If the speed of light (the phase speed) in Fabulite ($SrTiO_3$) is 1.245×10^8 m/s, what is its index of refraction?

3.52* What is the distance that yellow light travels in water (where $n = 1.33$) in 1.00 s?

3.53* A 500-nm lightwave in vacuum enters a glass plate of index 1.60 and propagates perpendicularly across it. How many waves span the glass if it's 1.00 cm thick?

3.54* Yellow light from a sodium lamp ($\lambda_0 = 589$ nm) traverses a tank of glycerin (of index 1.47), which is 20.0 m long, in a time t_1. If it takes a time t_2 for the light to pass through the same tank when filled with carbon disulfide (of index 1.63), determine the value of $t_2 - t_1$.

3.55* A lightwave travels from point A to point B in vacuum. Suppose we introduce into its path a flat glass plate ($n_g = 1.50$) of thickness $L = 1.00$ mm. If the vacuum wavelength is 500 nm, how many waves span the space from A to B with and without the glass in place? What phase shift is introduced with the insertion of the plate?

3.56 The low-frequency relative permittivity of water varies from 88.00 at 0°C to 55.33 at 100°C. Explain this behavior. Over the same range in temperature, the index of refraction ($\lambda = 589.3$ nm) goes from roughly 1.33 to 1.32. Why is the change in n so much smaller than the corresponding change in K_E?

3.57 Show that for substances of low density, such as gases, which have a single resonant frequency ω_0, the index of refraction is given by

$$n \approx 1 + \frac{Nq_e^2}{2\epsilon_0 m_e(\omega_0^2 - \omega^2)}$$

3.58* In the next chapter, Eq. (4.47), we'll see that a substance reflects radiant energy appreciably when its index differs most from the medium in which it is embedded.

(a) The dielectric constant of ice measured at microwave frequencies is roughly 1, whereas that for water is about 80 times greater—why?

(b) How is it that a radar beam easily passes through ice but is considerably reflected when encountering a dense rain?

3.59 Fuchsin is a strong (aniline) dye, which in solution with alcohol has a deep red color. It appears red because it absorbs the green component of the spectrum. (As you might expect, the surfaces of crystals of fuchsin reflect green light rather strongly.) Imagine that you have a thin-walled hollow prism filled with this solution. What will the spectrum look like for incident white light? By the way, anomalous dispersion was first observed in about 1840 by Fox Talbot, and the effect was christened in 1862 by Le Roux. His work was promptly forgotten, only to be rediscovered eight years later by C. Christiansen.

3.60* Take Eq. (3.71) and check out the units to make sure that they agree on both sides.

3.61 The resonant frequency of lead glass is in the UV fairly near the visible, whereas that for fused silica is far into the UV. Use the dispersion equation to make a rough sketch of n versus ω for the visible region of the spectrum.

3.62* Show that Eq. (3.70) can be rewritten as

$$(n^2 - 1)^{-1} = -C\lambda^{-2} + C\lambda_0^{-2}$$

where $C = 4\pi^2 c^2 \epsilon_0 m_e / N q_e^2$.

3.63 Augustin Louis Cauchy (1789–1857) determined an empirical equation for $n(\lambda)$ for substances that are transparent in the visible. His expression corresponded to the power series relation

$$n = C_1 + C_2/\lambda^2 + C_3/\lambda^4 + \cdots$$

where the Cs are all constants. In light of Fig. 3.41, what is the physical significance of C_1?

3.64 Referring to the previous problem, realize that there is a region between each pair of absorption bands for which the Cauchy Equation (with a new set of constants) works fairly well. Examine Fig. 3.41: what can you say about the various values of C_1 as ω decreases across the spectrum? Dropping all but the first two terms, use Fig. 3.40 to determine approximate values for C_1 and C_2 for borosilicate crown glass in the visible.

3.65* Crystal quartz has refractive indexes of 1.557 and 1.547 at wavelengths of 410.0 nm and 550.0 nm, respectively. Using only the first two terms in Cauchy's Equation, calculate C_1 and C_2 and determine the index of refraction of quartz at 610.0 nm.

3.66* In 1871 Sellmeier derived the equation

$$n^2 = 1 + \sum_j \frac{A_j \lambda^2}{\lambda^2 - \lambda_{0j}^2}$$

where the A_j terms are constants and each λ_{0j} is the vacuum wavelength associated with a natural frequency ν_{0j}, such that $\lambda_{0j}\nu_{0j} = c$. This formulation is a considerable practical improvement over the Cauchy Equation. Show that where $\lambda >> \lambda_{0j}$, Cauchy's Equation is an approximation of Sellmeier's. *Hint:* Write the above expression with only the first term in the sum; expand it by the binomial theorem; take the square root of n^2 and expand again.

3.67* If an ultraviolet photon is to dissociate the oxygen and carbon atoms in the carbon monoxide molecule, it must provide 11 eV of energy. What is the minimum frequency of the appropriate radiation?

Curriculum Vita

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Education

- Doctor of Philosophy, Department of Physics and Astronomy
  Arizona State University, Tempe, AZ - December 2001
  Dissertation: η and η' Meson Photoproduction on the Proton
  Adviser: Barry Graham Ritchie
- Bachelor of Science, *magna cum laude*, Department of Physics and Astronomy,
  Northern Arizona University, Flagstaff, AZ - December 1993
  Major: Merged Major in Physics and Mathematics

Employment

- 2017-present: Associate Professor, College of Integrative Sciences and Arts, ASU
- 2013-2017: Associate Research Professor, Department of Physics, ASU
- 2006-2013: Assistant Research Professor, Department of Physics, ASU
- 2002-2006: Postdoctoral Research Associate, Department of Physics, ASU
- 1996-2001: Graduate Research Associate, Department of Physics, ASU
- 1994-1996: Graduate Teaching Assistant, Department of Physics, ASU

Research grants

- 2019-2022: Department of Energy grant "Experimental Medium Energy Physics at Arizona State University" (PI: M. Dugger, 100%, award number DE-SC0020404, award amount: $450,000)
- 2013-2018: National Science Foundation grant "Meson Physics at Arizona State University" (PI: B.G. Ritchie 50%, Co-PI: M. Dugger 50%, award number PHY-1306737, award amount: $530,000)
- 2010-2013: National Science Foundation grant "Meson Physics at Arizona State University" (PI: B.G. Ritchie 50%, Co-PI: M. Dugger 50%, award number PHY-0969201, award amount: $510,000)
- 2007-2010: National Science Foundation grant "Meson Physics at Arizona State University" (PI: B.G. Ritchie 33%, Co-PI: E. Pasyuk 33%,Co-PI: M. Dugger 33%, award number PHY-0653630, award amount: $480,000)

Honors and Awards

- 2002: Mark Anderson Outstanding Doctoral Thesis Award
- 1993: Vesto Melvin Slipher Scholarship in the Sciences
- 1992: Northern Arizona University, Department of Physics Achievement Award

Teaching experience

2017-present: Arizona State University, Polytechnic Campus, Mesa, AZ

- PHY 112 - *General Physics II*
- PHY 321 - *Vector Mechanics and Vibrations*
- PHY 331 - *Principles of Modern Electromagnetism*
- PHY 493 - *Honors Thesis*
- PHY 495 - *Project Research*
- PHY 499 - *Individualized Instruction*

2016: Arizona State University, West Campus, Glendale, AZ

- PHY 113 - *University Physics Lab I*

1994-2016: Arizona State University, Tempe Campus, Tempe, AZ

- PHY 101 - *Introduction to Physics*
- PHY 111 - *Recitation for General Physics I*
- PHY 112 - *Recitation for General Physics II*
- PHY 113 - *General Physics Lab I*
- PHY 132 - *University Physics Lab I*
- PHY 361 - *Recitation for Introduction to Modern Physics*
- PHY 495 - *Project Research*
- PHY 499 - *Individualized Instruction*

Publications in refereed journals

The CLAS collaboration stands for CEBAF (Continuous Electron Beam Accelerator Facility) Large Acceptance Spectrometer, and articles from that collaboration list the lead authors first and then subsequent authors by alphabetical order. The GlueX collaboration obeys a strict alphabetical listing for all authors included on any paper.

The publications since 2017 have been annotated.

1. S. Adhikari *et al*.(GlueX Collaboration), "*Measurement of beam asymmetry for π−Δ++ photoproduction on the proton at EγE_\gammaEγ=8.5 GeV*, Phys.Rev.C **103**, L022201 (2021)

2. M. Carver *et al*.(CLAS Collaboration), "*Photoproduction of the f2(1270)f_2(1270)f2(1270) meson using the CLAS detector*", Phys.Rev.Lett. **126** (2021) 8, 082002

3. T.B. Hayward *et al*.(CLAS12 Collaboration), "*Observation of Beam Spin Asymmetries in the Process ep→e′π+π−Xep\rightarrow{e}^{'}{\pi}^{+}{\pi}^{-}Xep→e′π+π−X with CLAS12*", Phys.Rev.Lett. **126** (2021) 152501

4. U. Shresha, *et al*.(CLAS Collaboration), "*Differential cross sections for Λ(1520)\Lambda(1520)Λ(1520) using photoproduction at CLAS*", Phys.Rev.C **103** (2021) 2, 025206

5. N. Zachariou, *et al*.(CLAS Collaboration), "*Double polarisation observable G\mathbb GG for single pion photoproduction from the proton*", Phys.Lett.B **817** (2021) 136304
6. S. Adhikari *et al*., for the GlueX collaboration, *The GlueX beamline and detector*, Nucl. Inst. Meth. A **987** (2021) 164897
7. A. Celentano *et al*., for the CLAS Collaboration, *First measurement of direct photoproduction* of the $a_2(1320)^0$ meson on the proton, Phys. Rev. C **102** (2020) 3, 032201
8. S. Adhikari *et al*., for the GlueX collaboration, *Measurement of the photon beam asymmetry in* $\gamma p \to K^+ \Sigma^0$ *at* $E_\gamma = 8.5$ *GeV*, Phys. Rev. C 101 (2020) 6, 065206
9. A. Schmidt *et al*., for the CLAS Collaboration, *Probing the core of the strong nuclear interaction*, Nature **578** (2020) 7796, 540-544
10. S. Adhikari et al, for the GlueX collaboration, *Beam Asymmetry Σ for the Photoproduction of η and η′ Mesons at* $E_\gamma = 8.8$ *GeV*, Phys. Rev. C **100** (2019) 5, 052201
11. A. Ali *et al.*, *First measurement of near-threshold J/ψ exclusive photoproduction off the proton*, Phys. Rev. Lett. **123** (2019) (7), p. 072001

12. P. Roy *et al.*, *First Measurements of the Double-Polarization Observables F , P , and H in Photoproduction off Transversely Polarized Protons in the N* Resonance Region*, Phys. Rev. Lett. **122** (2019) (16), p. 162301

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14. S. Lombardo *et al.*, *Photoproduction of* K^+K^- *meson pairs on the proton*, Phys. Rev. **D98** (2018) (5), p. 052009

15. E. Golovatch *et al.*, *First results on nucleon resonance photocouplings from the* $\gamma p \to \pi^+\pi^- p$ *reaction*, Phys. Lett. **B788** (2019), pp. 371–379

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18. M. C. Kunkel *et al.*, *Exclusive photoproduction of* π^0 *up to large values of Mandelstam variables s, t and u with CLAS*, Phys. Rev. **C98** (2018) (1), p. 015207

19. P. Roy *et al.*, *Measurement of the beam asymmetry* Σ *and the target asymmetry T in the photoproduction of ω mesons off the proton using CLAS at Jefferson Laboratory*, Phys. Rev. **C97**

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20. Z. Akbar *et al.*, *Measurement of the helicity asymmetry E in $\omega \to \pi^+\pi^-\pi^0$ photoproduction*, Phys. Rev. **C96** (2017) (6), p. 065209

21. A. V. Anisovich, V. Burkert, P. M. Collins, M. Dugger, E. Klempt, V. A. Nikonov, B. G. Ritchie, A. V. Sarantsev and U. Thoma, *$N^* \to N\eta'$ decays from photoproduction of η'-mesons off protons*, Phys. Lett. **B772** (2017), pp. 247–252

22. P. Collins *et al.*, *Photon beam asymmetry Σ in the reaction $\vec{\gamma}p \to p\omega$ for E_γ = 1.152 to 1.876 GeV*, Phys. Lett. **B773** (2017), pp. 112–120

23. P. T. Mattione *et al.*, *Differential cross section measurements for $\gamma n \to \pi^- p$ above the first nucleon resonance region*, Phys. Rev. **C96** (2017) (3), p. 035204

24. A. V. Anisovich *et al.*, *Differential cross sections and polarization observables from CLAS K* photoproduction and the search for new N* states*, Phys. Lett. **B771** (2017), pp. 142–150

25. M. Dugger *et al.*, *Design and construction of a high-energy photon polarimeter*, Nucl. Instrum. Meth. **A867** (2017), pp. 115–127

26. P. Collins *et al.*, *Photon beam asymmetry Σ for η and η' photoproduction from the proton*, Phys. Lett. **B771** (2017), pp. 213–221

27. H. Al Ghoul *et al.*, *Measurement of the beam asymmetry Σ for π^0 and η photoproduction on the proton at E_γ = 9 GeV*, Phys. Rev. **C95** (2017) (4), p. 042201

28. R. Dickson *et al.*, *Photoproduction of the $f_1(1285)$ Meson*, Phys. Rev. **C93** (2016) (6), p. 065202

29. C. A. Paterson *et al.*, *Photoproduction of Λ and Σ^0 hyperons using linearly polarized photons*, Phys. Rev. **C93** (2016) (6), p. 065201

30. I. Senderovich *et al.*, *First measurement of the helicity asymmetry E in η photoproduction on the proton*, Phys. Lett. **B755** (2016), pp. 64–69

31. S. Strauch *et al.*, *First Measurement of the Polarization Observable E in the $\vec{p}(\vec{\gamma}, \pi^+)n$ Reaction up to 2.25 GeV*, Phys. Lett. **B750** (2015), pp. 53–58

32. O. Hen *et al.*, *Momentum sharing in imbalanced Fermi systems*, Science **346** (2014), pp. 614–617

33. K. Moriya *et al.*, *Spin and parity measurement of the Lambda(1405) baryon*, Phys. Rev. Lett. **112** (2014) (8), p. 082004

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45. M. Williams *et al.*, *Differential cross sections and spin density matrix elements for the reaction gamma p → p omega*, Phys. Rev. **C80** (2009), p. 065208

46. M. Dugger *et al.*, *pi+ photoproduction on the proton for photon energies from 0.725 to 2.875-GeV*, Phys. Rev. **C79** (2009), p. 065206

47. G. Gavalian *et al.*, *Beam spin asymmetries in deeply virtual Compton scattering (DVCS) with CLAS at 4.8 GeV*, Phys. Rev. **C80** (2009), p. 035206

48. J. Lachniet *et al.*, *A Precise Measurement of the Neutron Magnetic Form Factor* $G_n(M)$ *in the Few-GeV*^{2} *Region*, Phys. Rev. Lett. **102** (2009), p. 192001

49. M. Battaglieri *et al.*, *First measurement of direct f0(980) photoproduction on the proton*, Phys. Rev. Lett. **102** (2009), p. 102001

50. G. V. Fedotov *et al.*, *Electroproduction of p pi+ pi- off protons at* $0.2 < Q^2 < 0.6$*-GeV*^{2} *and* $1.3 < W < 1.57$*-GeV with CLAS*, Phys. Rev. **C79** (2009), p. 015204

51. M. Osipenko *et al.*, *Measurement of unpolarized semi-inclusive pi+ electroproduction off the proton*, Phys. Rev. **D80** (2009), p. 032004

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53. M. Nozar *et al.*, *Search for the photo-excitation of exotic mesons in the pi+ pi+ pi- system*, Phys. Rev. Lett. **102** (2009), p. 102002

54. A. S. Biselli *et al.*, *First measurement of target and double spin asymmetries for polarized-e polarized-p e-p pi0 in the nucleon resonance region above the Delta(1232)*, Phys. Rev. **C78** (2008), p. 045204

55. I. G. Aznauryan *et al.*, *Electroexcitation of the Roper resonance for* $1.7 < Q^2 < 4.5$ *-GeV2 in vec-ep → en pi+*, Phys. Rev. **C78** (2008), p. 045209

56. J. P. Santoro *et al.*, *Electroproduction of phi(1020) mesons at* $1.4 < Q^2 < 3.8$ *GeV*^{2} *measured*

with the CLAS spectrometer, Phys. Rev. **C78** (2008), p. 025210

57. M. H. Wood *et al.*, *Light Vector Mesons in the Nuclear Medium*, Phys. Rev. **C78** (2008), p. 015201

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60. P. E. Bosted *et al.*, *Ratios of N-15/ C-12 and He-4/ C-12 inclusive electroproduction cross sections in the nucleon resonance region*, Phys. Rev. **C78** (2008), p. 015202

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64. K. Park *et al.*, *Cross sections and beam asymmetries for vec(e) ~~p~~→en pi+ in the nucleon resonance region for $1.7 <= Q^2 <= 4.5$-(GeV)^2*, Phys. Rev. **C77** (2008), p. 015208

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66. M. Dugger *et al.*, *pi0 photoproduction on the proton for photon energies from 0.675 to 2.875-GeV*, Phys. Rev. **C76** (2007), p. 025211

67. H. Denizli *et al.*, *Q*2 dependence of the S(11)(1535) photocoupling and evidence for a P-wave resonance in eta electroproduction*, Phys. Rev. **C76** (2007), p. 015204

68. T. Mibe *et al.*, *First measurement of coherent phi-meson photoproduction on deuteron at low energies*, Phys. Rev. **C76** (2007), p. 052202

69. Y. Ilieva *et al.*, *Evidence for a backward peak in the gama d → pi0 d cross section near the eta threshold*, Eur. Phys. J. **A43** (2010), pp. 261–267

70. L. Guo *et al.*, *Cascade production in the reactions gamma p → K+ K+ (X) and gamma p → K+ K+ pi- (X)*, Phys. Rev. **C76** (2007), p. 025208

71. I. Hleiqawi *et al.*, *Cross-sections for the gamma p → K*0 Sigma+ reaction at E(gamma) = 1.7-GeV - 3.0-GeV*, Phys. Rev. **C75** (2007), p. 042201, [Erratum: Phys. Rev.C76,039905(2007)]

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73. R. K. Bradford *et al.*, *First measurement of beam-recoil observables C(x) and C(z) in hyperon photoproduction*, Phys. Rev. **C75** (2007), p. 035205

74. P. Ambrozewicz *et al.*, *Separated structure functions for the exclusive electroproduction of K+ Lambda and K+ Sigma0 final states*, Phys. Rev. **C75** (2007), p. 045203

75. P.E. Bosted *et al.*, *Quark-hadron duality in spin structure functions g(1)p and g(1)d*, Phys. Rev. **C75** (2007), p. 035203

76. R. De Vita *et al.*, *Search for the Theta+ pentaquark in the reactions gamma p → anti-K0 K+n and gamma p → anti-K0 K0p*, Phys. Rev. **D74** (2006), p. 032001

77. M. Ungaro *et al.*, *Measurement of the N → Delta+(1232) transition at high momentum transfer by pi0 electroproduction*, Phys. Rev. Lett. **97** (2006), p. 112003

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79. S. Chen *et al.*, *Measurement of deeply virtual compton scattering with a polarized proton target*, Phys. Rev. Lett. **97** (2006), p. 072002

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123. D. I. Sober *et al.*, *The bremsstrahlung tagged photon beam in Hall B at JLab*, Nucl. Instrum. Meth. **A440** (2000), pp. 263–284

Service 2017-present

Profession

- Member of the International Advisory Committee for the MENU (Meson Nucleon) 2019 Conference.
- Review Committee member of the 2018 Division of Nuclear Physics, Conference Experience for Undergraduates.
- Reviewer for Physical Review Letters.
- Reviewer for Physical Reviews C.

University

- Member of the Graduate College review committee for the 2018 ARCS (Achievement Rewards

for College Scientists) Fellowship.

- Member of the Graduate College review committee for the 2019 ARCS (Achievement Rewards for College Scientists) Fellowship.
- Member of the Graduate College review committee for the 2020 ARCS (Achievement Rewards for College Scientists) Fellowship.
- Member of the Polytechnic Science and Mathematics Safety Committee 2022

Invited talks at conferences and seminars

- *Overview of Spectroscopy Results in Meson Photoproduction with Polarization Observables*, XVI International Conference on Hadron Spectroscopy, September 14, 2015
- *Latest results from the CLAS N* polarization program*, American Physical Society, Denver, Colorado, April 16, 2013
- *First data from FROST*, JLab Users Group Meeting, Jefferson Lab, Newport News, Virginia, June 8, 2011
- *Non-strange pseudoscalar photoproduction from the proton*, Seminar at Idaho State University, Pocatello, ID, April, 15, 2010
- Σ *for* $\gamma p \to p\pi^0$, $n\pi^+$, *and* $p\eta$ *from CLAS g8b run period with 0.95 GeV* $< E_\gamma <$ 1.2 *GeV*, Narrow Nucleon Resonances Workshop, University of Edinburgh, Scotland, June 8, 2009
- *Pseudoscalar meson photoproduction with CLAS*, George Washington University Nuclear Physics Seminar, Washington D.C., March 11, 2008
- *Photoproduction of* η *and* η' *Mesons from the Proton*, The eleventh International Conference on Meson-Nucleon Physics and the Structure of the Nucleon,MENU 2007, Juelich, Germany, September 10, 2007
- $S = 0$ *pseudoscalar photoproduction from the proton*, The fifth annual International Workshop on Physics of Excited Nucleons, N^* 2005, Tallahassee, Florida, October 14, 2005