Flight Plan Physics

Overview

Description

This activity will challenge students to work in groups over an extended period of time (~1 month) to devise the “best” flight path across the USA. The groups of students will be working in a competition against their fellow classmates to come up with the flight path that minimizes cost.

Final Product: Students will submit a flight plan in a short report (about 500 words) that details the various legs of the journey including flying times, headings (directions), costs of operation, and total cost of the trip.

Subject

Physics

Task Level

Grade 11

Objectives

Students will:

- Be able to think through a complex situation breaking it down into simple pieces.
- Be able to apply their knowledge of vectors (velocity and displacement) to the task.
- Be able to incorporate the idea of efficiency and energy transfer/conservation to the task.
- Be able to try multiple iterations to refine and improve on their outcome.

Preparation

- For each student, make a copy of the Student Notes section.
- Provide the students with a notebook for each student (for writing down their thoughts).
- Access to a computer for keeping track of calculations (e.g., Excel, Word).

Prior Knowledge

Students should be able to perform vector addition, convert physical quantities from one set of units to another, read and interpret graphs, and engage in an iterative approach to problem solving. Students should understand the concepts of energy conservation, energy conversion from one form to another, and efficiency.

Key Concepts and Terms

- Coordinate systems
- Efficiency
- Energy conversion
- Graphing
- Ground speed
- Iterative approach to problem solving
- Minimizing/Maximizing functions
- Unit conversion
- Vector addition
- Wind speed

Time Frame

This assignment will require ~1 to 2 months broken down to a few hours per week. However, this assignment can be modified to meet the needs of different classroom schedules and student ability levels. For instance, graphs can be added or removed. Some values that vary (e.g., wind speed) can be given as a constant value (same at all altitudes) or be expanded to be more complicated (nonlinear with height and varying by location).

If required, the assignment may be modified and greatly shortened, as described in the Scaffolding section.

Instructional Plan

Getting Started

Learning Objectives

Students will:

- Be presented with the task.
- Brainstorm possible strategies for approaching the task.

Procedure

1. Present the students with the scenario given in the student notes on creating a flight plan across a portion of the United States of America.
2. Have them form groups of three (or four) either by their choice or yours.
3. Have them come up with a name for their airline.
4. Have them start to brainstorm on ideas of how to approach the problem. Specifically, ask them to consider 1) what variables are important, 2) what costs are associated with these variables, and 3) how the variables are connected to one another.
5. At the end of the brainstorming, students should submit a plan of approach for instructor review and suggestions.

Investigating

Learning Objectives

Students will:

- Work through the details of the task.
- Refine their approach to find the best solution possible.

Procedure

1. Students should attempt to work through their problem of figuring out the flight cost for the trip.
2. Students should recognize that they may need to modify their approach and try different ideas/paths to obtain the lowest cost.
3. Instructor should monitor the students' progression providing some help when needed. Students are expected to struggle with the task.
4. Instruct students to keep careful notes of what they are doing.

Drawing Conclusions

Learning Objectives

Students will:

- Write up their best solution.
- Present backup information to justify their claims.
- Make a presentation to the airline executives (Instructor) outlining their best flight plan.

Procedure

1. Instruct students to use their detailed notes from the Investigation section to determine what their best solution is.
2. Have them write up a flight plan that includes the flying speeds, altitudes, direction, flight times, cost, etc. The flight plan should also include a section for calculations on how any results were produced. The students may also include graphs and charts as they feel necessary.
3. The students will also give a short marketing presentation (3-5 minutes) with the intended audience as the airline executives (who are mainly concerned with cost effectiveness) in which they promote their flight plan.

Scaffolding/Instructional Support

The goal of scaffolding is to provide support to encourage student success, independence, and self-management. Instructors can use these suggestions, in part or all together, to meet diverse student needs. The more skilled the student, however, the less scaffolding that he or she will need. Some examples of scaffolding that could apply to this assignment include:

- Suggest to students that many of the important factors or variables in this activity rely on time and that time relies on the distance between the places and the speed the aircraft travels.
- Suggest that students assume maximum efficiency (i.e., the quickest travel time and maximum airplane speed) as a starting point and then vary parameters to minimize cost.
- Remind students that air speed and ground speed are related to each other through the wind speed via vector addition.
- If students are able, having them use a program such as Mathematica might be helpful.
- Consider sharing the flowchart on page 7 of the Instructor Tax Information with students, so that they might be able to organize their ideas in a similar manner.

A more limited version of this activity might involve presenting students with multiple already-complete models (the kinds of models that students would put together over the course of a month) that make different assumptions about the various parameters. Students may form groups, where each group is responsible for defending a specific model.

Solutions

The information below is intended to help you assess students' final work products. It may not represent all possible strategies and ideas. The accompanying scoring guide provides specific examples of ways a student might demonstrate content understanding and mastery of cross-disciplinary skills.

Necessary Elements

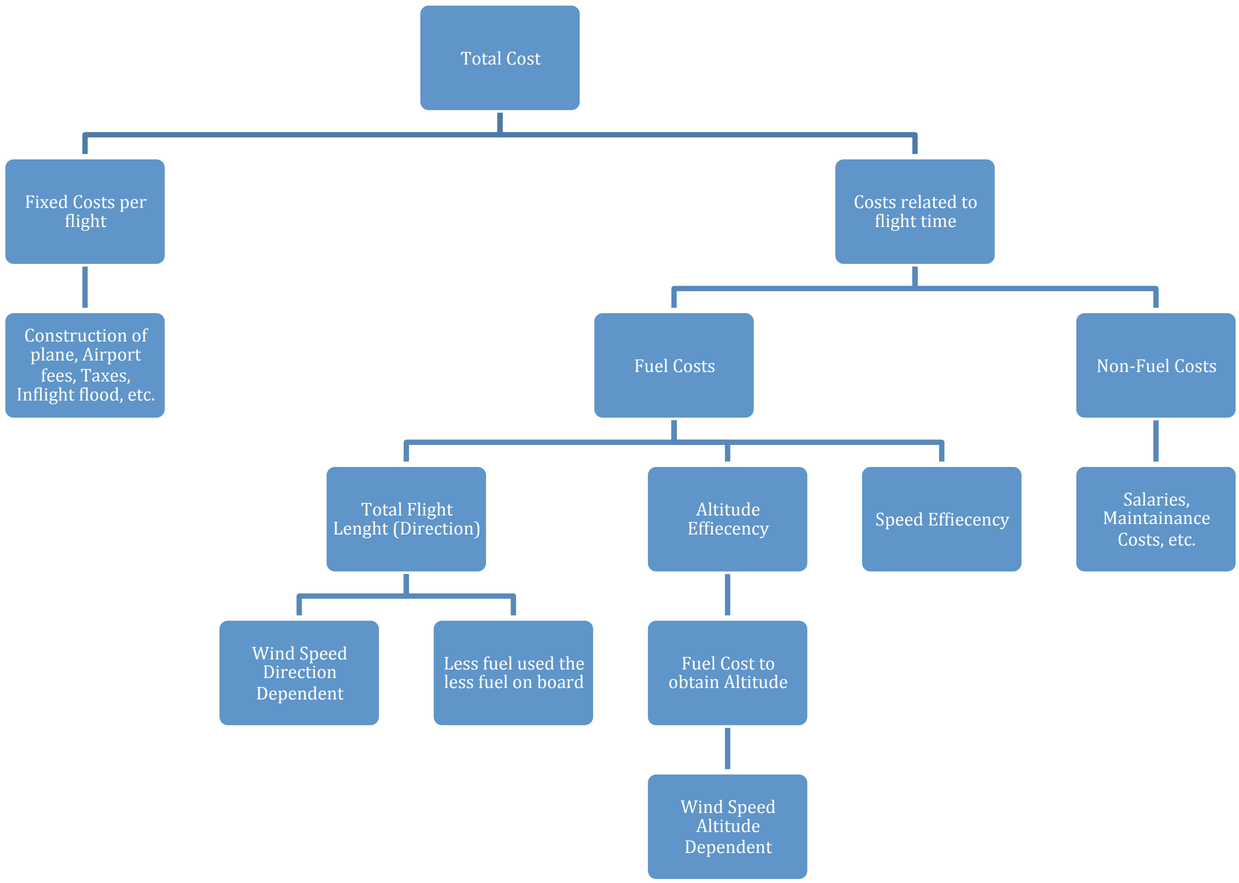
- The flowchart of cost shows the hierarchy and breakdown of the costs of the flight plan. Students should address all the issues related in the flow chart.
- Many of the elements that make up the total cost are related to each other. For example, the flying speed, direction and wind speed determine the total time of the flight, which in turn determines the salaries of the flight crew. In other words, even factors as disparate as flight crew salary and wind speed are actually related to one another.
- The report should cover all of the material that students present in their presentations but with more detail.
- Above all, groups competing against each other should include all the necessary elements in their presentations. Otherwise, they will not be considered when the airline execs award the winning contract.

Key Connections

- That cost is a combination of many different elements, some fixed and some that are able to be changed.
- The costs that are variable are related to each other.
- Minimizing the total cost is not necessary just minimizing every element (e.g., faster flying speed means more fuel cost but less cost for salaries).
- Thoughtful iteration (running the same thing over again but slightly varying the condition) is the key.
- Wind speed will relate ground speed to air speed via vector addition.
- Total distances are measured on the ground; therefore, ground speed is the primary speed-related quantity needed.
- Air speed is what all the graphs are given in.

Common Misconceptions

- The plane will be more efficient when descending and thus the fuel to obtain a certain height is balanced out by the lack of fuel spent on gliding back down to the ground (essentially, conservation of energy). However, since the plane is more efficient the less fuel it has, the height factor does propagate through the equations.


Total Cost
Fixed Costs per flight
Costs related to flight time
Construction of plane, Airport fees, Taxes, Inflight flood, etc.
Fuel Costs
Non-Fuel Costs
Total Flight Lenght (Direction)
Altitude Effiecency
Speed Effiecency
Salaries, Maintainance Costs, etc.
Wind Speed Direction Dependent
Less fuel used the less fuel on board
Fuel Cost to obtain Altitude
Wind Speed Altitude Dependent

TCCRS Cross-Disciplinary Standards Addressed

Performance Expectation	Getting Started	Investigating	Drawing Conclusions
I. Key Cognitive Skills			
A.1. Engage in scholarly inquiry and dialogue.	✓	✓	✓
A.2. Accept constructive criticism and revise personal views when valid evidence warrants.	✓	✓	✓
B.1. Consider arguments and conclusions of self and others.	✓	✓	✓
B.2. Construct well-reasoned arguments to explain phenomena, validate conjectures, or support positions.	✓	✓	✓
B.3.Gather evidence to support arguments, findings, or lines of reasoning.		✓	✓
B. 4. Support or modify claims based on the results of an inquiry.		✓	✓
C.1. Analyze a situation to identify a problem to be solved.	✓	✓	
C.2. Develop and apply multiple strategies to solve a problem.	✓	✓	
C.3. Collect evidence and data systematically and directly relate to solving a problem.		✓	✓
D.1. Self-monitor learning needs and seek assistance when needed.	✓	✓	✓
D.2. Use study habits necessary to manage academic pursuits and requirements.	✓	✓	✓
D.3. Strive for accuracy and precision.	✓	✓	✓
D.4. Persevere to complete and master tasks.	✓	✓	✓
E.2. Work collaboratively.	✓	✓	✓
F.1. Attribute ideas and information to source materials and people.		✓	✓
F.2. Evaluate sources for quality of content, validity, credibility, and relevance.		✓	✓
II. Foundational Skills			
A.4. Identify the key information and supporting details.	✓	✓	

B.1. Write clearly and coherently using standard writing conventions.			✓
B.2. Write in a variety of forms for various audiences and purposes.			✓
B.3. Compose and revise drafts.			✓
C.1. Understand which topics or questions are to be investigated.	✓	✓	✓
C.2. Explore a research topic.	✓	✓	✓
C.3. Refine a research topic based on research and devise a timeline for completing work.	✓	✓	
C.5. Synthesize and organize information effectively.	✓	✓	✓
C.6. Design and present an effective product.			✓
C.7. Integrate source material.	✓	✓	✓
C.8. Present final product.			✓
D.3. Present analyzed data and communicate findings in a variety of formats.			✓
E.2. Use technology to organize, manage, and analyze information.		✓	✓
E.3. Use technology to communicate and display findings in a clear and coherent manner.			✓
E.4. Use technology appropriately.		✓	✓

TCCRS Science Standards Addressed

Performance Expectation	**Getting Started**	**Investigating**	**Drawing Conclusions**
I. Nature of Science: Scientific Ways of Learning and Thinking			
A.1. Utilize skepticism, logic, and professional ethics in science	✓	✓	✓
A.3. Formulate appropriate questions to test understanding of natural phenomena	✓	✓	
C.1. Collaborate on joint projects	✓	✓	✓

E.1. Use several modes of expression to describe or characterize natural patterns and phenomena. These models of expression include narrative, numerical, graphical, pictorial, symbolic, and kinesthetic.	✓	✓	✓
E.2. Use essential vocabulary of the discipline being studied	✓	✓	✓
II. Foundation Skills: Scientific Applications of Mathematics			
A.6. Estimate results to evaluate whether a calculated result is reasonable.	✓	✓	✓
A.7. Use calculators, spreadsheets, computers, etc. in data analysis		✓	✓
B.1. Carry out formal operations using standard algebraic symbols and formulae	✓	✓	✓
B.2. Represent natural events, processes, and relationships with algebraic expressions and algorithms	✓	✓	✓
C.1. Understand simple vectors, vector notations, and vector diagrams, and carry out simple calculations involving vectors	✓	✓	✓
D.1. Use dimensional analysis in problem solving	✓	✓	
F.1. Select and use appropriate Standard International (SI) units and prefixes to express measurements for real world problems.		✓	✓
III. Foundation Skills: Scientific Applications of Communication			
A.1. Use correct applications of writing practices in scientific communication.			✓
B.3. Recognize scientific and technical vocabulary in the field of study and use this vocabulary to enhance clarity of communication.	✓	✓	✓
C.1. Prepare and present scientific/technical information in appropriate formats for various audiences.		✓	✓

VIII. Physics			
A.1. Demonstrate familiarity with length scales from subatomic particles through macroscopic objects.	✓	✓	✓
B.1. Understand how vectors are used to represent physical quantities	✓	✓	✓
B.3. Demonstrate knowledge of vector mathematics using a numerical representation		✓	✓
C.1. Understand the fundamental concepts of kinematics		✓	✓
D.1. Understand potential and kinetic energy		✓	✓
D.2. Understand conservation of energy		✓	✓

TEKS Standards Addressed

Flight Plan Physics - *Texas Essential Knowledge and Skills (TEKS): Physics*
112.39.c.2. Scientific processes. The student uses a systematic approach to answer scientific laboratory and field investigative questions. The student is expected to: 112.39.c.2.E. design and implement investigative procedures, including making observations, asking well-defined questions, formulating testable hypotheses, identifying variables, selecting appropriate equipment and technology, and evaluating numerical answers for reasonableness; 112.39.c.2.F. demonstrate the use of course apparatus, equipment, techniques, and procedures, including multimeters (current, voltage, resistance), triple beam balances, batteries, clamps, dynamics demonstration equipment, collision apparatus, data acquisition probes, discharge tubes with power supply (H, He, Ne, Ar), hand-held visual spectroscopes, hot plates, slotted and hooked lab masses, bar magnets, horseshoe magnets, plane mirrors, convex lenses, pendulum support, power supply, ring clamps, ring stands, stopwatches, trajectory apparatus, tuning forks, carbon paper, graph paper, magnetic compasses, polarized film, prisms, protractors, resistors, friction blocks, mini lamps (bulbs) and sockets, electrostatics kits, 90-degree rod clamps, metric rulers, spring scales, knife blade switches, Celsius thermometers, meter sticks, scientific calculators, graphing technology, computers, cathode ray tubes with horseshoe magnets, ballistic carts or equivalent, resonance tubes, spools of nylon thread or string, containers of iron filings, rolls of white craft paper, copper wire, Periodic Table, electromagnetic spectrum charts, slinky springs, wave motion ropes, and laser pointers; 112.39.c.2.G. use a wide variety of additional course apparatus, equipment, techniques, materials, and procedures as appropriate such as ripple tank with wave generator, wave motion rope, micrometer, caliper, radiation monitor, computer, ballistic pendulum, electroscope, inclined plane, optics bench, optics kit, pulley with table clamp, resonance tube, ring stand screen, four inch ring, stroboscope, graduated cylinders, and ticker timer; 112.39.c.2.J. organize and evaluate data and make inferences from data, including the use of tables, charts, and graphs; 112.39.c.2.K. communicate valid conclusions supported by the data through various methods such as lab reports, labeled drawings, graphic organizers, journals, summaries, oral reports, and technology-based reports; and 112.39.c.2.L. express and manipulate relationships among physical variables quantitatively,

Flight Plan Physics - *Texas Essential Knowledge and Skills (TEKS): Physics*
including the use of graphs, charts, and equations.
112.39.c.3. Scientific processes. The student uses critical thinking, scientific reasoning, and problem solving to make informed decisions within and outside the classroom. The student is expected to: 112.39.c.3.A. in all fields of science, analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing, including examining all sides of scientific evidence of those scientific explanations, so as to encourage critical thinking by the student; 112.39.c.3.B. communicate and apply scientific information extracted from various sources such as current events, news reports, published journal articles, and marketing materials; 112.39.c.3.C. draw inferences based on data related to promotional materials for products and services; 112.39.c.3.D. explain the impacts of the scientific contributions of a variety of historical and contemporary scientists on scientific thought and society; 112.39.c.3.E. research and describe the connections between physics and future careers; and 112.39.c.3.F. express and interpret relationships symbolically in accordance with accepted theories to make predictions and solve problems mathematically, including problems requiring proportional reasoning and graphical vector addition.
112.39.c.4. Science concepts. The student knows and applies the laws governing motion in a variety of situations. The student is expected to: 112.39.c.4.A. generate and interpret graphs and charts describing different types of motion, including the use of real-time technology such as motion detectors or photogates; 112.39.c.4.C. analyze and describe accelerated motion in two dimensions using equations, including projectile and circular examples; 112.39.c.4.D. calculate the effect of forces on objects, including the law of inertia, the relationship between force and acceleration, and the nature of force pairs between objects; 112.39.c.4.E. develop and interpret free-body force diagrams; and 112.39.c.4.F. identify and describe motion relative to different frames of reference.
112.39.c.6. Science concepts. The student knows that changes occur within a physical system and applies the laws of conservation of energy and momentum. The student is expected to: 112.39.c.6.D. demonstrate and apply the laws of conservation of energy and conservation of momentum in one dimension.

Flight Plan Physics

Introduction

In this activity, you will work in groups of 3 to come up with a bid for a flight plan for an airline flying between 3 cities (Austin, TX (AUS) to New Orleans, LA (MSY) to Jacksonville, FL (JAX) and back to Austin (AUS)). You and your group will consider multiple factors that affect the cost such as fixed costs and hourly costs as well as flying efficiencies based off of speed, altitude, direction, etc. This problem is not a straightforward plug and chug question but will require you and your group to think about how to approach the problem and possibly modify your approach to gain better results. It should be noted that this activity is a simplification of what real pilots and airlines have to consider many times a day; the numbers presented are realistic values.

Directions

Getting Started

1. Listen to your instructor as they explain the details of this activity. Take notes on the important points and ask questions if you are confused.
2. Get together with your group and come up with an airline name.
3. Work with your group to try to figure out how you are going to address the problem. Write up the approach you think you will be using, making notes on areas where you think you might have difficulties or are unsure of. You might find it helpful to start to think which values depend on other values and how changing one of the values (like altitude) will propagate through the other graphs and equations.
4. Submit your approach to your instructor for review and feedback.

Investigating

1. Review the feedback your instructor gave to you and your group.
2. Work with your group to modify the approach you will be using to find the least costly flight you can.
3. While keeping careful notes, work through the cost of the flight plan for the trip.
4. Within your group, see if you can modify anything in your approach to get a more cost effective flight path. Again keep careful notes of everything you are thinking and attempting.

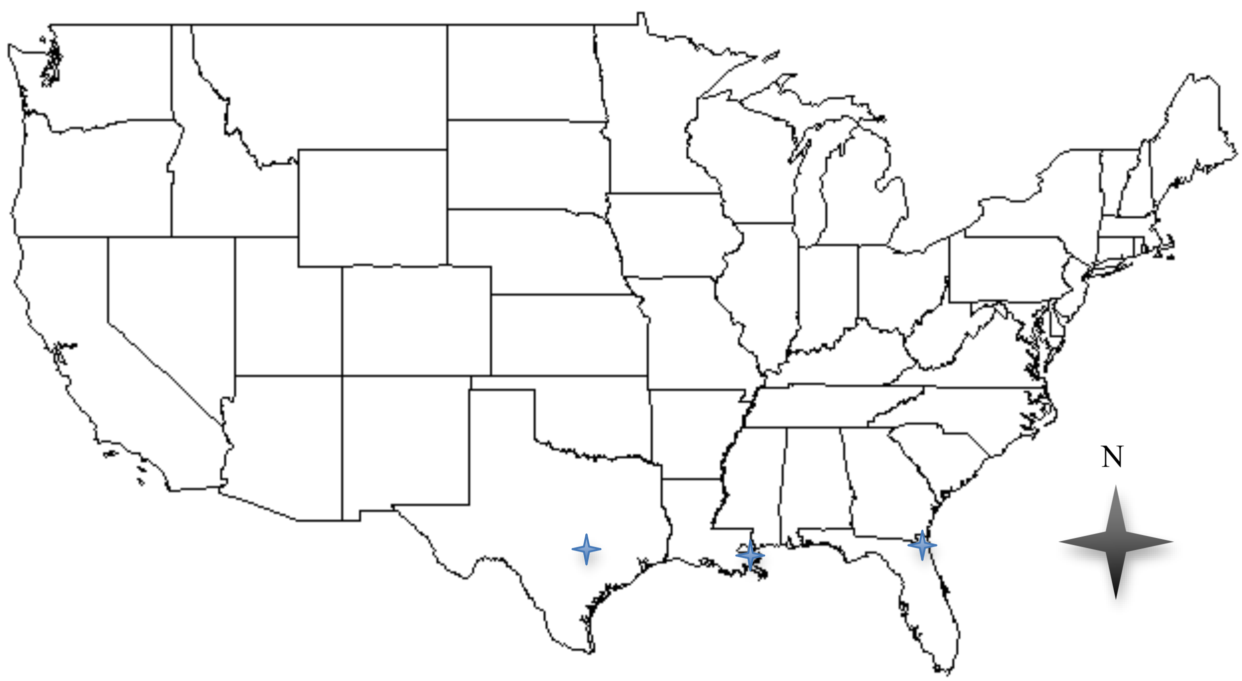
Drawing Conclusions

1. Look over your notes and figure out what you have deemed the most cost effective flight path your group was able to come up with.
2. Write up your flight plan in the form of a short report (about 500 words) to be submitted to the airline executives (your instructor) who will review your proposal and determine which of the proposals is the most cost effective. In order to be considered, your proposal has to be complete and address all the areas of concern, and only those passing this first round will be addressed on the merits of cost effectiveness.
3. Create and deliver a 3-5 minute sales pitch to the airline executives addressing the main points outlined in your flight plan.

Appendix A

Some of the more important assumptions made include:

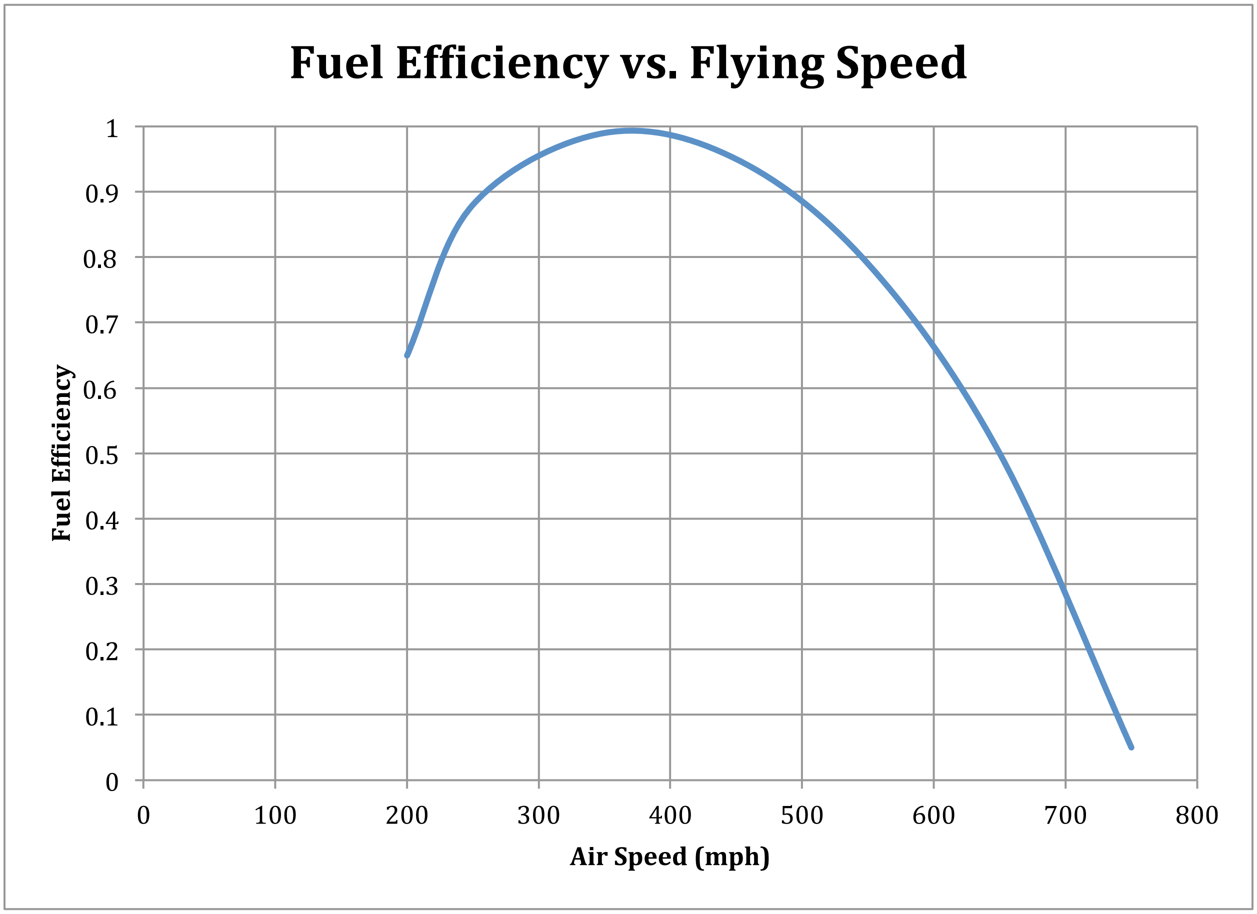
1. Earth is assumed to be flat (which, of course, is untrue) so that we can calculate in a Cartesian coordinate system. We also assume magnetic north is true north.
    a. The direction that an airplane flies is given by the direction the nose of the airplane if flying and not necessarily in the same direction as the plane is moving.
2. The efficiency graphs to first approximation are constant for the trip and are independent of the weight of the aircraft, however, the base cruising fuel consumption is weight dependent.
3. Altitude efficiency graph should be speed dependent, but we treat the two as independent. This is not the same, though, as the wind speed variation with height which is due to the weather patterns.
4. We can assume we instantly reach our flying altitude immediately after takeoff and don't limit ourselves to the FAA flight altitudes (e.g. East to West flying is limited to certain altitudes so as to ensure that planes don't crash into each other).
5. We can assume that unless otherwise stated, any values that vary (such as wind speed with altitude) vary in a linear fashion.



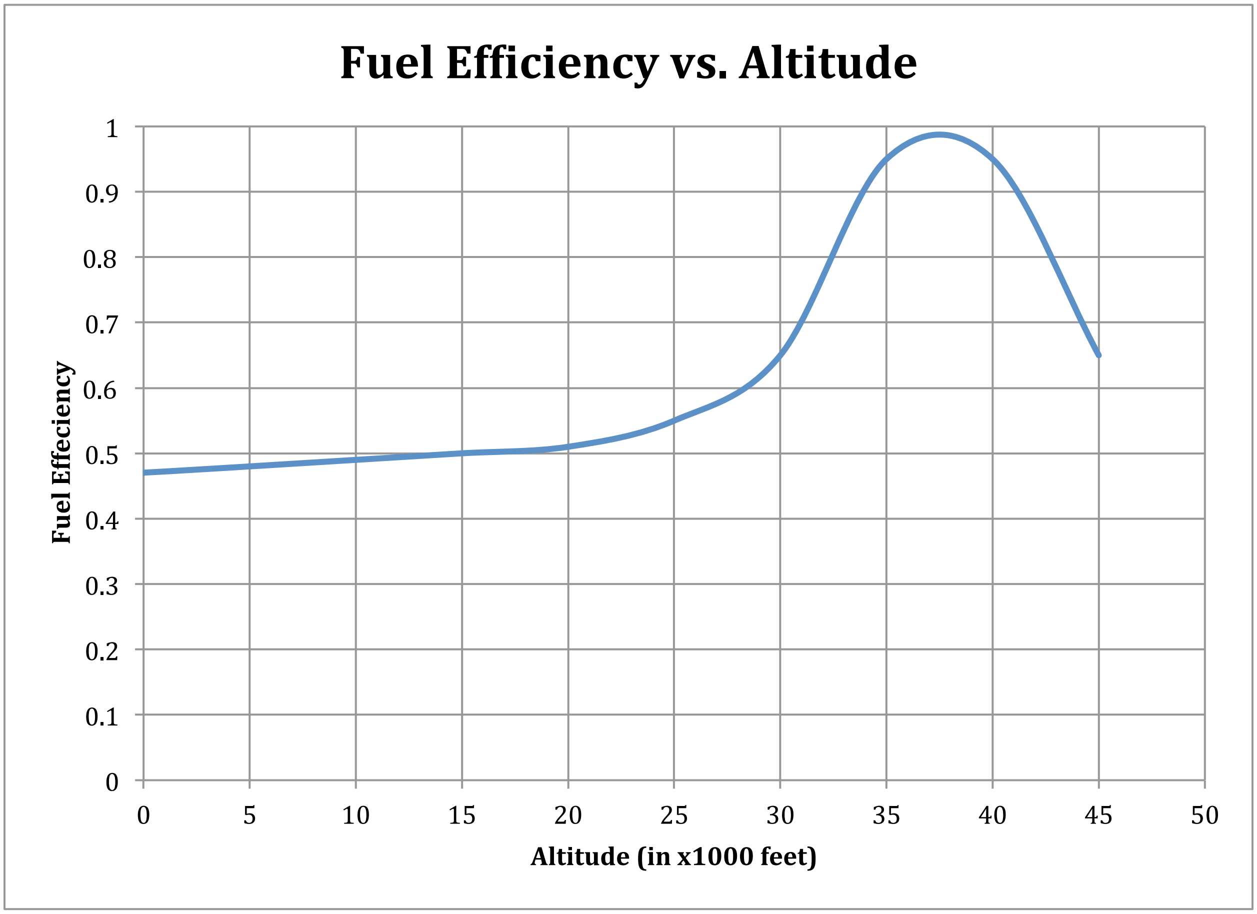
Appendix B

Useful Numbers	Value
Fuel Cost per Height	1 lbs/foot of altitude
Fuel Cost per Pound of Fuel	$0.50/gallon
Base Fuel Usage for Cruising	10 lbs/s with full fuel 5 lbs/s with just reserve fuel
Total amount of Fuel Held	380,000 Lbs
Cost to Leave an Airport (includes fees, fuel cost of taxing, onboard meals, ground crews, etc.)	$36,000 Per Takeoff
Non-Fuel Cost per Hour of Flying (Salaries, Aircraft maintenance, etc.)	$9,000/hour
Airport Altitudes	Assume all are at Sea Level
AUS to MSY MSY to JAX JAS to AUS	445 miles (point to point) 513 miles (point to point) 954 miles (point to point)
Wind Speed	5 mph at Sea Level 45 mph at 50,000 feet
Wind Direction	Blowing North to South at Sea Level Blowing West to East at 50,000 feet

Appendix C


Fuel Efficiency vs. Flying Speed
Fuel Efficiency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
700
800
Air Speed (mph)

Appendix D


Fuel Efficiency vs. Altitude
Fuel Effeciency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 5 10 15 20 25 30 35 40 45 50
Altitude (in x1000 feet)