ENHANCING THE FLIPPED PHYSICS CLASSROOM THROUGH THE USE OF

PREFLIGHT QUESTIONS

by

Daniel James DuBrow

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In presenting this professional paper in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

Daniel James DuBrow

July 2014

DEDICATION

This is for you, Dad.

ACKNOWLEDGEMENT

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ABSTRACT

Students in my sophomore honors physics course at Evanston Township High school appeared to have difficulty connecting the content they learned from my flipped classroom video lectures to their assignments, including homework, labs, and tests. In order to address this, I created several "preflights", which students completed after watching video lectures, but before coming to class. Two of my classes comprised the treatment group and two others comprised the comparison group. I wanted to determine the impact of preflights on student learning, including whether they help students understand video lecture material more effectively and whether they increase student confidence in their learning. I also wished to try out various formats of preflights to see which was most effective for student learning. I found that preflights had a positive effect on student learning overall, and modestly increased student confidence in their learning. Based on student interviews and other data, I determined that the most effective and preferred format of preflight was a guided tutorial, where I led students through a problem, and then asked them to perform a similar task. I concluded that in general, preflights were an effective way to increase student performance and confidence in their learning.

INTRODUCTION AND BACKGROUND

Evanston Township High School, just north of Chicago, IL, is located in an urban city of 75,000 residents. The city is bordered on the East by Lake Michigan, on the South by the City of Chicago, on the West by Skokie, and on the North by Wilmette. This makes for an extremely diverse city environment. Evanston is home to Northwestern University and therefore hosts an additional 10,000 undergraduate students during the school year. Although the median income in Evanston is about $66,000 for males and $53,000 for females, 12.1% of the population lives at or below the poverty line.

Evanston Township High School itself has a student population of 3,155, with 40.8% of its students classified as low-income enrollment. White students make up 42.9% of the student population at ETHS, while 32% are African American, 15.4% are Hispanic/Latino, 3.8% are Asian, and about 6% identify as biracial, Native Hawaiian, or American Indian.

Teaching and Classroom Environment

I have recently adopted a flipped classroom in my honors Physics class (called 2 Chem-Phys) at Evanston Township High School. In this classroom setup, students watch lectures on topics at home before working on labs, homework, and other activities in class. Students appeared to have difficulty connecting the content they learn from these video lectures to their assignments, including homework, labs, and tests. I suspected this resulted from difficulty overcoming common misconceptions students have on material even after viewing the video lectures. This may also have resulted from student inability to apply material learned on video lectures to homework and lab problems.

I want all students to be able to apply the content they learn to their assignments, and to have the opportunity to receive individualized attention during class. To accomplish this, I instituted the use of "preflights" which targeted specific misconceptions, and guided students through practice problems.

<u>Focus Question</u>

What is the impact of using "preflights" in-between video lectures and classroom discussion?

<u>Sub-Questions:</u>

1. Do preflights help students understand video lecture material more effectively?

2. Do preflights increase student confidence in their learning?

3. What format of preflights are most effective?

CONCEPTUAL FRAMEWORK

"If you considered how you learned something you are good at… how did you do it? No one would ever answer: I listened to this really great lecture! Instead, most people would respond: I learned by doing, and practicing many hours. So why do we set up our classes this way?"
-- Leigh Smith (2013, March Meeting of the American Physical Society)

The Inverted Classroom, also known as the Flipped Classroom, has been a very popular trend in math and science education in recent years. A review of the literature on the flipped classroom model reveals serious flaws in the lecture model of instruction, as well as reasons for instituting a flipped classroom. Finally, a discussion of how to improve a flipped classroom through Just-in-Time-Teaching (JiTT), or "Preflights" is presented.

For many years, the lecture model of instruction, where professors and high school teachers act as the "Sage on the Stage", has predominated in the math and science classroom, as anyone who has attended college can attest. This model ignores the existing literature on the drawbacks of lecture in favor of convenience or cost. Berrett (2012) states that the lecture model "endures because it makes economic sense" (p. 2). Putting hundreds of students in a lecture hall (or 40 or more in a high school classroom) saves money for universities and school districts. But Foertsch, Moses, Strikwerda and Litzkow (2002) argue that in math and science, instructor expertise and "face-to-face time is essentially wasted" (p. 2). Kaner and Fielder (2005) criticize live lecture, pointing out that "short-term memory capacity varies among learners" and "live lectures sometimes drift or ramble" (para. 23). Even with the most attentive classes possible and best lecturers available, "it is difficult to tell if students are learning" (Toto & Nguyen, 2009, p. 1), and student involvement is limited (Gannod, Burge, & Helmick, 2008, p. 3). Furthermore, lecture focuses on low-level thinking like memorization rather than deep understanding (Marcey & Jones, 2012, p. 2). Sadaghiani (2012) asserts that regular class time "competes with interactive demonstrations, simulations, cooperative problem solving, conceptual tutorials, and peer instruction" (p. 301), and Foertsch et al. (2002) remind us that "the 'problem' with lectures has more to do with their timing than their content" (p. 2). Some teachers and professors assign reading from the book before class to prepare students for lecture, but Chen, Stelzer, and Gladding (2010) show that "asking students to read the textbook prior to coming to lecture is not an effective strategy to provide such an initial exposure" (p. 1). The same research group found that in

engineering physics courses, "the textbook was the least valued resource in the course" (Stelzer, Brookes, Gladding, & Mestre, 2010, p. 755).

Although most of the problems with lecture stated above are most prevalent at the university level, they still exist, albeit in sometimes different forms, at the high school and middle school levels. Most readers can remember a high school class where they were extremely disengaged due to a teacher lecturing for 45-60 minutes. For this reason, "flipping the class" or the "inverted classroom" was first developed at the college level, but soon became adapted for high school and middle school use (Novak, 2011; Lage, Platt, & Treglia, 2000; Bergmann & Sams, 2007).

Given all of these difficulties with lecture, it is not surprising that teachers and professors began wondering if there was a better way to teach higher-order thinking skills. The development of the flipped classroom in the mid-to-late 1990s was a huge paradigm shift in education and changed the game for many teachers (Lage et al., 2000, p. 41).

In the flipped classroom, "typical in-class lecture time is replaced with laboratory and other in-class activities" (Gannod et al., 2008, p. 1). A flipped classroom model has been used for years in humanities and law courses where "the Socratic method compels students to study the material before class or risk buckling under a barrage of their professor's questions" (Berrett, 2012, p. 3). There are many variations of the flipped classroom, but one characteristic most have in common is the use of video lectures, podcasts, or PowerPoint slides in order to "move low level cognitive lecture material out of the classroom" (Toto et al., 2009, p. 2). This can be accomplished in a number of ways. For example, a program such as Microsoft OneNote may be used with a tablet PC

to write notes, while a program such as Screencast-o-matic (www.screencast-o-matic.com) can be used to record a teacher writing notes while talking.

Many of the reasons supporting the use of a flipped classroom model have already been presented in discussing the problems with lecture, but there are several positive components to flipping. Havana, IL Superintendent Mark Twomey reminds us "Technology is how they [students] learn today" (Finkel, 2012, p. 30), and one of the pioneers of flipping at the high school level, Aaron Sams, states, "They need us there to help them understand the content, not to deliver the content" (Aaron Sams, quoted in Elmore, 2012, p. 2). Foertsch et al. (2009) believe "most instructors will tell you it [when students have the most questions] is not when [they] are listening to a lecture, but when they are trying to apply the principles (p. 3)."

Other researchers have described various characteristics of the flipped classroom, such as Gannod et al. (2008) who believe the flipped classroom should be customized, provide immediate feedback, be constructive, be motivating, and be enduring. Brame (2012) says that among other things, the flipped classroom should "provide an opportunity for students to gain first exposure prior to class" and "provide an incentive for students to prepare for class" (p. 4). The flipped classroom must be carefully thought out and implemented.

The most impactful drawback of converting a classroom to a flipped model is the time commitment. Kaner and Fielder (2005) report taking up to 35 hours per lesson to make videos and digitize content. Others who have implemented flipped classes (Lage et al., 2000; Berrett, 2012) do not hide the fact that this is very-labor intensive and in some cases costly. This author has used aspects of the flipped classroom himself and can attest

to the amount of time needed to produce quality videos, including planning and outlining

lecture content, recording the video without major presentation errors, processing videos,

and finally uploading to a website for student viewing. A second major drawback is that

teachers who have until now filled their class time with lecture must adjust their

classroom teaching strategies, both by finding new activities for students, and ensuring

student buy-in to the new system (Bergmann & Sams, 2012; Finkel, 2012; Gerstein,

2011). Specifically, Bergmann and Sams (2012) emphasize how crucial it is for students

to "identify learning as their goal" rather than "completion of assignments" (p.2). And

sometimes teachers must be stricter with their classroom discipline in a more chaotic

flipped classroom (Brian Bennett quoted in Finkel, 2012, p. 29). Finally, there are still

many students and professors who resist the flipped classroom due to lingering

attachment to lecture. Foertsch et al. (2009) detail reasons students disliked the flipped

classroom they implemented, including things like they "missed [having] the opportunity

to ask questions in the middle of a lecture" and "some students felt the 'more formal' and

'more focused' setting of a live lecture would have encouraged them to pay fuller

attention" (p. 10).

The benefits of flipping the classroom far outweigh these drawbacks. As

mentioned previously, flipping allows for higher-order thinking. Lage et al. (2000) talk

about students being able to work in groups on difficult problems "without sacrificing

course coverage" (p. 39). Flipping gives instructors the ability to "hear – and correct –

misunderstandings as they arise" (Berrett, p. 3). Another major benefit to flipping that

several researchers have documented is placing more responsibility for learning on the

student's shoulders (Berrett, 2012; Elmore, 2012; Fulton, 2012; Gannod, 2008; Pierce &

Fox, 2012). For example, Andrew Martin, a biology instructor at the University of

Colorado at Boulder, states that "Students are effectively educating each other. It means

they're in control, and not me" (Andrew Martin, quoted in Berrett, 2012, p. 1). Because

of its nature, flipping facilitates differentiation. During a lecture, all students must

necessarily be on the same page. But if the flipped classroom is used, some students may

be working in small groups with the instructor on homework problems they didn't

understand, while others may be finishing a lab, watching videos, or working ahead. The

increase of one-on-one attention also addresses the "achievement gap" between some

groups of students. Mike Dronen, of Stillwater Area Public Schools (Minn.), states that

this extra attention "could improve prospects for lower-income students" as well as

special education students, who can "pause and rewind the videos to give themselves

extra time" (Mike Dronen, quoted in Finkel, 2012, p. 32-34, Finkel adds that this

classroom structure is "invaluable for students who get little homework help at home".

(p. 30) Whereas some students may get help from parents or siblings, flipping the

classroom promotes more equity in education.

Finally, flipping draws on the best talents of the instructor. As Gannod et al.

remind us, "valuable faculty 'face time' is not spent merely communicating information,

but rather is spent engaging directly with students when they are involved in in-depth

learning activities" (p. 1).

Berrett (2012) tells us how students at the University of Michigan's flipped

calculus courses showed "gains at about twice the rate of those in traditional lectures" on

concept inventories (p. 4). In a Renal Pharmacotherapy Module, Pierce et al (2012)

measured an increase of 4% on final exam scores for students in a flipped class vs. a

traditional lecture class (p. 3). In another study of flipped classrooms, there was a "control" class that received traditional lectures, and an "experimental" group that watched video lectures (Marcey et al., 2012, p. 5). The researchers noticed that students in the "control" group found out about the video lectures and started watching them! Gains have also been documented at the high school level. For example, at Byron High School (MN)), students increased their math mastery as measured on the MN. Comprehensive Assessments from 29.9% in 2006 (pre-flipped) to 73.8% in 2011 (post-flipped) (Fulton, 2012, p. 4). At Clintondale High School (MI), "failure rate among freshman math students dropped from 44 percent to 13 percent in one year's time" while juniors taking state math exams improved "by 10 percent" (Greg Green quoted in Finkel, 2012, p. 30). Since flipping moves low-level content outside of class, more time can be devoted to higher-order thinking, and Brame (2012) confirms that this time is spent well: "students taught with interactive engagement methods exhibited learning gains almost two standard deviations higher than those observed in the traditional courses" (p. 2).

Using Preflights/Just-in-Time-Teaching to improve the flipped classroom model.

The flipped classroom has already been shown to be effective in increasing student learning outcomes. But what specific strategies can teachers use to ensure that the flipped classroom is as effective as it could be? A major drawback that has already been discussed is that students need to be motivated enough to actually watch the videos prior to coming to class – if they do not, the entire premise of the flipped class is invalidated. One thing teachers can do to bridge the gap between watching videos and class discussions is called Just-in-Time-Teaching.

Just-in-Time-Teaching (JiTT) is "a pedagogical technique utilizing web-based pre-instruction assignments called warm-ups or preflights" (Novak, 2011, p. 64). Pioneered by Gregor Novak at IUPUI, Eric Mazur at Harvard, and the Physics Education Research group at UIUC (Mats Selen, Gary Gladding &Tim Stelzer, et al., 2010), among others, JiTT transforms how teachers use the flipped classroom (Novak, 2011; Stelzer et al., 2010). According to Novak (2011), students submit responses to different types of preflights, whether they are multimedia learning modules (MLMs), multiple choice Google forms, etc., and teachers are able to "incorporate insights gained by students' responses into the upcoming lesson" (Novak, 2011, p. 64). Zappe et al. (2006) describe JiTTs as "dynamic assessments" that focus on how students will understand the material better rather than "on understanding of past performance" (p. 2). Zappe goes on to explain that JiTTs serve to "create links between their background and conceptual understanding" (Zappe et al., 2006, p. 3). In this way, students are able to bridge the gap between what they watch in videos, and classroom discussions and homework sets.

Gregor Novak (2011) describes a process by which teachers can implement JiTT in their flipped classrooms. The steps include thinking about the lesson content and lesson type, identifying important concepts or equations [for a science or math course], writing questions that probe for misconceptions, and outlining a class session which anticipates responses to these probing questions (p. 66). For example, the author's student teacher recently implemented a preflight as part of a circuits unit. The student teacher identified the current (rate flow of charge in a circuit) as an area where students have many misconceptions. He wrote a preflight question, using Google Forms, which asked students to answer the true/false question, "When you flip the light switch, the

lights turn on almost instantly because charge flows through circuits at extremely fast speeds." Students also had to justify their response. This question represents a misconception because electrons themselves travel very slowly through materials (drift velocity is only a few cm/s) but the electric field travels at nearly the speed of light. Then he took student answers and worked them into his discussion of the topic of circuits at the beginning of the next class period, based on Zappe et al.'s (2006) recommendation to include example responses that "are particularly interesting or relevant" anonymously, as well as those that show "common misconceptions in the material" (p. 3).

Just as the flipped classroom model itself has many benefits and drawbacks which must be carefully weighed, so does JiTT, and in fact they run in parallel. One major drawback is that teachers using JiTT must ensure that students actually complete the preflights (Chen, 2010; Novak, 2011). Granted, this is no different from worrying about students completing homework or other assignments. Both Chen et al. (2010) and Novak (2011) advocate that teachers use the ultimate motivator, points, for preflights to encourage student completion. Some teachers might not allow students to participate in the lesson unless the preflight is completed. Another obstacle to overcome is that students may be afraid to submit answers if they could be wrong. To avoid this, Novak (2011) urges teachers to help students "see that 'wrong' answers are not evidence of failure" but rather of learning (p. 69). On the other hand, the positive aspects of JiTT are numerous. Using JiTT increases student responsibility, because starting a lesson with a preflight "invites students to assume some of the ownership of the process" (Novak, 2011, p. 65). Also, JiTT and preflights work wonders on student engagement in material (Zappe et al., 2006, p. 3). As the name suggests, "Just-in-Time" means that students get

immediate feedback on their work, and teachers can make sure "students' misconceptions [are]… corrected well before they emerge on a midterm or final exam" (Berrett, 2012, p. 2). At UIUC, using a form of preflights called MLMs (Multimedia Learning Modules) allowed instructors to "convert a 50 min lecture from all lecture to half overview of material and half solving more elaborate problems" (Stelzer et al., 2010, p. 756). As mentioned previously, flipping and JiTT bring more higher-order thinking into the classroom. Finally, JiTT can reduce student perception of course difficulty (Stelzer et al., 2010, p. 757). This is an enormous boon at the high school level, as much of the problem with student achievement at the author's school relates to students' motivation and self-confidence in achievement.

A search of past literature did not reveal any specific instances of JiTT performed at the high school level, but many college instructors are using them. As early as 1996, Lage et al. (2000) used worksheets which students completed prior to class which were "randomly… graded for completeness" in conjunction with videotaped lectures (p. 33). In a computer software testing course, Kaner and Fielder (2005) gave orientation exercises which "gives the students a problem to work through that they probably won't adequately solve – but that will be solved in next lecture" (p. 9). In a geosciences course, Zappe et al. (2006) used "DinoBytes" which asked multiple choice or short answer questions on the material (p. 4). For the past fifteen years, the Physics Education Research group at UIUC has used a JiTT model which incorporates the aforementioned Multimedia Learning Modules (MLMs), and more recently, has transformed them into what they have called SmartPhysics lessons (Chen, 2010, p. 1; SmartPhysics.com). The lack of research studies on teachers using JiTT at the high school level does not mean

suitable materials for the high school classroom are unavailable. The author has used

"nTIPERs", or Newtonian Tasks Inspired by Physics Education Research (Hieggelke,

Maloney, & Kanim, 2012) when he taught an AP Physics course in past years. At lower

levels, Paul Hewitt's "Next-Time Questions" would function perfectly as preflights

(Hewitt & Yan, 2001). These are similar to entrance slips or openers that many teachers

utilize now. In reality however, teachers can construct any sort of question as a preflight,

or use any of the aforementioned resources.

METHODOLOGY

The primary research question I investigated was the effect of using preflights to

enhance student learning. These preflights were administered after students watched

video lectures but before they took quizzes on the material in class. Specifically, I

examined whether preflights helped students learn material from the video lecture more

effectively, whether preflights increased student confidence, and finally which type of

preflight is most effective.

Participants

The participants for this study were students in my sophomore Chem-Phys class.

I have five sections of this sophomore course. For this study, I chose two sections to be

my treatment sections. I also used two sections as a comparison group. The treatment

group had 9 minority students, 21 girls, and 23 boys. The treatment group had one

student with an IEP, which was for extended test-taking time for medical reasons. The

socio-economic level varied within the treatment group, mirroring the school population

as a whole. Specific data was not available on student socio-economic level. The

comparison group consisted of 43 students, 8 of which were minorities, 19 girls, and 24

boys. The comparison group had one student with an IEP, which allowed extended test-taking time for cognitive reasons. The socio-economic level within the comparison group mirrored the school population as a whole. Specific data was not available on student socio-economic level..

This was an honors-level class and was the start of a three year sequence for students in science at ETHS. Students had a double period (43 min each) of chemistry one day, which was taught by my colleague, and a double period of physics taught by me the next day. The course is designed to show students the relationship between physics and chemistry and continues onto AP Chemistry and AP Physics during students' junior and senior years. In order to be enrolled in the course, students must have earned at least a B in Honors Biology and be concurrently enrolled in Algebra 2 Honors.

<u>Intervention</u>

The treatment took place for approximately 4 weeks during January and February 2014, during our unit on circular motion and gravity. In this unit, students typically struggle with several concepts, including the direction of centripetal acceleration, and the role of gravity as a centripetal force. These are natural concepts to focus on in terms of misconceptions. The unit was organized into several subsections. First, students studied concepts related to centripetal force and acceleration. They then learned how to apply Newton's 2nd Law of motion, $F_{net} = ma$, to various situations of circular motion, such as the forces on a car going over a hill. Next, they learned Newton's Law of Universal Gravitation, and the energy of an orbit. Finally, they learned about Kepler's Laws of Planetary Motion. They investigated the link between gravity as a centripetal force and Kepler's 3rd Law of motion, and also orbital and escape velocity.

The unit was organized in such a way that students watched videos about the first major topic, centripetal acceleration, and then came to class to discuss the topic and work on labs and problems related to it. The treatment group had the additional task of completing four preflights, which they did after watching the video lectures. A summary of the preflights, and the content they pertained to, is below, in Table 1.

Table 1:
Summary of Preflights

Preflight #	Preflight Description /Format	Concepts	Preflight Sample Question	Videos to be watched Prior to Preflight:
1	Short-answer, Google Doc Forms	Centripetal Motion, velocity & acceleration	"What is the direction of the velocity vector at point A?"	#55: Uniform Circular Motion & Centripetal Acceleration
2	Multiple-choice (conceptual)	Centripetal force, inertia	"If the string breaks at the point shown, what is the path of the rock?"	#56: Derivation of a = v^2/R #57: Centripetal acceleration example problem #58: Definition of centripetal force #59: Using F = ma with centripetal force
3	Tutorial & Free Response	Comparison of gravitational forces	"If the mass of planet 1 is doubled but the distance between them is doubled, how does the gravitational force compare to its original value?"	#60 & 61: Newton's Law of Gravity #62: Deriving 'g' #63 & 64: Gravitational potential energy
4	Multiple-choice (calculation)	Kepler's 3rd Law	"Calculate the orbital period of a planet which orbits the Sun at a distance of 3.0 AU."	#65: Kepler's Laws #66: Gravity as a Centripetal Force #67: Kepler's 3rd Law #68: Weightlessness

One of the preflights students completed dealt with centripetal force and inertia in circular paths. Figure 1, below, illustrates this preflight.
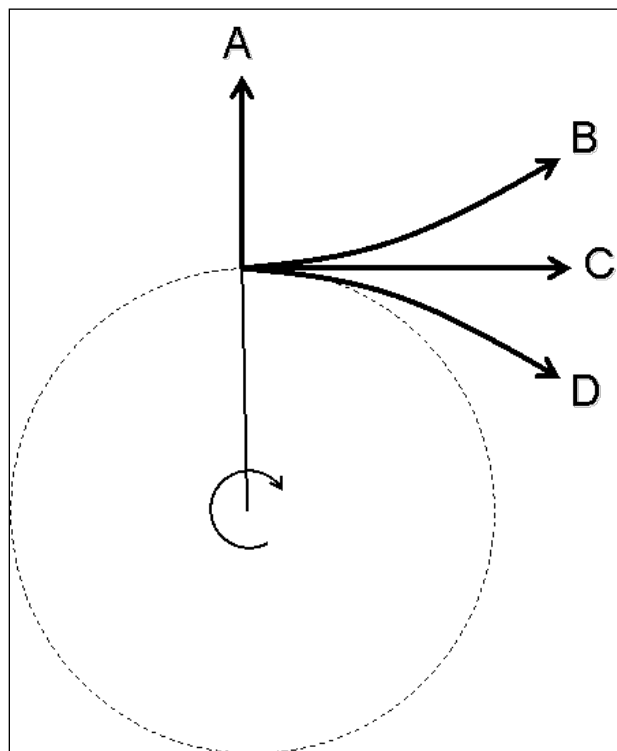
A girl twirls a rock on the end of a string in a horizontal circle above her head. The diagram illustrates how this looks from above. If the string breaks at the instant shown, which arrow best represents the path the rock will follow?

Figure 1. Preflight #2.

This particular preflight was adapted from a similar activity used in the

undergraduate physics courses at UIUC. Professors there have developed a whole series

of video lectures (with in-lecture questions), checkpoints such as Preflight #2 which I am

using, and homework assignments, all combined into a seamless unit at

www.SmartPhysics.com. For my study, however, I just used one of the checkpoints the

UIUC team has written.

Only the treatment groups were assigned to complete the preflights. Additional

preflights were used (Appendices E-H) and consisted of a multiple-choice question on

centripetal force, a tutorial on comparing gravitational forces, and a straightforward

calculation using Kepler's 3rd Law. Both treatment and comparison groups then took

video quizzes which covered material similar to that encountered in the video lectures,

and, for the treatment group, to that on the preflights. As an example, Video Quiz #2,

which follows Preflight #2, is shown below, in Figure 2.
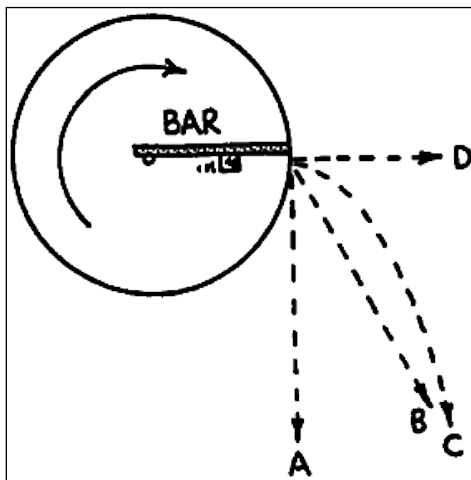
"If a small object is placed on a rotating disk (like a record player) it will slide off the edge. Suppose you fasten a bar on the disk as shown in the top view, and allow the object to slide from an inside position, along the bar, and off the edge. Which of the paths shown would be most likely?" (Hewitt, 2002, p. 49)

Figure 2. Video Quiz #2.

Data Collection

Several data collection instruments were used, along with student grades,

interviews, and surveys, in order to answer the research questions. At the beginning of

the unit, I administered a pretest to determine whether the treatment and comparison

groups were beginning in the same place in terms of their knowledge of circular motion

and gravity. I also examined both groups' prior performance on assessments in the

course, particularly, their first semester's final exam scores.

For my main focus question, I determined the impact that the preflights have on student learning. In order to achieve this quantitatively, I compared scores on the unit posttest between the two groups, as well as scores on the individual video quizzes. I also interviewed students, asking 5-6 students from both treatment and comparison groups to voluntarily take part in the interview. Also, I kept a journal with my observations. For example, I looked at the content and accuracy of student responses to the preflights, and recorded if there were noticeable differences between the two groups. The interview questions and journaling prompts are found in the Appendix.

In order to investigate the first sub-question, whether the preflights help students understand video material more effectively, I analyzed test scores and conducted student interviews.

The second sub-question dealt with whether preflights increased student confidence in their learning. I investigated this primarily by analyzing data from pre- and post-treatment attitude surveys. A student attitude survey focused on student confidence in learning, and perceived effectiveness of the video lectures. Since the attitude survey was administered to both treatment and comparison groups, I was able to look at the effect of preflights on student confidence and effectiveness of my video lectures. Additionally, I conducted student interviews, which gave me insight into whether the preflights built student confidence.

Finally, I determined which format of preflight was most effective. To analyze this, I developed a preflight format survey, where I asked students to think about the different types of preflights they experienced during a unit, and comment on what they felt worked best for them. This was only given to the treatment group. I also employed

instructor journaling and student interviews to answer this sub-question. Table 2, below,

summarizes my data collection strategy. All instruments can be found in the Appendix.

Table 2:
Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
Primary Question: What is the impact of using "preflights" in-between video lectures and classroom discussion on student learning?	Student performance on assessments	Pre and post-treatment attitude survey	
Secondary Questions: 2. Do preflights help students understand video lecture material more effectively?	Instructor observations and journaling	Student interviews	
3. Do preflights increase student confidence in their learning?	Pre and posttreatment attitude surveys	Posttreatment student interviews	Preflight format survey
4. What format of preflights are most effective?	Instructor observations and journaling	Preflight format survey	Posttreatment student interviews

DATA AND ANALYSIS

In order to analyze this data, it was necessary to establish that both comparison

and treatment groups were similar in terms of academic achievement and background. I

then discuss data which support or reject my focus and sub-questions.

Analysis of Comparison and Treatment Groups.

As mentioned in the Methodology section above, four classes of students were

selected; two of these became the comparison group, and two were the treatment group.

It was important to establish whether these groups were similar in achievement in order

to determine the validity of the data collected in this study. One measure of this was the

average score on the first semester final exam. A summary of these scores for the four

classes involved in the study are shown in Table 3.

Table 3
First Semester Final Exam Average Scores

Group	Average Score (points/100)	Standard Deviation (points)	N
Comparison	69.73	15.88	44
Treatment	68.89	15.45	43

Students in the comparison group scored similarly on the first semester physics final

exam to students in the treatment group ($M_{comparison} = 69.73$, $SD_{comparison} = 15.88$; $M_{treatment}$

$= 68.89$, $SD_{treatment} = 15.45$). It appeared that the comparison group (Sections 1 & 2) was

more homogeneous than the treatment group (Sections 3 & 4), but the range of abilities in

each class was approximately the same. The difference between the comparison and

treatment groups was not significant, $t(85) = 0.2500$, $p = 0.8032$.

A second measure used to ensure validity was the difference in pretest and

posttest scores for the comparison and treatment groups. The pretest and posttest were

identical, 10-question multiple choice assessments, drawn from

www.thephysicsclassroom.com (see Appendix M). This assessment did not focus on the

topics of the preflights, but was rather more general and conceptual. A summary of the

pretest and posttest scores, along with average student gains (posttest – pretest score) is

shown in Table 4.

Table 4
Average Pre/Posttest Scores and Gains

Group	Average Pretest Score (20 points max)	Average Posttest Score (20 points max)	Average Gain (Posttest – Pretest)
Comparison	6.49 (N = 44)	10.95 (N = 44)	4.49
Treatment	6.17 (N = 42)	10.32 (N = 41)	4.26

The standard deviation on average gain was 3.26 for the comparison group and 3.37 for

the treatment group. Student gains ranged anywhere from -1 to 11 in the comparison

group, and from -4.5 to 11 for the treatment group. Some students may not have taken

these tests as seriously as one might wish, even though extra credit was awarded to both

groups for improving their score on the posttest by a certain amount The difference

between the average posttest scores for the comparison and treatment groups was not

significant, $t(84) = .7844$, $p = .4350$.

Both of these indicators seem to suggest that the comparison and treatment groups

were similar enough to be analyzed for the purpose of the study.

Impact of Preflights on Student Learning.

Student scores on the end of unit exam and video quizzes showed mixed results in

regards to the impact of preflights on student learning. The unit exam (see Appendix M)

contained four questions which were directly related to the four preflights. Student

achievement on these particular questions is shown in Table 5.

Table 5
Student Performance on Unit Exam Selected Questions

Question # (Preflight #)	% Students Answering Correctly (Comparison)	% Students Answering Correctly (Treatment)	Difference (Treatment – Comparison)
#1 (PF 1)	86.36	97.62	+11.26
#2 (PF 2)	88.64	92.86	+4.22
#12 (PF 3)	86.36	80.95	-5.41
#13 (PF 4)	75.00	78.37	+3.37

Question #1 on the exam asked students to identify the direction of an object's

acceleration while in circular motion. The treatment group score of over 11 points more

than the comparison group was the highest of the four questions aligned with the

preflights. Question #2 was identical to preflight 2, where a girl twirls a rock on a string

and then lets go. The difference of about 4 points was significant but not as large as for

Question #1. The treatment group scored more than 5 points lower on Question #13,

which asked students to analyze the effect of changing mass and radius on gravitational

force, exactly like preflight 3. Question #13 asked students to solve a problem related to

Kepler's 3rd Law, like preflight 4. There was a slight positive difference for the treatment

group on this question.

Student scores on the four video quizzes also displayed mixed results. A

summary of scores, with P-values, is shown in Table 6.

Table 6
Student Performance on Video Quizzes (C = Comparison, T = Treatment)

	Video Quiz 1		Video Quiz 2		Video Quiz 3		Video Quiz 4	
	C	T	C	T	C	T	C	T
N	43	43	43	43	43	43	43	43
Mean	4.64	4.78	3.47	4.12	4.09	4.51	4.40	4.58
σ	0.77	0.44	0.98	0.96	1.06	0.86	1.16	0.98
P Value	0.3036		0.0026		0.0468		0.4392	

The difference in performance on Video Quiz 1 for the comparison group (M = 4.64, SD = 0.77) and the treatment group (M = 4.78, SD = 0.44), was not significant, t(84) = 1.0352, p = .3036. Similarly, student performance on Video Quiz 4 did not differ in a statistically significant fashion, t(84) = 0.7773, p = 0.4392. Students in the treatment group performed significantly better than those in the comparison group on Video Quiz 2, t(84) = 3.1070, p = 0.0026, and also on Video Quiz 3, t(84) = 2.0177, p = 0.0468. These results suggest that the Preflights were effective in increasing student achievement on video quizzes 2 and 3.

Finally, an attitude survey was administered to students both before and after the treatment (see Appendix A). The comparison group had an average of 4.37 points (out of 5) for Question 7, "I feel that the preflights help me to do better on the video quizzes". This reflects 6 students who chose "Neutral", 15 who chose "Agree", and 22 who chose "Strongly Agree". Zero students (N = 43) selected "Disagree" or "Strongly Disagree." This demonstrates the positive effect the preflights may have had on student confidence.

Effect of Preflights on Understanding Lecture Material.

In addition to student scores on assessments, during the study I took notes on student responses to the preflights and video quizzes, and analyzed these notes. I looked for any patterns which indicated that the preflights helped the treatment group understand the video material better. Specifically, I looked at student work on the preflights, and then at how the treatment and comparison groups answered the video quiz questions, to determine if there was a difference. Students in the treatment group in general had work that showed fuller understanding of the video lectures, and their responses to video quizzes showed more ability to apply the material.

The first preflight was a short answer format. Students were asked to give brief descriptions of how to calculate velocity and acceleration for objects moving in circular paths, and to describe the directions of these vectors. The average score on the preflight was 3.91/4.00 points, showing that most students were able to draw directly from their notes to answer the questions. The accompanying video quiz asked students to calculate the velocity and acceleration of an object moving in a circle, and to draw those vectors at a specific point. Student responses did not vary much between the comparison and treatment groups in terms of correctness, but students who completed the preflight seemed to have a deeper grasp of the material. For example, one student in the treatment group wrote, "The velocity vector is tangent to the circle in the direction the object is facing. It changes direction as the object moves around the circle." This indicated much more understanding of what was happening as compared to many students in the comparison group, who wrote answers such as "the velocity is tangent to the circle." Figure 3, below, shows an example of a student response. This is what I see after a student submits an answer using a Google Form.

A	B	C	D	E
Timestamp	Q1	Q2	Q3	Q4
1/22/2014 19:20:09	V=(2)(pi)(R)/T	Ac=(V^2)/r	The velocity vector is tangent to the circle in the direction the object is facing. It changes direction as the object moves around the circle.	The centripetal acceleration faces from the object towards the center of the circle.

Figure 3. Sample Preflight #1 Response.

The second preflight was a multiple choice question about a rock being twirled in a circle at the end of a string. Students had to predict which direction the rock would travel if the string was let go of at a certain point, and explain their reasoning (Appendix F). The average score on the preflight was 3.45/4.00 points (N = 41), with 32 students choosing the correct answer, C (tangent to the path). Eleven students chose answer D, a path that curved inwards. On the end of unit exam, however, the same question as the preflight appeared, and 0/42 students in the treatment group chose the inward-curving path as opposed to 2/42 students in the comparison group.

The accompanying video quiz was even more illustrative. The second video quiz was a more complicated example of an object moving in a circle, with two motions combined (Appendix J). More than 70% of students in the comparison group (32/45 = 71%) chose incorrect answers on the video quiz, while only 30% of students in the treatment group (13/44 = 30%) chose incorrect answers. Almost one-third of the students in the treatment group who got the preflight wrong (9/30) corrected their mistake on the video quiz.

Students in the treatment group also had more detailed and descriptive responses justifying their answers on the video quiz. For example, one student wrote, "The velocity at the exact moment it leaves the disk will have two parts, one [is] the tangent velocity all objects experience while moving in a circle, and two the outwards velocity causing the object to move along the bar. This would cause a diagonal, straight, end velocity." Another student wrote, "The velocity is tangent to the circle, but since it slides off the bar it will follow a straight path at an angle." By contrast, students in the comparison group were less able to successfully combine the two motions of the object to obtain the correct

answer. In particular, nine students chose a curved path for the object, because they were unable to correctly apply Newton's law of inertia to the situation. Student responses to the second video quiz are summarized in Table 7.

Table 7
Video Quiz #2 Answer Distribution

Section	Comparison (N = 45)	Treatment (N = 43)
Average (/5)	3.44	4.12
Choice A	22 (48.9%)	8 (18.6%)
Choice B	13 (28.9%)	30 (69.8%)
Choice C	9 (20.0%)	1 (2.3%)
Choice D	1 (2.2%)	4 (9.3%)

The third preflight was a tutorial which showed students how to compare a "before" and "after" gravitational force, when physical characteristics of the system changed (Appendix G). Students were then asked to do a similar calculation. The most common error on the preflight was not squaring the denominator of the expression correctly. In other words, students plugged in $(4d)^2$ and wrote this as $4d^2$, rather than the correct $16d^2$. This is an error that I have seen students commit for years when analyzing what happens to the gravitational force when objects are moved four times farther apart. After submitting their answers to this preflight, students were directed to a webpage that gave the answer and a step-by-step solution. At the beginning of the class after this preflight was due, many students exclaimed, "I forgot to square the 4 on the preflight!" It seemed these students were made aware of this pitfall by the preflight.

The third video quiz asked students to perform calculations similar to on the preflight (Appendix K). In the comparison group, many students answered the questions

correctly, and some (12/44) even followed a detailed analysis similar to that which I

presented to the treatment group on the preflight. Thirteen students made the error in

squaring the denominator which I mentioned previously. They turned $(2d)^2$ into $2d^2$

rather than $4d^2$. A few students came up with the correct answer by making up values for

the variables, and then calculating changes by hand. For example, they would say $m1 = 5$

kg, $m2 = 10$ kg, etc., so doubling $m1$ would turn it into 10 kg. While this leads to an

acceptable answer, it does not show an understanding of using proportional reasoning

such as I was trying to target on this preflight and quiz. Finally, four students solved

most of the problem correctly, but failed to separate the original force from the

coefficient relating to the new force. In other words, they wrote (2/3)*Fg when the

correct answer was (3/2)*Fg. This error showed an incomplete understanding of the

concept.

In the treatment group, seven students squared the denominator incorrectly. Six

of these seven also failed to do this correctly on the preflight. However, six students who

incorrectly squared the denominator on the preflight fixed their error on the video quiz,

answering it correctly. More than half (21/38) of the students in the treatment group

correctly solved the problem and followed a method that showed fuller understanding of

the underlying concept. They were able to write the new force in terms of a coefficient

times the old force, which was exactly how I solved it in my example on the preflight.

Figure 4, below, shows an example of a student response from the treatment group who

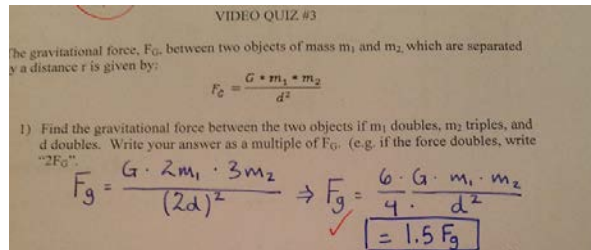wrote the new force in terms of a coefficient times the old force.

Figure 4. Sample Video Quiz Response.

However, some students in the treatment group made random math errors on the video

quiz, about similar in occurrence to the comparison group.

Finally, the fourth preflight (Appendix H) dealt with Kepler's 3rd Law of

planetary motion. It was a multiple-choice question dealing with a straightforward

calculation. But I made my answer choices such that common errors would lead to

certain answers. For example, in order to get to the final answer students had to take a

square root. One of my answers was the number you got if you didn't take this square

root. Just like the gravitational force preflight, this one showed students the correct

answer afterwards, along with why the other answers were wrong. The feedback given to

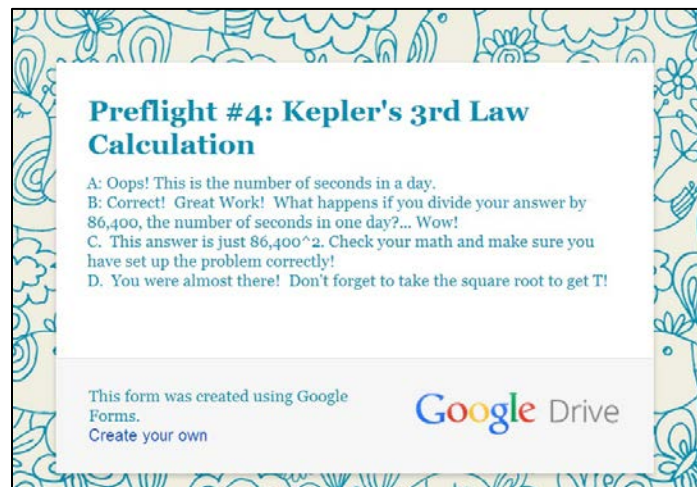students after they submitted their answers is shown in Figure 5 below.

Figure 5. Preflight #4 Feedback to Students.

Over three-quarters of students got this preflight correct, as it was a fairly straightforward calculation, but 14% chose answer D, which was the most common error. Students who chose answer A or C were most likely guessing.

The fourth video quiz (Appendix L) asked exactly the same type of question as the preflight and as an example problem solved in one of the video lectures. There were three major types of errors committed in the comparison group: failing to take the square root of T^2 (4 students), general math errors (4 students), and not knowing Kepler's 3rd Law (4 students). I should state again that students were allowed to use any notes they took while watching videos (or doing preflights) on the video quizzes.

Responses were mostly similar in the treatment group. There were three students who did not correctly solve for T; of these, one did it correctly on the preflight, one made the same error on the preflight, and one guessed on the preflight. There were three students who made general math errors, but all three of them got the preflight correct. Finally, there was one student who did not know the correct equation, and she chose one of the "guessing" answers on the preflight. Overall, though, student performance on the last video quiz did not differ much between the comparison and treatment groups.

Student interviews conducted during the study indicated several ways that preflights contributed to better understanding of course material. Question #2 on the student interview (Appendix C) asked students in the treatment group whether the preflight helped them understand the video material better. One student remarked, "Yes, because it [the preflight] showed me an example problem of what might be on a test, and think about it [the concept] in a deeper way." Several other students said that the preflights allowed them to immediately practice what they learned in the video, with

comments like "it [the preflight] put the information to use" or "I applied the concepts I learned." By contrast, when asked about the video material, students in the comparison group had comments such as "I don't think I have a full understanding of the video material" or "If I had to take the test immediately after watching the videos I don't think it would be good."

Effect of Preflights on Student Confidence.

The pre and posttreatment attitude surveys showed that students in the treatment group had higher confidence overall in their learning. Question #4 on the attitude survey asked students to rate how confident they felt solving physics problems similar to those seen in video lectures. The attitude survey was set up using a Likert scale, with "1" representing "Strongly Disagree" and "5" representing "Strongly Agree". The average score for this question for the comparison group was 3.58 at the beginning of the study and 3.31 at the end, while for the treatment group average scores started at 3.67 and went up to 3.91 by the end. Question #5 on the attitude survey asked students to rate their confidence in their ability to explain physics concepts similar to those they saw in the video lectures. Both the comparison and treatment groups saw gains of about the same magnitude (0.20 points) by the end of the study.

Student interviews gave further evidence that preflights increased confidence. Most comments focused on the fact that the preflight helped students know what kind of questions to expect, and how to solve certain types of problems. One student said that the preflights "were similar [to the video quizzes], so I had thought about them at home and re-looked through my notes then, so I didn't even use my notes on either of the video

quizzes." Another student remarked that "I knew what I had gotten wrong on the preflights so I wouldn't make the same mistake on the quizzes."

Student responses on the Preflight Format Survey (Appendix B) also showed increased confidence from the preflights. One student wrote about the 3rd preflight (guided tutorial), saying "If a student is unsure of how to do something, it is explained to them again. This reassures people of what they know." Another said that it is "Great to know exactly how to do something! Saw my mistake in preflight and was able to correct it for the video quiz."

Preferred Preflight Format.

The Preflight Format Survey showed that overwhelmingly, students preferred Preflight #3, which had a tutorial format. Over 50% (23 of 45) of students in the treatment group chose the Tutorial format as their favorite, while 20% (9 of 45) of students preferred the Calculation format (Preflight #4) and 18% (8 of 45) preferred the Short Answer format (Preflight #2). Only 12% of students preferred the Multiple Choice format.

I asked students to give me feedback on each of the formats, in order to gain insight into which format helped them learn best. Students who liked the short answer preflight mentioned a few reasons, such as "I learn best when I need to explain, because it makes me think more than on multiple choice." Other students said it helped them learn the equations for circular velocity and centripetal acceleration, while some students said that the preflight was basically repeating exactly what was already explained in the videos, which wasn't helpful. Students in general felt that the short-answer format was conducive to a deeper level of thinking.

Many students critiqued the multiple choice preflight as being too easy, and not as transferrable to the video quiz. However, other students appreciated feedback on their answers after they finished the preflight. One student commented, "I liked being able to see what the choices were and be able to rule choices out using what I recently learned."

Most students had favorable comments on the tutorial preflight. A few common themes emerged, such as the worked-out example being very helpful to students. Many students wrote comments such as "I liked trying the problem by myself, with guidance" or "It guided me step-by-step and I could refer back to it easily." Students also liked the diagram, saying "it helped me visualize the process" and it "allowed me to see how to do the problem, so I wasn't as confused on how to apply our equations to problems."

The fourth preflight was a straightforward calculation of the period of orbit of a planet using Kepler's 3rd Law (see Appendix H). Immediately after submitting answers to this preflight, students received feedback on their work, as described previously. Student comments focused on how useful this feedback was, saying "I forgot to sqrt(T^2) and the instant feedback allowed me to understand that." Students also seemed to appreciate similarity between the type of question asked on this preflight and the video quiz. One student said he preferred this type of preflight and that "it helped because I had experience doing the problem."

INTERPRETATION AND CONCLUSION

I believe that the use of preflights does improve student performance on subsequent assessments, as well as helps students understand video lecture material more effectively. Data for the unit exam shows that the treatment group performed better on

three of four questions that were directly related to the preflights. The video quiz data

show that for two of the four preflight formats and corresponding video quizzes, there

was a significant difference in performance between the treatment and comparison

groups. I suspect that no significant difference was seen on the first and last video

quizzes because of the very basic nature of the material on those quizzes, and the fact that

students were more easily able to apply what they learned on the videos to the video

quizzes. However, for the "rotating disk" video quiz (#2), and the "comparing

gravitational forces" video quiz (#3), I believe that the preflights helped bridge the gap

between the basic information presented in the videos and the more complicated

questions asked on the video quizzes. This aligns very well with what Zappe et al. have

written about preflights (JiTTs), stating that they "create links between their background

and conceptual understanding" (Zappe et al., 2006, p. 3). I also believe that the

gravitational force preflight helped students hone their skills at proportional reasoning, or

calculating changes without actual numbers.

Student interviews and attitude survey data indicate that preflights also increase

student confidence in their learning. I suspect that the extra practice the preflights gave

helped them understand any mistakes and give confidence that they could do similar

problems again. This seems to support what Novak has written, "that 'wrong' answers

are not evidence of failure" but rather of learning (p. 69). Since the preflights did not

count for a grade, students felt safe to go out on a limb and write anything. The majority

of students were mature enough to take advantage of this opportunity, and did so, even

though the preflights were not for points. I found this fact itself to be strong evidence in

favor of using preflights in the future – students would not complete an assignment that

was not for points just because I asked them to, unless it was truly helpful to their learning!

VALUE

The findings of this study reinforced my conviction that preflights have great value in enhancing the flipped classroom. The limited data I collected suggest that preflights are helpful to students in clarifying, expanding upon, and practicing the skills and knowledge presented in video lectures. I continue to look for methods to improve my flipped classroom structure, and I think that preflights can serve as a useful tool to bridge the gap between video lectures and class discussions.

One area which I would like to explore further is the ways in which preflights can be used to address misconceptions at the start of a class. I did address this in this study to a certain extent, for example after the gravitational force preflight I was able to warn students to square the entire denominator, not just the "d" or "r", but there is potential to use them in a more specific manner to target topic-specific misconceptions in physics.

Another improvement I have made to preflights as a result of using them in this study, is including a question where students can write comments about the preflight, indicating steps in the explanation that are unclear to them. For example, on a recent preflight I showed students how to calculate a location where the electric field is zero in a region with two co-linear charges. I provided space for students to write comments about steps they didn't fully understand. Before class, I read through these comments and noticed two or three main questions coming up. I wrote these on the board, and had students perform a think-pair-share in order to discuss the answers to these questions. I

feel that this unleashes the power of preflights to target concepts students don't quite understand, or struggle with even after much practice.

The process of implementing this action research project in my class has been extremely informative and educational. As a result of my research, I have endeavored to incorporate preflights into each new unit, providing feedback to students afterwards. While the effort required to undertake a study of this detail was quite intense, I feel that when teachers proactively enact positive change in their classrooms, everyone benefits.

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APPENDICES

APPENDIX A

ATTITUDE SURVEY

Attitude Survey

Instructions: Please rate the extent to which you agree or disagree with the following statements. If you agree or strongly agree with a statement, mark 4 or 5. If you disagree or strongly disagree, mark 2 or 1. If you do not have an opinion either way, mark 3. **Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at anytime. Your participation or non-participation will not affect your grade or class standing.**

Q1) After I watch a video lecture, I feel I understand the material.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Q2) I feel like I do not understand the material until we discuss it in class.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Q3) Watching video lectures is a good way for me to learn the material.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Q4) I feel confident in my ability to solve physics problems similar to those I saw in the video lectures.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Q5) I feel confident in my ability to explain physics concepts similar to those I saw in the video lectures.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Q6) I feel that I do well on the video quizzes that we have after watching videos.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

Q7) I feel that the preflights help me to do better on the video quizzes.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

APPENDIX B

PREFLIGHT FORMAT SURVEY

Preflight Format Survey: During this unit, you completed different types of 'preflights'.

These included short answer, calculation, multiple-choice, and guided tutorial.

Short answer = First preflight, where you told me which direction velocity and acceleration vectors pointed.
Multiple choice = Second preflight, where you told me what direction the force was on a car going around a curve.
Guided tutorial = Third preflight, where I took you through a comparison of gravitational forces, and you then tried one on your own with feedback.
Calculation = Fourth preflight, where you calculated the period of an orbit using Kepler's 3rd Law.
Please answer the following questions. **Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at anytime. Your participation or non-participation will not affect your grade or class standing.**
On a scale from 1 to 5, rate how well each of these preflights prepared you for the video quiz which we took in class each day.

Q1) Short-answer

Not at all		Neutral		Extremely well
1	2	3	4	5

Please explain your choice:

Q2) Multiple choice

Not at all		Neutral		Extremely well
1	2	3	4	5

Please explain your choice:

Q3) Guided tutorial

Not at all		Neutral		Extremely well
1	2	3	4	5

Please explain your choice:

Q4) Calculation

Not at all		Neutral		Extremely well
1	2	3	4	5

Please explain your choice:

Q5) Which format did you feel was most effective in helping you prepare for the video quiz?

    A) Short-Answer
    B) Multiple choice
    C) Guided Tutorial
    D) Calculation

Please explain your choice:

Q6) Please briefly tell me what would improve the preflights.

APPENDIX C

STUDENT INTERVIEW QUESTIONS

Interview Questions:

Student Code: _____

Date: _____

Section: _____

Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at anytime. Your participation or non-participation will not affect your grade or class standing.

1) (All) How well did you understand the video material? What concepts were unclear or hard to understand?

2) (Treatment only) Did the preflight help you understand the video material better? To what extent? What do you understand better now that was unclear before?

3) (All) How well did you feel you were able to show your knowledge on the video quiz?

4) (Treatment only) Did the preflight help you do better on the video quiz? To what extent? Give specifics please.

5) (All) What do you think will help you better use and/or understand the videos?

APPENDIX D

INSTRUCTOR JOURNALING PROMPTS

Teacher Journal Prompts

1) In the treatment classes, how many students completed the preflight?

2) Of those that completed it, did their work show deeper understanding of the material? What evidence supports this?

3) In general how did answers on the video quiz differ between the treatment and non-treatment groups?

APPENDIX E

PREFLIGHT #1 – CENTRIPETAL MOTION GOOGLE FORM

PREFLIGHT #1: CENTRIPETAL MOTION GOOGLE FORM

(This Preflight was published as a Google Form [here])

Q1 *
How do you calculate the speed V of an object going in a circle of radius R in a period of time T? (write a mathematical expression, or describe in words)

Q2 *
How do you calculate the centripetal acceleration Ac for an object traveling with a speed V in a circular path of radius R?

Q3 *
Describe the direction of the velocity vector for an object moving in a circle.

Q4 *
Describe the direction of the centripetal acceleration vector for an object moving in a circle.

* Indicates a required question.

APPENDIX F

PREFLIGHT #2: CENTRIPETAL FORCE MULTIPLE CHOICE

PREFLIGHT #2: CENTRIPETAL FORCE MULTIPLE CHOICE
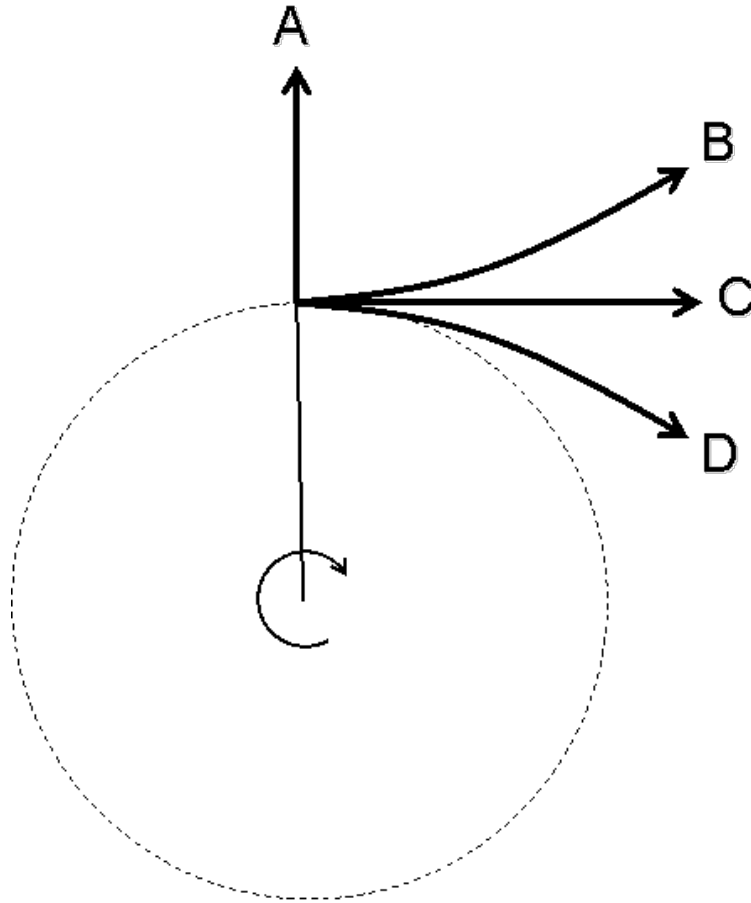
A girl twirls a rock on the end of a string in a horizontal circle above her head.
The diagram illustrates how this looks from above.

1) If the string breaks at the instant shown, which arrow best represents the path the
   rock will follow?

● A   ● B   ● C   ● D

2) Briefly explain your answer to the previous question.

Note: This preflight is provided courtesy of http://www.SmartPhyiscs.com

APPENDIX G

PREFLIGHT #3: GRAVITATIONAL FORCE COMPARISON TUTORIAL

PREFLIGHT #3: GRAVITATIONAL FORCE COMPARISON TUTORIAL

(This Preflight was published as a Google Form here)

Calculating the Gravitational forces between two masses m1 and m2, separated by a distance r (from the center of one to the center of the other) is very easy:

$$F_G = \frac{Gm_1 m_2}{r^2}$$

(G = 6.67 x 10^-11 N*m^2/kg^2, m1 & m2 = mass in kg, r = center-to-center distance in m)

But comparing two situations is tough!

For example, see the diagram below. The force between two objects of mass M and distance d apart is F. How do we know that the force is 2F for the next situation, where one mass is M and the other is 2M, separated by d? (you don't have to write anything in the answer box)
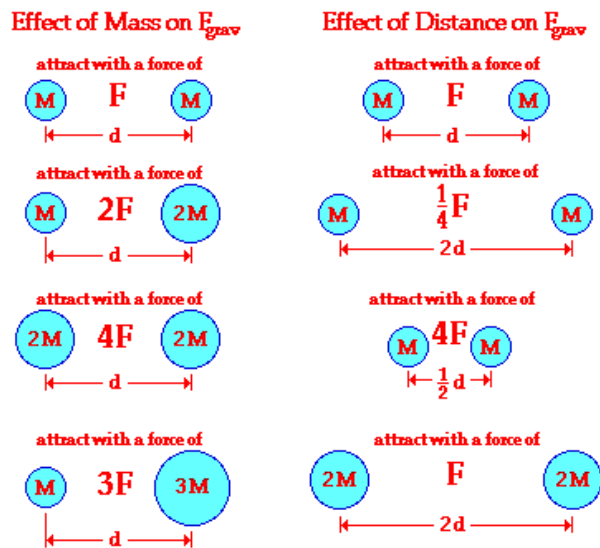
(www.physicsclassroom.com)

For that matter, why is the force F when we have 2M and 2M separated by 2d? (last diagram on right side)

If you're not sure of the answer to WHY this is true, keep reading!

Let's see what happens when we plug in 2M, 2M, and 2d into the equation!

$$F_G = \frac{G * m_1 * m_2}{d^2}$$

And if we begin with m1 = M and m2 = M, we get:

$$F_G = \frac{G * M * M}{d^2} = F$$

Now we substitute m_1 = 2M and m_2 = 2M, and d = 2d:

$$F_G = \frac{G * 2M * 2M}{(2d)^2}$$

$$F_G = \frac{4 * G * M * M}{4d^2}$$

$$F_G = \frac{4}{4} * \frac{G * M * M}{d^2}$$

Which is the exact same force, F, that we started with! In other words, doubling the distance and doubling each of the masses cancel each other out because we are multiplying our original force F by 4/4 = 1.

Now You Try!

What would the new force be if m1 was 0.5M, m2 was 3M, and d was 4d? Set up the gravitational force equation as shown above, and then input your answer in decimal form. For example, if you found it was (1/4)*F, write 0.25 as your answer.

(After inputting an answer, students are brought to a new webpage which shows the following text):

The correct answer was 0.09375. Did you get it? Remember, F = G(0.5M*3M)/(4d)^2 = G*1.5M*M/16d^2 = (1.5/16) * original force = 0.09375.

APPENDIX H

PREFLIGHT #4: KEPLER'S 3RD LAW CALCULATION

PREFLIGHT #4: KEPLER'S 3RD LAW CALCULATION

(This Preflight was published as a Google Form here)

Kepler's 3rd Law is:

$$\frac{R^3}{T^2} = \frac{GM}{4\pi^2}$$

Where R = average radius of orbit in meters, T = period of orbit in seconds, G = Gravitational constant (6.67 x 10^{-11} N*m^2/kg^2), M = mass of object being orbited.

Here is the derivation of Kepler's 3rd Law, for review.

$$F_c = F_G$$

$$m_{sat} \frac{v^2}{r} = G \frac{m_{sat} M}{r^2}$$

$$v^2 = G \frac{M}{r}$$

$$\left(\frac{2\pi r}{T}\right)^2 = G \frac{M}{r}$$

$$\frac{4\pi^2 r^2}{T^2} = G \frac{M}{r}$$

$$\frac{r^3}{T^2} = G \frac{M}{4\pi^2}$$

Q1) Use Kepler's 3rd Law to calculate the period T of Earth's orbit around the Sun.
Important information: Mass of the Sun = 1.99 x 10^30 kg, R = 1.49 x 10^11 m.
A) 8.64 x 10^4 seconds   B) 3.14 x 10^7 seconds
C) 7.46 x 10^9 seconds   D) 9.84 x 10^14 seconds

(after choosing an answer, students are taken to a new page which says:)

A: Oops! This is the number of seconds in a day.
B: Correct! Great Work! What happens if you divide your answer by 86,400, the number of seconds in one day?... Wow!
C. This answer is just 86,400^2. Check your math and make sure you have set up the problem correctly!
D. You were almost there! Don't forget to take the square root to get T!

APPENDIX I

VIDEO QUIZ #1

VIDEO QUIZ #1
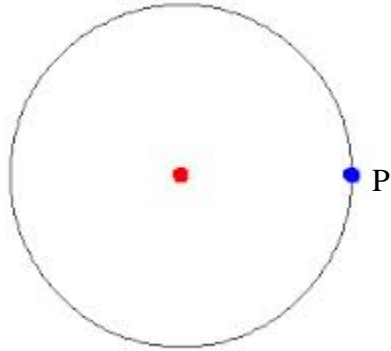
1. An object is traveling in a circular path, as shown above. Draw the directions of the velocity and acceleration vectors when the object is at point P.

2. Calculate the speed of the object if it travels in a circle of radius 10.0 m in a time of 5.00 seconds.

3. Calculate the centripetal acceleration of the object if it moves with a speed of 25.0 m/s in a circle of radius 100.0 m.

APPENDIX J

VIDEO QUIZ #2

VIDEO QUIZ #2
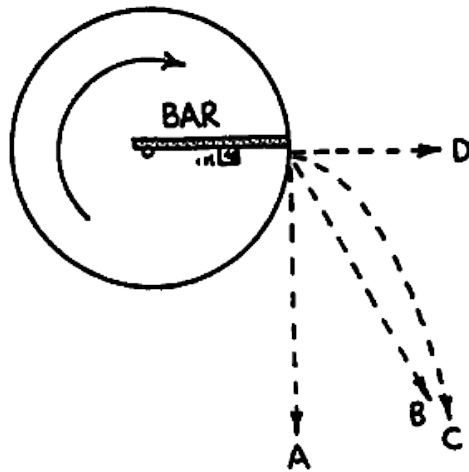
If a small object is placed on a rotating disk (like a record player) it will slide off

the edge. Suppose you fasten a bar on the disk as shown in the top view, and

allow the object to slide from an inside position, along the bar, and off the edge.

Which of the paths shown would be most likely? Circle your answer, and explain

your choice.

A   B   C   D

APPENDIX K

VIDEO QUIZ #3

VIDEO QUIZ #3

The gravitational force, F_G, between two objects of mass m_1 and m_2, which are separated by a distance r is given by:

$$F_G = \frac{G * m_1 * m_2}{d^2}$$

1) Find the gravitational force between the two objects if m_1 doubles, m_2 triples, and d doubles. Write your answer as a multiple of F_G. (e.g. if the force doubles, write "$2F_G$".

2) Find the gravitational force between the two objects if m_1 doubles, m_2 is cut in half, and d is cut in half. Write your answer as a multiple of F_G.

APPENDIX L

VIDEO QUIZ #4

VIDEO QUIZ #4

Q1) Use Kepler's 3rd Law to calculate the period T of the Moon's orbit around the Earth. Important information: Mass of the Earth = 5.97 x 10^24 kg, R = 3.84 x 10^8 m.

A) 8.64 x 10^4 seconds   B) 2.70 x 10^5 seconds
C) 2.37 x 10^6 seconds   D) 5.60 x 10^12 seconds

APPENDIX M

PRETEST

1. Which of the following statements are true of an object moving in a circle at a constant speed? Include all that apply.

a. The object experiences a force which has a component directed parallel to the direction of motion.
b. Inertia causes objects to move in a circle.
c. There can be a force pushing outwards on the object as long as the net force in inwards.
d. Because the speed is constant, the acceleration is zero.
e. The acceleration and the net force vector are directed perpendicular to each other.
f. If the net force acting upon the object is suddenly reduced to zero, then the object would suddenly depart from its circular path and travel tangent to the circle.
g. The acceleration of the object is directed tangent to the circle.

For **Questions #2-#5**, identify the type of force which causes the following **bold-faced** objects to travel along a circular path.

2. An **eraser** is tied to a string swung in a horizontal circle.

a. gravity   b. normal   c. tension   d. applied

e. friction   f. spring   g. electrical   h. magnetic
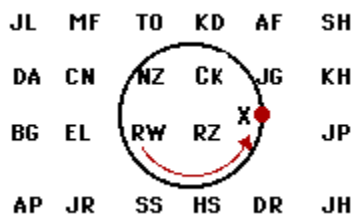

3. The **moon** orbits the earth.

a. gravity   b. normal   c. tension   d. applied

e. friction   f. spring   g. electrical   h. magnetic

4. A **car** makes a sharp right-hand turn along a level roadway.

a. gravity   b. normal   c. tension   d. applied

e. friction   f. spring   g. electrical   h. magnetic

5. A **roller coaster car** passes through a loop. Consider the car at the bottom of the loop.

a. gravity   b. normal   c. tension   d. applied

e. friction   f. spring   g. electrical   h. magnetic

```
JL   MF   TO   KD   AF   SH

DA   CN   NZ   CK   JG   KH

BG   EL   RW   RZ   X      JP

AP   JR   SS   HS   DR   JH
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6. A physics teacher ties an eraser to the end of a string and then whirls it in a counter-clockwise circle. If the teacher lets go of the string, then the eraser hits a student (or several students) in the classroom. If the string is let go when the eraser is at point X on the diagram at the right, then which student(s) in the class will the eraser hit? Write the initials in this space: _____

7. Which of the following statements are true about gravitational force? Identify all that apply.

a. The gravitational force only acts between very, very massive objects.
b. The gravitational force between an object and the earth is inversely related to the distance between the object's and the earth's center.
c. The gravitational force can ALWAYS be accurately calculated by multiplying the object mass by the acceleration of gravity (m•g).
d. The gravitational force acting upon an object is the same as the weight of the object.
e. The gravitational force between two objects is independent of the mass of the smaller of the two objects.
f. If object A gravitationally attracts object B with a force of X Newtons, then object B will also gravitationally attract object A with the same force of X Newtons.
g. The doubling of the separation distance (measured from the center) between two objects will halve the gravitational force between the objects.
h. It an object is placed two earth-radii above the surface of the earth, then the force of gravitational attraction between the object and the earth will be one-fourth the magnitude as on earth's surface.
i. Orbiting astronauts do not experience a force of gravity; this explains why they feel weightless.

8. Which of the following statements are true about the acceleration of gravity? Identify all that apply.

a. The acceleration of gravity experienced by objects located near to (and far from) from the earth depends upon the mass of the object.
b. The acceleration of gravity experienced by objects located near to (and far from) from the earth depends upon the mass of the Earth.
c. The acceleration of gravity experienced by objects located near to (and far from) the earth is inversely related to the distance between the center of the object and the center of the earth.

d. Increasing the mass of an object will increase the acceleration of gravity experienced by the object.
e. Doubling the distance between an object and the earth's center will decrease the acceleration of gravity by a factor of four.
f. The acceleration of an orbiting satellite is equal to the acceleration of gravity at that particular location.
g. If the mass of the Earth were doubled (without an alteration in its radius), then the acceleration of gravity on its surface would be approximately 20 m/s^2.
h. If the mass of the Earth were doubled and the radius of the earth were doubled, then the two changes would offset each other and the acceleration of gravity on its surface would still be approximately 10 m/s^2.

9. Which of the following statements are true about satellites? Identify all that apply.

a. Satellites are falling projectiles.
b. All satellites follow circular paths.
c. The orbital velocity required of a satellite is dependent upon the mass of the satellite; a more massive satellite would require a greater orbital speed.
d. The orbital velocity of a satellite does not depend upon the mass of the planet around which it orbits.
e. A *high-altitude* satellite will require a greater orbital speed than a *low-altitude* satellite.
f. By definition, a geosynchronous satellite orbits the earth in a perfect circle, maintaining the same distance above the surface of the earth.
g. Satellites travel faster along their orbital path when they are closest to the earth.
h. The acceleration of a satellite varies inversely with its distance from the center of the earth. More distant satellites have smaller accelerations.

10. Which of the following statements are true about the motion of planets about the sun? Identify all that apply.

a. The force of gravity is the only force which acts upon the planets.
b. Their trajectories are highly elliptical.
c. The planets which are furthest from the sun have the greatest period.
d. For any given planet, the speed is greatest when the planet is closest to the sun.
e. The velocity vector is directed tangent to the elliptical path.
f. The net force vector is at all times directed perpendicular to the velocity vector.
g. To keep the planet from escaping the sun's gravitational field, the net force vector is greatest when the planet is furthest from the sun.

APPENDIX N:

UNIT EXAM

Circular Motion & Gravity Exam
Unless otherwise stated, use $G = 6.67 \times 10^{-11}$ N*m^2/kg^2. The mass of Earth is 5.97×10^{24} kg. The mass of the Sun is 1.99×10^{30} kg. If you need any other constants please ask!
Please do not write on this Test Booklet!!
SHORT ANSWER. For Questions #1&2, mark your answer on the scantron. (2pts each). For Questions #19-25, show your work neatly on scratch paper. (pts given after question)
1) A planet revolves clockwise around a star, with constant speed
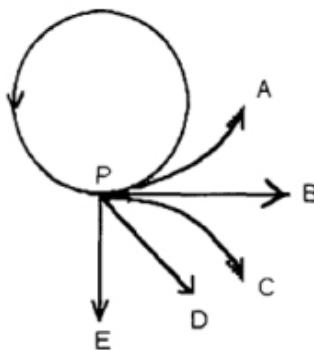
Figure 7-3
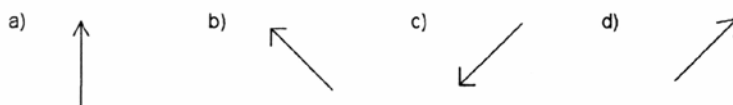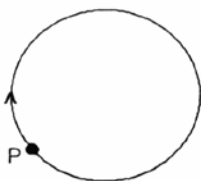
Which graph shows the direction of the planet's acceleration at point P: graph a, graph b, graph c, or graph d?

2) A girl attaches a rock to a string, which she then swings counter-clockwise in a horizontal circle. The string breaks at point P in Figure 7-4, which shows a bird's-eye view (i.e., as seen from above).

Figure 7-4

Which path (A-E) will the rock follow?

MULTIPLE CHOICE. Mark the correct answer on your scantron. (2 pts each).
3) Does the centripetal force acting on an object do work on the object?
A) yes, since a force acts and the object moves, and work is force times distance
B) yes, since it takes energy to turn an object
C) no, because the object has constant speed
D) yes, because the force and the displacement of the object are perpendicular

E) no, because the force and the displacement of the object are perpendicular

4) The speed needed at the bottom of a loop-the-loop track so that a car can coast to the top, with sufficient speed to stay on the track, depends on the mass of the car. (Neglect the effects of friction.
A) always true, since potential energy is a function of mass
B) never true
C) always true, since kinetic energy is a function of mass
D) sometimes true, since potential energy is a function of mass
E) sometimes true, since kinetic energy is a function of mass

5) A roller coaster car is on a track that forms a circular loop in the vertical plane. If the car is to just maintain contact with track at the top of the loop, what is the minimum value for its centripetal acceleration at this point?
A) 0.5 g downward
B) g downward
C) 2 g downward
D) g upward
E) 2 g upward

6) A roller coaster car (mass = M) is on a track that forms a circular loop (radius = r) in the vertical plane. If the car is to just maintain contact with the track at the top of the loop, what is the minimum value for its speed at that point?
A) Mrg
B) $\sqrt{(rg)} / \sqrt{(2)}$
C) $\sqrt{(2rg)}$
D) $\sqrt{(rg)}$
E) 2 Mrg

7) A race car, traveling at a constant speed of 50. m/s, drives around a circular track of radius 250. m. What magnitude acceleration does it experience?
A) zero   B) 2.2 m/s^2 C) 10. m/s^2 D) 0.63 km/s^2 E) 1.0 m/s^2

8) A space station of diameter 40. meters is turning about its axis at a constant rate. What is the period of revolution of the space station if the outer rim experiences an acceleration of 2.5 m/s^2?
A) 10. s B) 14. s C) 18. s D) 11. s E) 13. S

9) A spaceship is traveling to the moon. At what point is it beyond the pull of Earth's gravity?
A) when it is three-fourths of the way there
B) when it gets above the atmosphere
C) when it is closer to the moon than it is to Earth
D) when it is half-way there
E) It is never beyond the pull of Earth's gravity.

10) The escape speed from the moon is what fraction of Earth's escape speed?
(Mass of Moon = 0.0123 *Mass of Earth; Radius of Moon = 0.272 *Radius of Earth.)
    A) 4.70 B) 0.21 C) 0.41 D) 0.17 E) 0.045

11) An astronaut goes out for a "space-walk" at a distance above the Earth equal to the radius of the Earth. Her acceleration will be
A) g. B) 2 g. C) 1/2 g. D) zero. E) 1/4 g.

12) A spherically symmetric planet has four times the Earth's mass and twice its radius. If a jar of peanut butter weighs 12. N on the surface of the Earth, how much would it weigh on the surface of this planet?
A) 24 N B) 18 N C) 6 N D) 12 N E) 30 N

13) Kepler's 3rd law says $T^2 / r^3 = K$. What does the constant K depend upon?
A) mass
B) frequency
C) period
D) temperature
E) size

14) The speed of Halley's comet, while traveling in its elliptical orbit around the sun,
A) decreases as it nears the sun.
B) increases as it nears the sun.
C) is constant.
D) is zero at four points in the orbit.
E) is zero at two points in the orbit.

15) Consider an Earth satellite in an elliptical orbit. Its centripetal acceleration is
A) g at the satellite.
B) > g at the satellite.
C) zero.
D) constant.
E) < g at the satellite.

16) The following statements refer to man-made, artificial satellites in orbit around Earth. Which is an accurate statement?
A) The velocity required to keep a satellite in a given orbit depends on the mass of the satellite.
B) It is possible to have a satellite traveling at either a high speed or at a low speed in a given circular orbit.
C) The period of revolution of a satellite moving about the Earth is independent of the size of the orbit it travels.

D) A satellite in a large diameter circular orbit will always have a longer period of revolution about the Earth than will a satellite in a smaller circular orbit.
E) Only circular orbits are possible for artificial satellites.
17) A satellite encircles Mars at a distance **above** its surface equal to 3 times the radius of Mars. The acceleration of gravity at the satellite, as compared to the acceleration of gravity on the surface of Mars, is
A) one-sixteenth as much.
B) one-ninth as much.
C) the same.
D) zero.
E) one-third as much.

18) A car, driven around a circle with constant speed, must have
A) a centrifugal acceleration.
B) zero velocity.
C) a centripetal acceleration.
D) a tangential acceleration.
E) zero acceleration.

SHORT ANSWER. For Questions #1&2, mark your answer on the scantron. (2pts each). For Questions #19-25, show your work neatly on scratch paper. (pts given after question)
19) Jenny drives at a constant speed of 15. m/s around a circular drive of diameter 60. meters.
(4 pts)
(a) Her acceleration is _____ m/s^2.
(b) Is her acceleration tangential, centripetal, or centrifugal?
(c) Is her velocity tangential, centripetal, or centrifugal?

20) A pilot makes a vertical loop of radius 320 m. At the top of his loop he notices a bathroom scale under his feet reads only one-half of his normal weight. How fast is he moving? (4 pts)

21) The maximum acceleration a pilot can stand is about 7.0 g. What is the minimum radius of curvature that a jet plane's pilot, pulling out of a vertical dive, can tolerate at a speed of 250 m/s? (3 pts)

22) What is the gravitational force on a 70. kg person on the Earth, due to the moon? The mass of the moon is 7.36×10^{22} kg and the distance to the moon is 3.82×10^8 m. (3 pts)

23) Consider the planet Mars:
[Mars mass = 6.45×10^{23} kg = 10.8% of Earth's Mass;
Mars radius = 3380.km =52.9% of Earth's radius]
What is the acceleration of gravity on Mars? (4 pts)

24) a) What is the acceleration due to gravity on the top of Mt. Everest? The summit is about 8.80 km above sea level. (Use 6380 km for the radius of the Earth). (Report to three significant figures.) (3 pts.)
b) What is the weight of a 75.0 kg mountain climber on top of Mt. Everest? (1 pt.)
c) How tall a mountain should Mr. DuBrow climb in order to lose 75% of his weight? (2 pts).

25) A satellite is in a low circular orbit about the Earth (i.e., it just skims the surface of the Earth). How long does it take to make one revolution around the Earth? (Use 6380 km for the radius of the Earth). (3 pts)

6