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One course selected from AA courses numbered and above, excluding seminars and independent research Course Waivers Waivers of the basic courses required for the M. Students who believe that they have had a substantially equivalent course at another institution should consult with the course instructor to determine if they are eligible for a waiver, and with their adviser to judge the effect on their overall program plans. One additional technical elective must be added for each basic course that is waived. Students meet this requirement by taking two courses, for a minimum of 6 units, of either advanced mathematics offered by the Mathematics Department or technical electives that strongly emphasize applied mathematics. Other Electives It is recommended that all candidates enroll in a humanities or social sciences course to complete the unit requirement. Practicing courses in, for example, art, music, and physical education do not qualify in this category. Language courses may qualify. Stanford undergraduates who wish to continue their studies for the master of science degree in the coterminal program must have earned a minimum of units towards graduation. This includes allowable Advanced Placement AP and transfer credit. A completed application including letters of recommendation, transcripts and GRE scores must be received no later than the quarter prior to the expected completion of the undergraduate degree. Admission is granted or denied through the departmental faculty admissions committee. Transfer of courses to the graduate career requires review and approval of both the undergraduate and graduate programs on a case by case basis. Master of Science in Engineering AA Students whose career objectives require a more interdepartmental or narrowly focused program than is possible in the M. Sponsorship by the Department of Aeronautics and Astronautics in this more general program requires that the student file a proposal before completing 18 units of the proposed graduate program. The proposal must be accompanied by a statement explaining the objectives of the program and how the program is coherent, contains depth, and fulfills a well-defined career objective. The grade and unit requirements are the same as for the M. Engineer in Aeronautics and Astronautics The degree of Engineer represents an additional year or more of study beyond the M. The following are department requirements. See the list of mathematics courses under Related Courses tab above. All courses in the Mathematics Department numbered or above are included. The remaining 15 units are chosen in consultation with the adviser, and represent a coherent field of study related to the thesis topic. The remaining 24 units may be thesis, research, technical courses, or free electives. Candidates for the degree of Engineer are expected to have a minimum grade point average GPA of 3. All courses except seminars and directed research should be taken for a letter grade. The department recommends that students follow the format defined in the handbook Directions for Preparing Doctoral Dissertations , available in the Graduate Degree Progress Office. Department requirements are stated below. Applicants who have received their M. Students who are currently pursuing the M. Before beginning dissertation research for the Ph. A student must meet the following conditions by the appropriate deadline to be able to take the qualifying examination: A student who has completed fewer than 30 units may petition to take the qualifying examination. Stanford graduate GPA of 3. Investigation of a research problem, under the direction of a faculty member who evaluates this work as evidence of the potential for doctoral research. Additional information about the deadlines, nature, and scope of the Ph. After passing the exam, the student must submit an approved program of Ph. Course Requirements Each individual Ph. A total of 90 units of credit is required beyond the M. Of these 90 units, a minimum of 27 must be formal course work excluding research, directed study and seminars , consisting primarily of graduate courses in engineering and the pertinent sciences. The remainder of the 90 units may be in the form of either Ph. See the list of mathematics courses under Related Courses tab for suggestions. University requirements for continuous registration apply to doctoral students for the duration of the degree. It is incumbent upon Ph. There are two requirements for admission to Ph. The candidacy form lists the courses the student will take to fulfill the requirements for the degree. The form must include the 90 non-M. Candidacy is valid for five years; this term is not affected by leaves of absence. Dissertation Reading Committee Each Ph. Thereafter, the student should consult frequently with all members of the committee about the direction and progress of the dissertation research. A dissertation reading committee consists of the principal dissertation adviser and at least two other readers. If the principal adviser is emeritus, there should be a non-emeritus co-adviser. The initial committee, and any subsequent changes, must be approved by the department Chair. Although all readers are usually members of the Stanford Academic Council, the department Chair may approve one non-Academic Council reader if the person brings unusual and necessary expertise to the dissertation research. Generally, this non-Academic Council reader will be a fourth reader, in addition to three Academic Council members. University Oral Examination The Ph. The examination consists of a public presentation of dissertation research, followed by substantive private questioning on the dissertation and related fields by the University oral committee four faculty examiners, plus a chairman. The chairman must not be in the same department as the student or the adviser. Once the oral examination has been passed, the student finalizes the dissertation for reading committee review and final approval. Students must be enrolled during the quarter when they take their University oral examination. If the oral examination takes place during the vacation time between quarters, the student must be enrolled in the prior quarter. All members of the reading committee must sign the dissertation before the filing deadline. Minor in Aeronautics and Astronautics A student who wishes to obtain a Ph. Graduate Advising Expectations The Department of Aeronautics and Astronautics is committed to providing academic advising in support of graduate student education and professional development. The advising relationship should entail collaborative engagement by both the adviser and the advisee. As a best practice, advising expectations should be discussed and reviewed to ensure mutual understanding. Both the adviser and the advisee are expected to maintain professionalism and integrity. Graduate students are active contributors to the advising relationship, proactively seeking academic and professional guidance and taking responsibility for informing themselves of policies and degree requirements for their graduate program. In addition, the faculty Candidacy Chair is available for consultation during the academic year by email and during office hours. Staff in the office inform students and advisers about university and department requirements, procedures, and opportunities, and maintain the official records of advising assignments and approvals. For a statement of University policy on graduate advising, see the " Graduate Advising " section of this bulletin. The Guide to Graduate Studies in Aeronautics and Astronautics provides information and suggested timelines for advising meetings. In rare instances, a formal adviser change request may be considered. The Guide to Graduate Studies in Aeronautics and Astronautics provides information and suggested timelines for advising meetings in the different stages of the doctoral or engineering program. Juan Alonso, Brian J. Sigrid Close Assistant Professors: Scott Hubbard, James Spilker Lecturers:

Chapter 2 : Aeronautics - Wikipedia

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Theory of Flight Flight is a phenomenon that has long been a part of the natural world. Birds fly not only by flapping their wings, but by gliding with their wings outstretched for long distances. Smoke, which is composed of tiny particles, can rise thousands of feet into the air. Both these types of flight are possible because of the principles of physical science. Likewise, man-made aircraft rely on these principles to overcome the force of gravity and achieve flight. Lighter-than-air craft, such as the hot air balloon, work on a buoyancy principle. They float on air much like rafts float on water. The density of a raft is less than that of water, so it floats. Although the density of water is constant, the density of air decreases with altitude. The density of hot air inside a balloon is less than that of the air at sea level, so the balloon rises. It will continue to rise until the air outside of the balloon is of the same density as the air inside. Smoke particles rise on a plume of hot air being generated by a fire. When the air cools, the particles fall back to Earth. Heavier-than-air flight is made possible by a careful balance of four physical forces: A plane uses its wings for lift and its engines for thrust. Lift In order for an aircraft to rise into the air, a force must be created that equals or exceeds the force of gravity. This force is called lift. In heavier-than-air craft, lift is created by the flow of air over an airfoil. The shape of an airfoil causes air to flow faster on top than on bottom. The fast flowing air decreases the surrounding air pressure. Because the air pressure is greater below the airfoil than above, a resulting lift force is created. To further understand how an airfoil creates lift, it is necessary to use two important equations of physical science. It was derived by Daniel Bernoulli, a Swiss mathematician, to explain the variation in pressure exerted by flowing streams of water. The Bernoulli equation is written as: It simply states that in any given flow, the density rho times the cross-sectional area A of the flow, times the velocity V is constant. The continuity equation is written as: Imagine air flowing over a stationary airfoil, such as an aircraft wing. Far ahead of the airfoil, the air travels at a uniform velocity. To flow past the airfoil, however, it must "split" in two, part of the flow traveling on top and part traveling on the bottom. The shape of a typical airfoil is asymmetrical - its surface area is greater on the top than on the bottom. As the air flows over the airfoil, it is displaced more by the top surface than the bottom. According to the continuity law, this displacement, or loss of flow area, must lead to an increase in velocity. Consider an airfoil in a pipe with flowing water. Water will flow faster in a narrow section of the pipe. The large area of the top surface of the airfoil narrows the pipe more than the bottom surface does. Thus, water will flow faster on top than on bottom. The flow velocity is increased some by the bottom airfoil surface, but considerably less than the flow on top. The Bernoulli equation states that an increase in velocity leads to an decrease in pressure. Thus the higher the velocity of the flow, the lower the pressure. Air flowing over an airfoil will decrease in pressure. The pressure loss over the top surface is greater than that of the bottom surface. The result is a net pressure force in the upward positive direction. This pressure force is lift. There is no predetermined shape for a wing airfoil, it is designed based on the function of the aircraft it will be used for. To aid the design process, engineers use the lift coefficient to measure the amount of lift obtained from a particular airfoil shape. Lift is proportional to dynamic pressure and wing area. The lift equation is written as: In designing an aircraft wing, it is usually advantageous to get the lift coefficient as high as possible. Drag Every physical body that is propelled through the air will experience resistance to the air flow. This resistance is called drag. Drag is the result of a number of physical phenonmena. Pressure drag is that which you feel when running on a windy day. The pressure of the wind in front of you is greater than the pressure of the wake behind you. Skin friction, or viscous drag, is that which swimmers may experience. A rough surface will induce more frictional drag than a smooth surface. To reduce viscous drag, swimmers attempt to make contact surfaces as smooth as possible by wearing swim caps and shaving their legs. Like lift, drag is proportional to dynamic pressure and the area on which it acts. The drag coefficient, analgous to the lift coefficent, is a measure of the amount of dynamic pressure gets converted into drag. Unlike the lift coefficient however, engineers usually design the drag coefficient to be as low as possible.

Weight The weight of an aircraft is a limiting factor in aircraft design. A heavy plane, or a plane meant to carry heavy payloads, requires more lift than a light plane. It may also require more thrust to accelerate on the ground. On small aircraft the location of weight is also important. A small plane must be appropriately "balanced" for flight, for too much weight in the back or front can render the plane unstable. Thrust Propulsion involves a number of principles of physical science. Thermodynamics, aerodynamics, fluid mathematics, and physics all play a role. The basic form of this law is: Acceleration is the rate of change of velocity over time. Thrust T is produced therefore by accelerating a mass of air. Would more lift be provided by a fluid with a greater density than air? How do aircraft designers determine the correct shape for a wing? Explain how a propeller provides thrust in the same way a wing generates lift. An equation for lift was supplied previously. What would be the two forces involved on a propeller? Would a propeller work better in a fluid with a greater density than air? Do you think different planes need differently shaped airfoils? How are the wings of a small plane, like a Cessna, different from a large one, like a passenger jet? How are the propulsion systems of a biplane different than that of a fighter jet? What kind of propulsion does a Lear jet use? Make a list of the differences between fixed wing aircraft and helicopters. How does each generate lift? How fast can each go? What are the advantages and disadvantages of each? Some planes have more than one engine to propel the craft. Are the multiple engines necessary or a safety precaution? Take a trip to your local airport or an airshow. Visit the control tower and the aircraft hangers. Determine the wing area of a large aircraft. Describe what kind of plane it is. What kind of propulsion system does the space shuttle use, as opposed to an airplane? Who are the leading manufacturers of aircraft engines? Note any assumptions that you make. What is the density of air? Does it differ from high altitudes to low altitudes? Draw a free-body diagram of an aircraft.

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Early ideas[edit] Designs for flying machines by Leonardo da Vinci, circa Attempts to fly without any real aeronautical understanding have been made from the earliest times, typically by constructing wings and jumping from a tower with crippling or lethal results. An early example appears in ancient Egyptian texts. The founders of modern aeronautics, Leonardo da Vinci in the Renaissance and Cayley in , both began their investigations with studies of bird flight. Man-carrying kites are believed to have been used extensively in ancient China. In the European explorer Marco Polo described the Chinese techniques then current. An early European to provide any scientific discussion of flight was Roger Bacon , who described principles of operation for the lighter-than-air balloon and the flapping-wing ornithopter , which he envisaged would be constructed in the future. The lifting medium for his balloon would be an "aether" whose composition he did not know. Although his designs were rational, they were not based on particularly good science. He did at least understand that "An object offers as much resistance to the air as the air does to the object. His analysis led to the realisation that manpower alone was not sufficient for sustained flight, and his later designs included a mechanical power source such as a spring. Around Cyrano de Bergerac wrote some fantasy novels in which he described the principle of ascent using a substance dew he supposed to be lighter than air, and descending by releasing a controlled amount of the substance. These would be lighter than the displaced air and able to lift an airship. His proposed methods of controlling height are still in use today; by carrying ballast which may be dropped overboard to gain height, and by venting the lifting containers to lose height. Montgolfier brothers flight, From the midth century the Montgolfier brothers in France began experimenting with balloons. Their balloons were made of paper, and early experiments using steam as the lifting gas were short-lived due to its effect on the paper as it condensed. Meanwhile, the discovery of hydrogen led Joseph Black in c. Charles and two craftsmen, the Robert brothers, developed a gas tight material of rubberised silk for the envelope. The hydrogen gas was to be generated by chemical reaction during the filling process. The Montgolfier designs had several shortcomings, not least the need for dry weather and a tendency for sparks from the fire to set light to the paper balloon. The manned design had a gallery around the base of the balloon rather than the hanging basket of the first, unmanned design, which brought the paper closer to the fire. On the other hand, the manned design of Charles was essentially modern. The principle was to use the hydrogen section for constant lift and to navigate vertically by heating and allowing to cool the hot air section, in order to catch the most favourable wind at whatever altitude it was blowing. The first flight ended in disaster and the approach has seldom been used since. He was first called the "father of the aeroplane" in [12] and Henson called him the "father of aerial navigation. He developed the modern conventional form of the fixed-wing aeroplane having a stabilising tail with both horizontal and vertical surfaces, flying gliders both unmanned and manned. He introduced the use of the whirling arm test rig to investigate the aerodynamics of flight, using it to discover the benefits of the curved or cambered aerofoil over the flat wing he had used for his first glider. He also identified and described the importance of dihedral , diagonal bracing and drag reduction, and contributed to the understanding and design of ornithopters and parachutes. Important investigators included Otto Lilienthal and Horatio Phillips. He developed plans for a "torpedo plane", which is why he is considered ahead of his time. When the internal explosion engines were invented, small enough to be able to propel a flying device with them, a race started between two flight possibilities:

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