**CMU Fall 2010**

**Final Exam Schedule**

**Operations Research II Project**

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ABSTRACT

The paper investigates the optimal final exam schedule for Fall 2010 semester at Carnegie Mellon University. By optimal, we seek to minimize the number of students having a conflict or three consecutive exams within 24-hour period in their final exam schedule. This problem is a realistic problem and an interesting problem to approach at the same time. The fact that the final exam schedule is finalized almost a week or two before the actual final exam implies us the difficulty and complexity of this problem. We hope to explore this problem with sufficient but reasonable assumptions to enable us to apply the mathematical reasoning learnt in Operations Research class.

ASSUMPTIONS

In order to reduce the complexity of the problem, we made several assumptions that are reasonable so that we can approach the problem and apply the solution in reality at the same time. These assumption are categorized mainly in four categories: the number of students enrolled for fall semester in 2010 at Carnegie Mellon University, course schedules for the students, room information where the final exams are taken, and miscellaneous assumptions beside the first three assumptions.

**Number of Students Enrolled**

We first made an assumption on the number of students enrolled for fall semester in 2010 at Carnegie Mellon University for undergraduates. In order to do so, we looked up the undergraduate first-year admission statistics for year 2010-2011 so that we make our assumption on the number of students enrolled as realistic as possible. We rounded up the numbers of students enrolled in each department such as Carnegie Institute of Technology (CIT), College of Fine Arts (CFA), College of Humanities and Social Sciences (H&SS), Tepper School of Business (Tepper), H. John Heinz II College (IS), Mellon College of Science (MCS), and School of Computer Science (SCS). We assumed zero students for BHA/BSA/BCSA students since they comprise only about 0.01% of the total students. Hence, we came up with the total number of 6000 students, having 1500 students in each grade, Freshmen, Sophomore, Junior, and Senior, and distributed reasonable number of students following the statistics for 2010-2011 year (Appendix A).

**Students’ Course Schedule**

Constructing course schedules for each student, we looked up the student catalogue on CMU website where suggested schedules and requirements are displayed for each major in each department (Appendix A). From there, we created schedules for each major in each department, considering only courses that are offered during the fall semester. In order to make our assumed students’ schedules more realistic, we took a survey on which electives are most frequently taken by juniors and seniors for each major (Appendix A). We also assumed that students take four or five courses on average. Then we put our data together and created schedules for each major for each year from freshmen to seniors (Appendix A).

**Room Information where Final Exams are taken**

Next, we made an assumption on the capacity of the classrooms where the final exams will be taken. We researched on CMU website and obtained information on capacity of how many students can fit in each room at a maximum (Appendix A). We assumed that 35 classrooms including MM 103 are used for the final exams and the largest room came out to be UC McConomy and the smallest room came out to be Wean Hall 5304.

**Miscellaneous**

Beside three assumptions above, we assume that the final exams are taken for six days excluding the reading day, which is same as the current policy at CMU. Also, we assume that there are three exam periods per day. We assume that the schedule we receive is fixed before we make an optimal final exam schedule, which means our information on students’ schedule for fall semester is the information after the add/drop day so that the course registration is fixed for the students. No two exams can be taken simultaneously in the same room although the room is not full; however, for over-capacity courses, multiple rooms are available for the final exams during the same time period. Lastly, students are asked to take the final exams in every other seat.

IP FORMULATION

As it is mentioned above, our goal of the project is to minimize the number of students who are taking three exams within a 24-hour period. When we minimize the number of students taking three consecutive exams within a 24-hour period, we need to take some constraints into account. The most important limitation we should consider is that a student is not able to take two or more exams on any exam period – no time conflict. Secondly, on any exam period, the number of exams on that period should be less or equal to the number of rooms available for exams. Thirdly, there should be no room conflicts. In other words, no two exams can be taken in the same room. Thirdly, on any exam period, the number of exams on that period should be less or equal to the number of rooms available for exams. Fourthly, the capacity of the room(s) for certain exam should be able to accommodate all students who take that exam. Before we write equations and constraints, the very first thing we need to do is to define variables that appear in the equations.

**Defining Variables: Object Equation**

Xi,g,k is an indicator variable that specifies whether a student has three consecutive exams within 24-hour period. We note as one if a student’s exam schedule applies to the above indicator variable condition (by this, we mean that a student has three exams in 24-hour period), and zero otherwise. The subscription *i* indicates major of a student. There are total 23 majors so *i* consists of 1 from 23 – i [1, 23]. *g* signifies grade level of a students; since typical college including Carnegie Mellon University divides students into freshmen, sophomore, junior and senior, g consists of 1 from 4 - g [1, 4] , and *k* denotes the time period in which an exam is taken. Sj,g,t is the number of grade level *g*-students taking exam *j* at time *t*. Since there are 3 exam periods in one day – morning, afternoon, and evening- and all the exams are scheduled such that it finishes in 6 days, *t* consists of 1 from 18 - [1, 18] in which one indicates the first exam period of the first day, two indicates the second exam period of the first day and so on.

Before we construct our object equation, recall that we assumed that students in the same major take the same courses; hence, all the students of certain grade and of certain major have the same exam schedule. For example, let us assume that a freshmen student in mathematic major has programming exam on the first period of the first day, history exam on the second period and principles of economics exam on the third period. Then all the freshmen students in mathematics major have the same exam schedule as the student above. Now, if we multiply above two variables, Xi,g,k and Sj,g,k, we obtain the number of students in major *i*, grade level *g* and exam *j* as a starting exam who has three exams in 24-hour period as a result. We must sum over all time periods, majors, and grade levels to acquire the total number of students who take three consecutive exams. By minimizing this sum, we achieve our aim of the object equation.

**Defining Variables: Constraint Equations**

We also used integer programming to represent constraints in mathematical formula. mi,j,g is an integer variable. It corresponds to one if a grade level *g* of major *i* take exam *j* at certain time *t* or zero otherwise. Since we defined such that no student is able to take two or more exams on any exam period, we should get zero or one when we sum mi,j,g over all *j* (there are total 126 exams so *j* consists of 1 to 126 – j [1, 126]). If we sum this variable over all *i,j* and *g*, and limit this summation to be less than 35 (the total number of rooms used for final exams), this inequality represents the constraint three – the number of exams held on any period should be less or equal to the number of rooms available for exams.

Not only students but rooms should have no conflicts – meaning that no two exams can be taken simultaneously in the same room. We created integer variable r l,t  and defined to be one if room *l* is not used at time *t* or zero otherwise (the total of 35 rooms are used for final exams, so *l* consists of 1 to 34 – l [1, 35]).

Students are asked to take the final exams in every other seat. Let nl represent the room capacity divided by two. Since we assumed that one or more rooms can be used for one exam, the number of seats of remaining rooms should be able to accommodate all students who take that exam. Hence Sj,g,t summed over all g (the result gives all the students who take exam *j* and time *t*) should be less or equal the total number of seats of remaining rooms – ∑l nl · r l,t.

In *Defining Variables: Object Equation* section, we introduced variable Xi,g,k but did not explicate in detail of the variable’s composition. If a student a student has three exams in 24-hour period, we define the variable to be one. The kernel of the argument is the method of deciding whether a student has three exams in 24-hour period. If we sum mi,j,g over three exam periods, we are able to know the number of exams a student takes in 24-hour period.

**Object and Constraint Equations in Mathematical Symbols**

Subject to

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i [1, 23], j [1, 126], g [1,4], t [1, 18]

=

l [1, 35]

j [1, 126]

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We will use this Integer Programming Formula in Simple Optimal Algorithm later on.

INSIGHT FOR AN APPROACH

As Prof. Frieze has gently warned us, our problem is NP-hard, extraordinarily difficult problem to achieve the optimal solution. Hence it is reasonable and sufficient to pursue achieving a good solution rather than the optimal solution. Since we did not have a proficient knowledge of LINDO nor other ILP solvers, we have shifted our focus in generating an iterative optimality method using Java. Given an initial schedule, only bound to the room and reality constraint but ignoring the students’ schedule constraint, we wish to generate an iterative optimality method that rebalances the schedule by decreasing the number of students having a schedule conflict.

In describing the Java approach in detail, it is assumed that the reader has a sufficient knowledge of Java. Of course, we are to provide non-Java explanation along with it.

**Generating an Initial Schedule**

In order for the iterative optimality schedule to work, we need an initial schedule to work with. An initial schedule is generated as follows:

First, store all the room, student and course data into the Java code using an ArrayList class in a sorted decreasing order. In other words, room, student and course information are stored in distinct memories inside Java so that we can access the data conveniently.

Starting from time 1(8:30 ~ 11:30 am of Exam Day 1), choose the course with largest student number. Then check whether this course can be assigned to the corresponding time, meaning iterate over all the empty class rooms and add up its capacity to compare it with the number of students taking a chosen course. If course can be assigned, fill in the rooms from largest to the smallest. If not, move on to the next time period for availability. Repeat such process with all the courses. Always start from time period 1.

Given the maximum room capacity throughout 18 periods and the sum of the number of students taking an exam, it is feasible to schedule classes, only bound to room constraints but ignoring the students’ schedule conflict.

Repeating the above process with all the course lists, an initial schedule is generated only filling rooms up to time period 10 out of 18.

OPTIMALITY ALGORITHM

**Identifying the Conflict**

An initial schedule is set. Now we ought to find the optimality algorithm that reduces the number of students in conflict. To identify such a conflict, the following method is applied:

When assigning an exam in a room R at time T, the course variable stores the information within. In other words, once the exam is assigned to a specified room at specified time, the course now holds account of this information. Since no two different exams are scheduled in same room, due to the nature of constructing an initial algorithm, we only need to take an account of time conflict. Comparing the time periods of each student’s exams, we can easily identify whether this student has a schedule conflict.

First, if two time periods are equal, it means two different exams a student is taking has been scheduled at same time period, which is a definite schedule conflict. We identify this conflict as a Concurrency conflict. For students having three or more exams, we need to identify whether three exams are scheduled within 24-hour period. We do such by discovering an interesting property such a combination provides. Iterate over each number, computing the absolute difference between the iterating number and the list of numbers. Increase the counter when we find the absolute difference to be less than three. If the resulting counter is greater than (five + size of the list of number) then the student has a 24-hour period conflict.

Iterating the initial schedule, we noticed total of 46 out of 80 student groups had a conflict in their course. Their schedule can be categorized in two distinct ones: Concurrency issue and 3-exams-in-24-hour issue. The prior being a student group has been assigned to take two or more exams at same time period, which is realistically impossible. The latter is that three exams are within the range of 24-hour period for student, which is very stressful and is ought to be avoided.

**Optimality Algorithm**

First, we wish to put the concurrency constraint in our algorithm. Student groups with concurrency issue are separated from that of 24-hour period conflict. Among the concurrent exams, an exam with the least number of students is to be re-scheduled at other time period. Then the existing exam schedule is removed. Repeating the above process provides us with the adapted schedule without concurrency issue but only with 24-hour period constraint. After imposing concurrency constraint, the number of conflicts was reduced to 31 from 46.

SIMPLE OPTIMALITY ALGORITHM

In dealing with the second and the most important constraint, 24-hour period constraint, we used what we named as simple optimally algorithm. With an initial schedule given from the result using Java, we apply simple optimal algorithm to get optimal final exam schedule. First, we have to check at which time periods students have three consecutive exams within 24-hour period by using these constraints:

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i [1, 23], j [1, 126], g [1,4], t [1, 18]

If the sum of mi,j,g in three consecutive periods equals to 3, then grade level-g students majoring in i have three exams within 24 hours. In this schedule, we find that 150 CS major sophomores from time period 2 to 4 and 50 philosophy major sophomores from time period 14 to 16 have three consecutive exams. Refer to Appendix C (a)

As our objective is to minimize the number of students who takes three exams consecutively, we decide to move the second exam to another period, before the first exam or after the last one. In order to choose the value of t, we should consider two things: conflicts and room capacity. Using the constraints below, we can find a better period for the second exam:

mi,j,g =

i [1, 23], j [1, 126], g [1,4]

If ∑j m i,j,g = 1 or 0 at given t, there is no conflict.

If ∑j m i,j,g > 1, there is a conflict.

Sj,g,t = # of grade level g-students taking exam j at t

j [1, 126], t [1, 18]

rl,t =

l [1, 35], t [1, 18]

nl = capacity of room l / 2 (every other seat)

∑g Sj,g,t ≤ ∑l nl · r l,t

The second exam of CS sophomores, 15-212 principle of programming course, can be moved to t <2, or t > 4. Since it has conflicts with 85-102 at time period 6, and 21-241 at time period 14, we can exclude t = 6, and 14. Even though exam of course number 15-212 does not have a conflict at time period 5, we cannot choose t=5 because CS sophomores would have another three consecutive exams from time period 4 to 6. Among the rest of t-values, for enough room capacity, we take the period with the smallest total number of students taking exams. At time period 9, 15, and 18, total 660 students, the smallest number, have exams. Finally, we compare remaining room capacity: at time period 18, the largest room capacity exists. Therefore, for the best schedule, we should move 15-212 course exam to the third period on the last day. Similarly, the second exam of philosophy major sophomores, 21-256 Multivariate Analysis and Approximations course, can be moved to t<14, or t>16. We can exclude t=1, 12, 13 because of conflicts with 15-110 and 36-225, and another three consecutive exams from time period 12 to 14. After moving 15-212 course exam, time period 3 has the smallest total number of students, 480 students. Since there is enough room capacity at t=3, we should move 21-256 course exam to third period on the first day.

RESULT

Since there are no students who are taking three exams in 24-hour period, the schedule in Appendix C (b) is one of the optimal final exam schedules that we could get through simple optimal algorithm.

IN REALITY

Carnegie Mellon University has been continuously dealing with the issues on final exam schedule every semester. Due to the large number of exams and students, it is evidently difficult to construct a schedule that fits for every student on campus. According to the CMU registrar, they have been using software called “Schedule Expert” from Strathman Associates. At the end of the add/drop period, they download each student course registration and the courses with exams and cross-listed courses, and then run the program to create a schedule, which minimizes direct conflicts and three exams within 24-hour period. CMU pre-schedules large courses, first year student courses, or special faculty request with little difficulty when it makes sense to grant the request.

FURTHER

In conclusion, to our surprise, we have come up with *the* optimal final exam schedule modeled upon 2010 Fall Semester CMU. We believe our optimal schedule was obtained purely from the benefit of simplistic assumptions. We dealt only with limited number of classes and majors, and restricted students’ freedom to take courses. In reality, each student manages to create their own schedule based on their personal need and interest. About half the students have minor or other major, some re-take courses for academic or personal reasons and some have cross-department majors that has its unique catalog to follow.

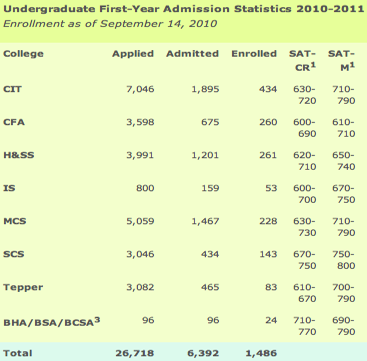
In simple word, reality is far more complex. There are far too many variables, combinations, possibilities, and exceptions to consider. In pursuit of achieving a more insightful and competitive algorithm to take further steps, we have come up with a rebalancing algorithm. The rebalancing algorithm is the following: it is an algorithm that balances or obtains the optimal schedule, given an extra schedule to add in or extract out from the existing feasible schedule. The basic thought being - by iteratively adding a new exam to our current optimal exam schedule, we would eventually attain realistic final schedule. This way, we can extend our scope of insight from a feasible solution to a *better* solution.

Yet, noting the difficulty and intricacy of the problem, we faced an invincible challenges that are far beyond of our scope of knowledge both in programming-wise and approach-wise. Hence, we would like to let prospective future students who may want to research similar problem to take above suggestive approach into consideration and possibly get better optimal schedule.

**Appendix**

APPENDIX A

Undergraduate First-Year Admission Statistics for 2010-2011 Year:



APPENDIX A

Assumed number of students for each major in each department enrolled for fall in 2010:

|  |  |
| --- | --- |
| **Tepper 100**   1. Business 50 2. Econ 50   **MCS 250**   1. Biology 60 2. Chem 60 3. Physics 60 4. Math 70   **CIT 450**   1. ECE 90 2. MechE 90 3. ChemE 90 4. CivilE 90 5. MaterialScienceE 90 | **H&SS 250**   1. Psych 50 2. English 50 3. Stat 50 4. Philosophy 50 5. Social&Decision Sciences 50   **CFA 250**   1. Fine Art 60 2. Design 60 3. Archi 60 4. Music 40 5. Drama 30   **SCS 150**  **IS 50** |

**🡪 Total number of students per grade level: 1500**

APPENDIX A

Sample Survey for Elective Requirements:

Grade: Freshmen / Sophomore / Junior / Senior

Department:

Major:

* What elective courses are you taking this semester?

1)

2)

3)

* What elective courses are you planning to take later / have you taken before?

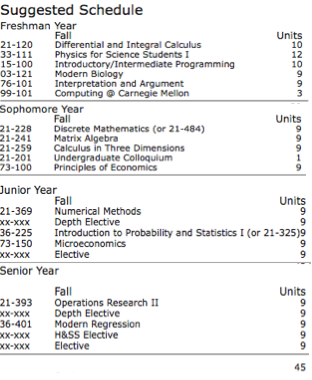
1)

2)

3)

APPENDIX A

Sample Suggested Schedule from CMU catalogue:



APPENDIX A

Assumed Students’ Course Schedules for fall semester in 2010:

**Carnegie Institute of Technology (CIT)**

1. **Electrical and Computer Engineering**

First Year:

21-122 Integration, Differential Equations and Approximation

76-101 Interpretation and Argument

99-101 Computing at Carnegie Mellon

15-110 Principles of Computing

82-131 Elementary Chinese I

Second Year:

33-106 Physics for Engineering Students I

18-220 Electronic Devices and Analog Circuits

18-231 Sophomore Projects

18-240 Structure and Design of Digital Systems

18-290 Signals and Systems

Third Year:

18-320 Microelectronic Circuits

18-342 Fundamentals of Embedded Systems

18-370 Fundamentals of Control

21-259 Calculus in Three Dimensions

Fourth Year;

18-431 Undergraduate Projects – Senior

18-450 Digital Wireless Communications

18-491 Fundamentals of Signal Processing

18-493 Electroacoustics

1. **Mechanical Engineering**

First Year:

21-122 Integration, Differential Equations and Approximation

76-101 Interpretation and Argument

99-101 Computing at Carnegie Mellon

15-110 Principles of Computing

82-131 Elementary Chinese I

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Second Year:

33-106 Physics for Engineering Students I

21-259 Calculus in Three Dimensions

42-221 Thermodynamics I

24-261 Statics

Third Year:

24-302 Mechanical Engineering Seminar

24-311 Numerical Methods

24-322 Heat Transfer

24-351 Dynamics

36-220 Engineering Statistics and Quality Control

Fourth Year:

24-441 Design II: Conceptualization and Realization

24-452 Mechanical Systems Experimentation

24-424 Energy and the Environment

24-451 Feedback Control Systems

1. **Chemical Engineering**

First Year:

21-122 Integration, Differential Equations and Approximation

76-101 Interpretation and Argument

99-101 Computing at Carnegie Mellon

42-101 Introduction to Biomedical Engineering

09-105 Introduction to Modern Chemistry I

Second Year:

09-106 Modern Chemistry II

15-110 Principles of Computing

82-131 Elementary Chinese I

06-222 Sophomore Chemical Engineering Seminar

06-221 Thermodynamics

Third Year:

06-323 Heat and Mass Transfer

06-321 Chemical Engineering Thermodynamics

09-347 Advanced Physical Chemistry

09-217 Organic Chemistry I

82-231 Intermediate Chinese I

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Fourth Year:

06-421 Chemical Process Systems Design

06-422 Chemical Reaction Engineering

06-423 Unit Operations Laboratory

42-401 Foundation of BME Design

1. **Biomedical Engineering**

First Year:

21-122 Integration, Differential Equations and Approximation

76-101 Interpretation and Argument

99-101 Computing at Carnegie Mellon

42-101 Introduction to Biomedical Engineering

03-121 Modern Biology

Second Year:

15-110 Principles of Computing

82-131 Elementary Chinese I

42-203 Biomedical Engineering Laboratory

42-201 Professional Issues in Biomedical Engineering

06-221 Thermodynamics

Third Year:

06-323 Heat and Mass Transfer

42-300 Junior BME Research Project

42-341 Introduction to Biomechanics

09-347 Advanced Physical Chemistry

Fourth Year

06-421 Chemical Process Systems Design

06-423 Unit Operations Laboratory

42-444 Medical Devices

42-401 Foundation of BME Design

1. **Civil and Environmental Engineering**

First Year:

21-122 Integration, Differential Equations and Approximation

76-101 Interpretation and Argument

99-101 Computing at Carnegie Mellon

33-106 Physics for Engineering Students I

82-131 Elementary Chinese I

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Second Year:

12-212 Statics

21-259 Calculus in Three Dimensions

09-101 Intro to Experimental Chemistry

09-105 Modern Chemistry I

Third Year:

21-301 Civil and Environmental Engineering Projects

12-335 Soil Mechanics

12-336 Soil Mechanics Lab

12-355 Fluid Mechanics

12-356 Fluid Mechanics Lab

Fourth Year:

12-401 Civil and Environmental Engineering Design

12-411 Project management

12-421 Engineering Economics

12-600 Auto CAD

12-651 Air Quality Engineering

**College of Humanities and Social Sciences (H&SS)**

1. **Psychology**

First Year:

76-101 Interpretation and Argument

76-145 Freshman Seminar

21-111 Calculus I

36-201 Statistical Reasoning and Practice

03-121 Modern Biology

Second Year:

21-120 Differential and Integral Calculus

85-211Cognitive science

79-104 World History

33-124 Astronomy

85-241 Social Psychology

Third Year:

85-219 Biological Foundations of Behavior

09-105 Introduction to Modern Chemistry I

15-102 Exploring Programming with Graphics

33-111 Physics I for Science Students

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Fourth Year

85-370 Perception

85-421 Language and Thought

85-310 Research Methods in Cognitive Psychology

36-309 Experimental Design for Behavioral and Social Sciences

1. **English**

First Year:

76-101 Interpretation and Argument

76-145 Freshman Seminar

36-201 Statistical Reasoning and Practice

79-104 Global Histories

21-120 Differential and Integral Calculus

Second Year:

76-272 Language in Design

76-270 Writing for the Professions

76-239 Introduction to Film Studies

76-247 Shakespeare: Comedies and Romances

76-321 Genre Studies

Third Year:

76-260 Survey of Forms: Fiction

76-294 Interpretive Practices

76-394 Research in English Studies

76-386 Language & Culture

76-390 Style

Fourth Year:

76-425 Science in the Public Sphere

76-397 Instructional Text Design

76-462 Advanced Fiction Workshop

76-391 Document Design

76-306 Editing and Publishing

1. **Statistics**

First Year:

21-120 Differential and Integral Calculus

36-201 Statistical Reasoning and Practice

76-101 Interpretation and Argument

76-145 Freshman Seminar

79-104 World History

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Second Year:

21-256 Multivariate Analysis and Approximations

21-241 Matrix Algebra

36-225 Introduction to Probability and Statistics I

15-110 Principles of Computing

Third Year:

73-150 Microeconomics

36-350 Data Mining

21-127 Concepts of mathematics

21-292 Operations Research I

Fourth Year:

36-401 Modern Regression

36-463 Topics in Statistics

80-226 Revolutions in Science

88-305 Rational Choice

1. **Philosophy**

First Year:

21-120 Differential and Integral Calculus

36-201 Statistical Reasoning and Practice

76-101 Interpretation and Argument

76-145 Freshman Seminar

79-104 World History

Second Year:

21-256 Multivariate Analysis and Approximations

21-241 Matrix Algebra

80-226 Revolutions in Science

80-130 Introduction to Ethics

15-110 Principles of Computing

Third Year:

80-208 Critical Thinking

80-220 Logic and Proofs

80-365 Ramsey

80-210 Logic and Proofs

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Fourth Year:

80-383 Language in Use

80-270 Philosophy of Mind

80-226 Revolutions in Science

80-413 Category Theory

1. **Social & Decision Science**

First Year:

21-111 Calculus I

36-201 Statistical Reasoning and Practice

76-101 Interpretation and Argument

76-145 Freshman Seminar

79-104 World History

Second Year:

21-120 Differential and Integral Calculus

88-122 Introduction to Game Theory & Strategy

85-221 Cognitive Psychology

15-110 Principles of Computing

Third Year:

88-220 Policy Analysis I

88-223 Decision Analysis and Decision Support Systems

88-302 Behavioral Decision Making

88-377 Attitude Persuasion

Fourth Year:

70-381 Marketing

88-412 Economics of Global Warming

73-347 Game Theory for Economists

88-387 Social Norms and Economics

**College of Fine Arts (CFA)**

1. Architecture

First Year:

48-100 Architecture Design Studio: Foundation I

48-120 Introduction to Digital Media I

48-130 Architectural Drawing I: A Tactile Foundation

21-114 Calculus for Architecture (mini 2)

64-100 Critical Histories of the Arts

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Second Year:

48-200 Architecture Design Studio: Composition   
48-210 Statics  
48-230 Architectural Drawing III: Perspective  
48-240 Architecture History I: Historical Survey of World Architecture and Urbanism   
76-101 Interpretation and Argument

Third Year:

48-300 Architecture Design Studio: Site   
48-312 Site Engineering and Foundations  
48-315 Environment I: Climate and Energy   
48-448 History of Sustainable Architecture  
99-101 Computing @ Carnegie Mellon

Fourth Year:

48-400 Architecture Design Studio: Occupancy

48-410 Environment II: Acoustics and Light

48-412 Environment III: Mechanical Systems

48-452 Real Estate Design and Development

48-338 European Cities in the XIX Century: Planning, Architecture, Preservation

Fifth Year:

48-500 Architecture Design Studio: The Urban Lab

48-497 Thesis Preparation (optional)

48-550 Issues of Practice

48-453 Urban Design Theory and Practice

48-470 Experimenting with Lamination, Clamping, and Cutting

1. **Fine Arts**

First Year

60-101 Concept Studio I

60-110 Electronic Media Studio I: Computer Art

60-150 2D Media Studio I: Drawing

60-104 Contemporary Issues Forum

99-101 Computing @ Carnegie Mellon

76-101 Interpretation and Argument

Second Year

60-201 Concept Studio III 10

60-230 3D Media Studio II: Foundry, Metals, Construction 10

60-250 2D Media Studio III: Painting 10

60-205 Modern Visual Culture: 1789-1945

79-104 Global Histories

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Third Year

60-301 Contextual Practice

60-409 Advanced ETB: Video & Performance

60-415 Advanced ETB: Animation

60-486 The Art and Science of Color

82-131 Chinese

Fourth Year

60-401 Senior Project

60-435 SIS:Metals

60-432 Advanced CP/SIS Site-Work Braddock

60-371 Breathelss: Internation new Wave Cinemas

73-100 Principles of Economics

1. **Design**

First Year

51-101 Design Studio I

51-121 Design Drawing I

51-171 Human Experience in Design

76-101 Interpretation & Argument

85-100 Introduction to Intelligence

99-101 Computing @ Carnegie Mellon

Second Year

51-201 Basic Typography: CD Studio I

51-203 Communication Design Computer Lab

51-241 How People Work: Human Factors

51-229 Digital Photographic Imaging

51-271 Design History I

51-785 Designing for Service

Third Year

51-301 Advanced Typography: CD Studio III

51-321 Photography and Communication

51-327 Web Design

51-399 Junior Independent Study

51-765 Introduction to Industrial Design Fundamentals

82-131 Elementary Chinese I

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Fourth Year

51-403 Sr. Project: Interaction Design

51-421 Visual Interface Design

51-471 Issues of Professional Practice

51-499 Senior Independent Study

51-707 Visual Processes

82-132 Elementary Chinese

1. **School of Drama**

First year

54-011 Warmup   
54-101 Acting I  
54-103 Speech I   
54-105 Voice/Alexander I   
54-107 Movement I   
54-111 Text   
54-159 Production Symposium I   
54-175 Conservatory Hour   
54-177 Foundations of Drama I   
64-100 Critical Histories of the Arts

Second year

54-201 Acting II   
54-203 Voice & Speech II   
54-207 Movement II   
54-211 Actor Dance II   
54-221 Directing II   
54-259 Production Symposium II   
54-281 Foundations of Drama III   
82-1311 Elementary Chinese I

Junior Year

54-301 Acting III 12  
54-303 Speech III (accents) 6  
54-305 Voice/Alexander III 6  
54-307 Movement III 6  
54-311 Acting Symposium III 10  
54-325 Actor Dance III 3  
54-382 History of Drama   
82-131 Elementary Chiense II

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Senior Year

54-401 Camera Lab   
54-405 Graduate Directing   
54-407 Movement IV   
54-409 Theatre Lab   
54-411 Acting Symposium IV   
54-413 Showcase   
54-437 Acting for the Camera   
54-494 Business of Acting   
21-120 Differential and Integral Calculus

1. **School of Music**

First year:

57-501 Studio

57-420 Jazz Vocal Ensemble

57-193 Skills of Accompanying I

57-152 Harmony I

57-161 Eurhythmics I

57-181 Solfege I 3 57-189 Repertoire and Listening for Musicians I

57-173 Survey of Western Music History

76-101 Interpretation and Argument

Second Year

57-501 Studio

57-417 Major Choral Ensemble

57-228 Chamber Music

57-151 Principles of Counterpoint

57-163 Eurhythmics III

57-183 Solfege III

57-289 Repertoire and Listening for Musicians III

57-283 Music History I

82-171 Elem. Japanese

Third Year

57-501 Studio

57-418 Major instrumental ensemble

57-228 Chamber Music

57-480 History of Black American Music

82-271 Inter. Japanese

57-103 Elective Studio(Beginning Piano Class)

APPENDIX A

Fourth Year

57-501 Studio

57-234 Performance for Composers

57-349 Supervised Theory Teaching

82-141 Elementary Spanish

57-107 Elective Studio(Jazz Piano I class)

**The Tepper School of Business (Tepper)**

1. **Undergraduate Business Administration**

First year:

73-100 Principles of Economics

70-100 Introduction to Business

21-120 Differential and Integral Calculus

76101 Interpretation and Argument

99-101 Computing at CMU

Second year:

21-257 Models and Methods of Optimization

70-122 Introduction to Accounting

70-207 Probability and Statistics

79-104 Introduction to World History

Third year:

70-371 Production and Operations management

70-381 Marketing

73-200 Macroeconomics

70-391 Finance

70-451 Management Information Systems

Fourth year:

70-201 Service project

85-102 Introduction to Psychology

70-492 Investment Analysis

70-440 Corporate Strategy

1. **Undergraduate Economics Program**

First year:

76-101 Interpretation and Argument

15-100 Introductory Programming

21-120 Differential and Integral Calculus

73-100 Principles of Economics

36-201 Statistical Reasoning

APPENDIX A

Second year:

36-303 Sampling, Survey and Society

73-270 Writing for Economics

73-310 History of Economic Issues and Analysis

73-200 Intermediate Macroeconomics

82-132 Elementary Chinese 1

Third year:

73-261 Econometrics

76-270 Writing in the Professions

73-252 Advanced Microeconomic Theory

73-253 Advanced Macroeconomic Theory

73-359 Benefit-cost Analyses

Fourth year:

73-347 Game Theory Economics

73-497 Senior Project

76-271 Introduction to Professional and Technical Writing

36-303 Sampling, Survey, and Society

**Mellon College of Science (MCS)**

1. **Department of Mathematical Sciences**

First year:

21-120 Differential and Integral Calculus

33-111 Physics 1 for Science

15-100 Introductory Programming

03-121 Modern Biology

76-101 Interpretation and Argument

99-101 Computing at CMU

Second year:

21-228 Discrete Mathematics

21-341 Linear Algebra 1

21-259 Calculus is Three Dimensions

79-104 Introduction to World History

21-201 Undergraduate Colloquium

Third year:

21-355 Principles of Real Analysis 1

36-225 Introduction to Probability and Statistics 1

82-132 Elementary Chinese 1

21-369 Numerical Methods

21-370 Discrete Time Finance

APPENDIX A

Fourth year:

21-393 Operations Research 2

36-401 Modern Regression

21-600 Math Logic 1

21-476 Ordinary Differential Equations

1. **Department of Chemistry**

First year:

09-105 Introduction to Modern Chemistry

21-120 Differential and Integral Calculus

33-111 Physics I for Science

76-101 Interpretation and Argument

99-101 Computing at CMU

Second year:

09-201 Undergraduate Seminar 1

09-219 Modern Organic Chemistry 1

09-221 Lab 1: Introduction to chemical Analysis

09-231 Mathematical Methods for Chemists

03-121 Modern Biology

Third year:

09-301 Undergraduate Seminar 3

09-321 Lab 3: Molecular Design and Synthesis

09-344 Physical Chemistry

09-331 Modern Analytical Instrumentation

09-507 Nanoparticles

Fourth year:

09-401 Undergraduate Seminar 5

09-445 Undergraduate Research

09-711 Physical Organic Chemistry

09-518 Bioorganic Chemistry

1. **Department of Physics**

First year:

33-111 Physics 1 for Science Students

15-100 Introductory Programming

21-120 Differential and Integral Calculus

99-101 Computing at CMU

76-101 Interpretation and Argument

APPENDIX A

Second year:

33-211 Physics 3: Modern Essentials

33-231 Physical Analysis

21-259 Calculus in Three Dimensions

09-105 Introduction to Modern Chemistry

33-201 Physics Sophomore Colloquium 1

Third year:

33-331 Physical Mechanics 1

33-338 Intermediate Electricity and Magnetism 1

33-341 Thermal Physics 1

33-301 Physics Upper Class Colloquium

82-132 Elementary Chinese 1

Fourth year:

21-228 Discrete Mathematics

33-445 Advanced Quantum Physics 1

79-104 Introduction to World History

85-102 Introduction to Psychology

1. **Department of Biological Sciences**

First year:

03-121 Modern Biology

09-105 Introduction to Chemistry

21-120 Differential and Integral Calculus

99-101 Computing at CMU

76-101 Interpretation and Argument

Second year:

03-201 Undergraduate Colloquium Sophomore

03-231 Biochemistry

21-259 Calculus in Three Dimensions

33-111 Physics 1 for Science Students

03-240 Cell Biology

Third year:

03-301 Undergraduate Colloquium Junior

03-343 Experimental Genetics and Molecular Biology

03-325 Evolution

82-171 Elementary Japanese 1

APPENDIX A

Fourth year:

03411 Topics in Research

79-104 Introduction to World History

03-330 Genetics

03-401 Undergraduate Colloquium Seniors

**Information Systems (IS)**

First year:

76-101 Interpretation and Argument

36-201 Statistical Reasoning

21-120 Differential and Integral Calculus

15-100 Introductory Programming

99-101 Computing at CMU

Second year:

67-250 Information Systems Milieux

36-201 Statistics Reasoning Practics

88-220 Policy Analysis 1

57-337 Sound Recording

79-104 Introduction to World History

Third year:

67-271 Fundamentals of Systems Development

67-306 Management Computers Information Systems

67-371 Fundamentals System Development 1

70-414 Tech Based Entre

Fourth year:

67-475 Information Systems Applications

85-102 Introduction to Psychology

**School of Computer Science (SCS)**

First year:

15-110 Intermediate/Advanced Programming

15-128 Freshman Immigration Course

21-120 Differential & Integral Calculus

21-127 Concepts of Mathematics

76-101 Interpretation and Argument

99-101 Computing Skills Workshop

09-105 Introduction to Modern Chemistry

APPENDIX A

Second year:

15-123 Effective Programming in C and UNIX

15-212 Principles of Programming

21-241 Matrix Algebra

03-121 Biology

85-102 Introduction to Psychology

Third year:

15-451 Algorithm Design and Analysis

15-410 Operating System Design and Implementation

36-225 Introduction to Probability and Statistics I

73-100 Principles of Economics

70-381Marketing I

Fourth year:

15381 Artificial Intelligence: Representation and Problem Solving

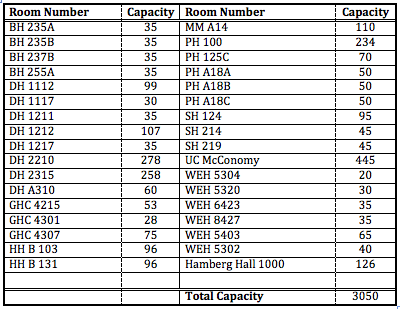
82-273 Introduction to Japanese Language and Culture

70-483 Advertising and Marketing Communications

70-122 Introduction to Accounting

APPENDIX A

Classroom Information where the Final Exams are taken:



115

MM 103

APPENDIX B

import java.util.\*;

public class Course

{

public int courseNumber;

public int studentNumber;

public int numLeft;

public List<String> room;

public int time;

public Course(int courseNumber, int studentNumber) {

this.courseNumber = courseNumber;

this.studentNumber = studentNumber;

this.numLeft = studentNumber;

this.room = new ArrayList<String>();

}

public void courseStatus() {

System.out.print("Course " + this.courseNumber);

if (room != null)

System.out.println(" has been assigned to room " + room + " at time " + time);

else

System.out.println(" has no assigned room.");

}

public boolean fillThis(Room[] rooms, int time) {

// checks whether there are enough spaces in this time to fit in the schedule

int totalSpaceInTime = totalSpaceInTime(rooms,time);

if (totalSpaceInTime/2 < this.studentNumber) {

return false;

}

else {

for (int i=1;i<rooms.length;i++) {

if (numLeft != 0 && rooms[i].spaceAtTime(time) !=0) {

this.fillIn(rooms[i],time);

this.room.add(rooms[i].roomName());

this.time = time;

}

}

return true;

}

}

public boolean fill(Room[] rooms, int time) {

if (time == 19)

return false;

// checks whether there are enough spaces in this time to fit in the schedule

int totalSpaceInTime = totalSpaceInTime(rooms,time);

if (totalSpaceInTime/2 < this.studentNumber) {

// go with the next time period

return fill(rooms,time+1);

}

else {

for (int i=1;i<rooms.length;i++) {

if (numLeft != 0 && rooms[i].spaceAtTime(time) !=0) {

this.fillIn(rooms[i],time);

this.room.add(rooms[i].roomName());

this.time = time;

}

}

return true;

}

}

private void fillIn(Room room, int time) {

room.scheduleAtTime(this, time);

}

private int totalSpaceInTime(Room[] rooms, int time) {

int totalSpace = 0;

for (int i=1; i<rooms.length; i++) {

totalSpace += rooms[i].spaceAtTime(time);

}

return totalSpace;

}

public String toString() {

String t = "Course: " + courseNumber + ", " + studentNumber + " students";

return t;

}

}

public class Room

{

// create an array of Room with roomNumber, time(18 for each), capacity and availability

public String room;

public Node root;

public int capacity;

public Room(String room, int capacity) {

this.room = room;

this.capacity = capacity;

}

public void removeCourse(int time) {

Node temp = this.root;

while (temp != null && temp.time != time) {

temp = temp.next;

}

if (temp.course != null)

temp.course = null;

temp.space = this.capacity;

}

public String roomName() {

String t = this.room;

return t;

}

public void createTime() {

root = new Node(18,this.capacity);

for (int i=17;i>0;i--)

root.add(new Node(i,this.capacity));

}

public int spaceAtTime(int time) {

Node temp = this.root;

while (temp != null) {

if (temp.time == time && temp.isOpen()) {

return temp.space;

}

temp = temp.next;

}

return 0;

}

public int scheduleAtTime(Course course, int time) {

Node temp = this.root;

while (temp != null && temp.time != time) {

temp = temp.next;

}

int toReturn = 0;

if (course.numLeft - temp.space/2 >= 0)

toReturn = temp.space;

else

toReturn = course.numLeft;

temp.space = 0;

temp.course = course;

course.numLeft -= toReturn;

return toReturn;

}

public void roomStatus() {

Node temp = this.root;

System.out.println("Room " + this.room + " has the following exam schedule: ");

while (temp != null) {

System.out.print("Time: " + temp.time + ". Status: ");

if (temp.isOpen())

System.out.println("Open");

else

System.out.println("Filled with course " + temp.course.courseNumber);

temp = temp.next;

}

}

public String toString() {

String t = "Room: " + room + " Capacity: " + capacity;

return t;

}

public boolean isOpen(int time) {

Node temp = this.root;

while (time>1) {

temp = temp.next;

time--;

}

return temp.isOpen();

}

//availability of room in each time period represented as a linked list

public class Node {

int time;

Node next;

Course course;

int space;

public Node(int time, int space) {

this.time = time;

next = null;

this.space = space;

}

public boolean isOpen() { return space != 0; }

public void add(Node t) {

Node temp = root;

root = new Node(t.time,t.space);

root.next = temp;

}

}

}

import java.util.\*;

public class Student

{

public String major;

public int grade;

public int number;

public List<Integer> courseList;

public Student(String major, int grade, int number, int[] course)

{

this.major = major;

this.grade = grade;

this.number = number;

this.courseList = new ArrayList<Integer>();

for (int i=0; i<course.length; i++) {

this.courseList.add(course[i]);

}

}

public String toString() {

String year;

if (grade == 1)

year = "Freshman";

else if (grade == 2)

year = "Sophomore";

else if (grade == 3)

year = "Junior";

else

year = "Senior";

; String t = year + " " + major + " major";

return t;

}

}

import java.util.\*;

public class ORFinal {

public static void main(String[] args) {

Student[] students = fall10Student();

List<Course> courses = fall10Course();

Room[] rooms = fall10Room();

initialSchedule(courses,rooms);

List<Student> unfits = new ArrayList<Student>();

int conflicts = conflictStatus(courses,students,unfits);

//////////////// Things to show //////////////////////

// ROOM STATUS //

//System.out.println("ROOM STATUS : ");

//for (int i=1; i<rooms.length; i++) {

//rooms[i].roomStatus();

//System.out.println();

//}

// COURSE STATUS //

//System.out.println("COURSE STATUS : ");

//for (int i=0;i<courses.size();i++)

//courses.get(i).courseStatus();

// CONFLICT STATUS //

//System.out.println(unfits.toString());

//////////////// Things to show //////////////////////

int counter = 0;

while (conflicts != 0 && counter != 50) {

optimizeSchedule(rooms, courses,unfits); // so that no exams are scheduled at the same period for each students

unfits = new ArrayList<Student>();

conflictStatus(courses,students,unfits);

counter++;

}

for (int i=1; i<rooms.length; i++) {

rooms[i].roomStatus();

System.out.println();

}

// COURSE STATUS //

System.out.println("COURSE STATUS : ");

for (int i=0;i<courses.size();i++)

courses.get(i).courseStatus();

}

public static void optimizeSchedule(Room[] rooms, List<Course> courses, List<Student> unfits) {

// moving two exams scheduled at the same period - moving the one with less students to other period

for (int i=0; i<unfits.size();i++) {

List<Integer> list = timeList(courses,unfits.get(i).courseList);

for (int j=0;j<list.size();j++) {

for (int k=0; k<list.size();k++) {

if (j != k && list.get(j) == list.get(k)) {

if (getStudentNumber(courses, unfits.get(i).courseList.get(j)) < getStudentNumber(courses, unfits.get(i).courseList.get(k)))

move(rooms, courses, getCourse(courses, unfits.get(i).courseList.get(j)),list.get(j));

else

move(rooms,courses,getCourse(courses, unfits.get(i).courseList.get(k)),list.get(k));

}

}

}

}

}

public static void move(Room[] rooms, List<Course> courses, Course course, int from) {

boolean flag = false;

for (int i=1;i<19;i++) {

if (from == 0) {

course.fill(rooms,1);

i = 20;

}

else if (i != from && flag == false) {

remove(rooms, course,from);

flag = course.fillThis(rooms,i);

}

}

if (!flag)

System.out.println("Cannot fit in " + course.toString());

}

public static void remove(Room[] rooms, Course course,int from) {

for (int j=0; j<course.room.size();j++) {

for (int i=1;i<rooms.length;i++) {

if (rooms[i].room.equals(course.room.get(j)))

rooms[i].removeCourse(from);

}

}

course.room = new ArrayList<String>();

course.time = 0;

course.numLeft = course.studentNumber;

}

private static Course getCourse(List<Course> courses, int courseNumber) {

Course course = null;

for (int i=0; i<courses.size(); i++)

if (courses.get(i).courseNumber == courseNumber) {

course = courses.get(i);

}

return course;

}

public static int conflictStatus(List<Course> courses, Student[] students, List<Student> unfits) {

// returns the status of conflict.

int conflicts=0;

for (int i=1; i<students.length; i++) {

List<Integer> list = timeList(courses,students[i].courseList);

// CONFLICT STATUS //

//System.out.println(students[i].toString() + "'s exam schedule: " + list.toString());

conflicts += conflictStatus(students[i],list,unfits);

}

System.out.println("Total of " + conflicts + " students have a schedule conflict!" );

return conflicts;

}

private static int conflictStatus(Student student, List<Integer> list, List<Student> unfits) {

// Also check that no two exams for a student is scheduled at the same time period

int counter = 0;

int counter2 = 0;

for (int i=0;i<list.size();i++) {

for (int j=0;j<list.size();j++) {

if (list.get(i) == list.get(j))

counter2++;

if (Math.abs(list.get(i) - list.get(j)) < 4)

counter++;

}

}

if (counter > 5 + list.size() || counter2 > list.size()) {

unfits.add(student);

return 1;

}

return 0;

}

private static List<Integer> timeList(List<Course> courses, List<Integer> courseList) {

List<Integer> list = new ArrayList<Integer>();

for (int i=0; i<courseList.size();i++) {

list.add(findTime(courses,courseList.get(i)));

}

return list;

}

private static int findTime(List<Course> courses, int courseNumber) {

int time = -1;

for (int i=0;i<courses.size();i++) {

if (courses.get(i).courseNumber == courseNumber)

time = courses.get(i).time;

}

if (time == -1) {

throw new IllegalArgumentException("something wrong");

}

return time;

}

public static List<Course> unfitCourses(List<Course> courses) {

List<Course> unfit = new ArrayList<Course>();

for (int i=0;i<courses.size();i++) {

if (courses.get(i).room == null)

unfit.add(courses.get(i));

}

return unfit;

}

public static boolean isFeasibleSchedule(List<Course> courses) {

for (int i=0;i<courses.size();i++) {

if (courses.get(i).room == null)

return false;

}

return true;

}

public static void initialSchedule(List<Course> courses, Room[] rooms) {

// initiate the schedule

List<Course> unfitList = courses;

for (int i=1;i<19; i++) {

for (int j=0; j<unfitList.size(); j++)

initialSchedule(unfitList.get(j),rooms,i);

unfitList = unfitCourses(courses);

}

}

// precondition - course is in descending order

private static void initialSchedule(Course course, Room[] rooms,int time) {

if (!course.fill(rooms,time)) {

}

}

private static int getStudentNumber(List<Course> courses, int courseNumber) {

int number = 0;

for (int i=0; i<courses.size(); i++)

if (courses.get(i).courseNumber == courseNumber)

number = courses.get(i).studentNumber;

return number;

}

public static Room[] fall10Room() {

Room[] rooms = new Room[26];

rooms[1] = new Room("UCMcConomy",450);

rooms[2] = new Room("DH2210",280);

rooms[3] = new Room("DH2315",280);

rooms[4] = new Room("PH100",250);

rooms[5] = new Room("HH1000",140);

rooms[6] = new Room("MM103",120);

rooms[7] = new Room("MMA14",110);

rooms[8] = new Room("DH1212",110);

rooms[9] = new Room("SH124",100);

rooms[10] = new Room("HHB103",100);

rooms[11] = new Room("HHB131",100);

rooms[12] = new Room("DH1112",100);

rooms[13] = new Room("GHC4307",80);

rooms[14] = new Room("PH125C",70);

rooms[15] = new Room("BH235",70);

rooms[16] = new Room("BH237",70);

rooms[17] = new Room("BH255",70);

rooms[18] = new Room("WEH5403",70);

rooms[19] = new Room("DHA310",60);

rooms[20] = new Room("GHC4215",60);

rooms[21] = new Room("PHA18A",60);

rooms[22] = new Room("PHA18B",60);

rooms[23] = new Room("PHA18C",60);

rooms[24] = new Room("SH214",60);

rooms[25] = new Room("SH219",60);

for (int i=1; i<26; i++)

rooms[i].createTime();

return rooms;

}

public static Student[] fall10Student() {

Student[] students = new Student[80];

int[] b1 = {73100,70100,21120};

students[1] = new Student("Business", 1,50, b1);

int[] b2 = {21257,70122,70207,79104};

students[2] = new Student("Business", 2,50, b2);

int[] b3 = {70371,73200,70391};

students[3] = new Student("Business", 3,50, b3);

int[] b4 = {85102,70492,70440};

students[4] = new Student("Business", 4,50, b4);

int[] e1 = {15110,21120,73100,36201};

students[5] = new Student("Economics", 1,50, e1);

int[] e2 = {73270,73310,73200};

students[6] = new Student("Economics", 2,50, e2);

int[] e3 = {76270,73253,73359};

students[7] = new Student("Economics", 3,50, e3);

int[] e4 = {73347,73497};

students[8] = new Student("Ecnomics", 4,50, e4);

int[] bio1 = {03121,9105,21120};

students[9] = new Student("Biology", 1,60, bio1);

int[] bio2 = {03201,03231,21259,33111};

students[10] = new Student("Biology", 2,60, bio2);

int[] bio3 = {03301,03325,82171};

students[11] = new Student("Biology", 3,60, bio3);

int[] bio4 = {79104,03330,03401};

students[12] = new Student("Biology", 4,60, bio4);

int[] ma1 = {21120,33111,15110,03121};

students[13] = new Student("Mathematics", 1,70, ma1);

int[] ma2 = {21228,21341,21259,79104};

students[14] = new Student("Mathematics", 2,70, ma2);

int[] ma3 = {21355,36225,21369,21370};

students[15] = new Student("Mathematics", 3,70, ma3);

int[] ma4 = {21600,21476};

students[16] = new Student("Mathematics", 4,70, ma4);

int[] ch1 = {9105,21120,33111};

students[17] = new Student("Chemistry", 1,60, ch1);

int[] ch2 = {9219,9221,9231,03121};

students[18] = new Student("Chemistry", 2,60, ch2);

int[] ch3 = {9344,9507};

students[19] = new Student("Chemistry", 3,60, ch3);

int[] ch4 = {9711,9518};

students[20] = new Student("Chemistry", 4,60, ch4);

int[] ph1 = {15110,21120,33111};

students[21] = new Student("Physics", 1,60, ph1);

int[] ph2 = {9105,21259,33231,33211};

students[22] = new Student("Physics", 2,60, ph2);

int[] ph3 = {33331,33338,33341,33301};

students[23] = new Student("Physics", 3,60, ph3);

int[] ph4 = {21228,33445,79104,85102};

students[24] = new Student("Physics", 4,60, ph4);

int[] i1 = {36201,21120,15110};

students[25] = new Student("InformationSystems", 1,50, i1);

int[] i2 = {67250,36201,79104};

students[26] = new Student("InformationSystems", 2,50, i2);

int[] i3 = {67306,67371,70414};

students[27] = new Student("InformationSystems", 3,50, i3);

int[] i4 = {85102};

students[28] = new Student("InformationSystems", 4,50, i4);

int[] cs1 = {15110,21120,21127,9105};

students[29] = new Student("ComputerScience", 1,150, cs1);

int[] cs2 = {15123,15212,21241,03121,85102};

students[30] = new Student("ComputerScience", 2,150, cs2);

int[] cs3 = {15451,15410,36225,73100};

students[31] = new Student("ComputerScience", 3,150, cs3);

int[] cs4 = {15381,70122};

students[32] = new Student("ComputerScience", 4,150, cs4);

int[] ps1 = {21111,36201,03121};

students[33] = new Student("Psychology", 1,50, ps1);

int[] ps2 = {21120,85211,79104,33124,85241};

students[34] = new Student("Psychology", 2,50, ps2);

int[] ps3 = {85219,9105,33111};

students[35] = new Student("Psychology", 3,50, ps3);

int[] ps4 = {85370,85421,36309};

students[36] = new Student("Psychology", 4,50, ps4);

int[] en1 = {36201,79104,21120};

students[37] = new Student("English", 1,50, en1);

int[] en2 = {76270,76321};

students[38] = new Student("English", 2,50, en2);

int[] st1 = {21120,36201,79104};

students[39] = new Student("Statistics", 1,50, st1);

int[] st2 = {21256,21241,36225};

students[40] = new Student("Statistics", 2,50, st2);

int[] st3 = {73150,36350,21127};

students[41] = new Student("Statistics", 3,50, st3);

int[] st4 = {36463,80226};

students[42] = new Student("Statistics", 4,50, st4);

int[] p1 = {21120,36201,79104};

students[43] = new Student("Philosophy", 1,50, p1);

int[] p2 = {21256,21241,80226,15110};

students[44] = new Student("Philosophy", 2,50, p2);

int[] p4 = {80383,80226};

students[45] = new Student("Philosophy", 4,50, p4);

int[] sd1 = {21111,36201,79104};

students[46] = new Student("DecisionScience", 1,50, sd1);

int[] sd2 = {21120,88122,15110};

students[47] = new Student("DecisionScience", 2,50, sd2);

int[] sd3 = {88302,88377};

students[48] = new Student("DecisionScience", 3,50, sd3);

int[] sd4 = {88412,73347};

students[49] = new Student("DecisionScience", 4,50, sd4);

int[] ece1 = {21122};

students[50] = new Student("ECE", 1,90, ece1);

int[] ece2 = {33106,18220,18240,18290};

students[51] = new Student("ECE", 2,90, ece2);

int[] ece3 = {18320,18342,21259};

students[52] = new Student("ECE", 3,90, ece3);

int[] ece4 = {18450,18491};

students[53] = new Student("ECE", 4,90, ece4);

int[] me1 = {21122};

students[54] = new Student("MechE", 1,90, me1);

int[] me2 = {33106,21259};

students[55] = new Student("MechE", 2,90, me2);

int[] me3 = {24302,24322,24351,36220};

students[56] = new Student("MechE", 3,90, me3);

int[] me4 = {24424,24451};

students[57] = new Student("MechE", 4,90, me4);

int[] ce1 = {21122,42101,9105};

students[58] = new Student("ChemE", 1,90, ce1);

int[] ce2 = {9106,06221};

students[59] = new Student("ChemE", 2,90, ce2);

int[] ce3 = {06323,06321,9217};

students[60] = new Student("ChemE", 3,90, ce3);

int[] ce4 = {06422,06423,42401};

students[61] = new Student("ChemE", 4,90, ce4);

int[] be1 = {21122,42101,03121};

students[62] = new Student("BiomedE", 1,90, be1);

int[] be2 = {15110,06221};

students[63] = new Student("BiomedE", 2,90, be2);

int[] be3 = {06323};

students[64] = new Student("BiomedE", 3,90, be3);

int[] be4 = {42444,06423,42401};

students[65] = new Student("BiomedE", 4,90, be4);

int[] cve1 = {21122,33106};

students[66] = new Student("CivilE", 1,90, cve1);

int[] cve2 = {12212,21259,9105};

students[67] = new Student("CivilE", 2,90, cve2);

int[] cve3 = {12335,12355};

students[68] = new Student("CivilE", 3,90, cve3);

int[] ar2 = {48210,48240};

students[69] = new Student("Architecture", 2,60, ar2);

int[] ar3 = {48315};

students[70] = new Student("Architecture", 3,60, ar3);

int[] ar5 = {48550};

students[71] = new Student("Architecture", 5,60, ar5);

int[] fa2 = {79104};

students[72] = new Student("FineArts", 2,60, fa2);

int[] fa4 = {73100};

students[73] = new Student("FineArts", 4,60, fa4);

int[] de2 = {51271};

students[74] = new Student("Design", 2,60, de2);

int[] d4 = {21120};

students[75] = new Student("Drama", 4,30, d4);

int[] m1 = {57152,57173};

students[76] = new Student("Music", 1,90, m1);

int[] m2 = {57289,82171};

students[77] = new Student("Music", 2,90, m2);

int[] m3 = {57480};

students[78] = new Student("Music", 3,90, m3);

int[] m4 = {82141};

students[79] = new Student("Music", 4,90, m4);

return students;

}

public static List<Course> fall10Course() {

List<Course> course = new ArrayList<Course>();

course.add(new Course(21120,830));

course.add(new Course(15110,800));

course.add(new Course(79104,600));

course.add(new Course(9105,560));

course.add(new Course(21259,560));

course.add(new Course(21122,500));

course.add(new Course(03121,480));

course.add(new Course(73100,360));

course.add(new Course(21241,350));

course.add(new Course(33111,300));

course.add(new Course(36225,220));

course.add(new Course(21127,200));

course.add(new Course(70122,200));

course.add(new Course(85102,200));

course.add(new Course(36201,200));

course.add(new Course(73200,200));

course.add(new Course(33106,180));

course.add(new Course(06221,180));

course.add(new Course(06323,180));

course.add(new Course(06423,180));

course.add(new Course(36463,180));

course.add(new Course(42101,180));

course.add(new Course(76321,150));

course.add(new Course(15123,150));

course.add(new Course(15212,150));

course.add(new Course(15381,150));

course.add(new Course(15410,150));

course.add(new Course(15451,150));

course.add(new Course(21228,130));

course.add(new Course(80383,120));

course.add(new Course(82171,110));

course.add(new Course(73347,100));

course.add(new Course(76270,100));

course.add(new Course(21111,100));

course.add(new Course(21256,100));

course.add(new Course(06321,90));

course.add(new Course(06422,90));

course.add(new Course(9106,90));

course.add(new Course(9217,90));

course.add(new Course(12212,90));

course.add(new Course(12335,90));

course.add(new Course(12355,90));

course.add(new Course(18220,90));

course.add(new Course(18240,90));

course.add(new Course(18290,90));

course.add(new Course(18320,90));

course.add(new Course(18342,90));

course.add(new Course(18450,90));

course.add(new Course(42401,90));

course.add(new Course(18491,90));

course.add(new Course(24302,90));

course.add(new Course(24322,90));

course.add(new Course(24351,90));

course.add(new Course(24424,90));

course.add(new Course(24451,90));

course.add(new Course(82141,90));

course.add(new Course(33445,90));

course.add(new Course(21341,70));

course.add(new Course(21355,70));

course.add(new Course(21369,70));

course.add(new Course(21370,70));

course.add(new Course(21476,70));

course.add(new Course(21600,70));

course.add(new Course(03201,60));

course.add(new Course(03231,60));

course.add(new Course(03301,60));

course.add(new Course(03325,60));

course.add(new Course(42444,60));

course.add(new Course(48210,60));

course.add(new Course(48240,60));

course.add(new Course(48315,60));

course.add(new Course(48550,60));

course.add(new Course(03330,60));

course.add(new Course(03401,60));

course.add(new Course(9219,60));

course.add(new Course(9221,60));

course.add(new Course(9231,60));

course.add(new Course(9344,60));

course.add(new Course(9507,60));

course.add(new Course(33124,60));

course.add(new Course(33211,60));

course.add(new Course(33231,60));

course.add(new Course(33301,60));

course.add(new Course(33331,60));

course.add(new Course(33338,60));

course.add(new Course(33341,60));

course.add(new Course(9518,60));

course.add(new Course(9711,60));

course.add(new Course(21257,50));

course.add(new Course(70100,50));

course.add(new Course(70207,50));

course.add(new Course(70371,50));

course.add(new Course(70391,50));

course.add(new Course(70440,50));

course.add(new Course(70492,50));

course.add(new Course(73253,50));

course.add(new Course(73270,50));

course.add(new Course(73310,50));

course.add(new Course(73359,50));

course.add(new Course(73497,50));

course.add(new Course(33106,50));

course.add(new Course(36220,50));

course.add(new Course(36225,50));

course.add(new Course(36309,50));

course.add(new Course(36350,50));

course.add(new Course(57480,50));

course.add(new Course(67250,50));

course.add(new Course(67306,50));

course.add(new Course(67371,50));

course.add(new Course(70414,50));

course.add(new Course(73150,50));

course.add(new Course(80226,50));

course.add(new Course(85102,50));

course.add(new Course(85211,50));

course.add(new Course(85219,50));

course.add(new Course(85241,50));

course.add(new Course(85370,50));

course.add(new Course(85421,50));

course.add(new Course(88122,50));

course.add(new Course(88302,50));

course.add(new Course(88377,50));

course.add(new Course(88412,50));

course.add(new Course(51271,30));

course.add(new Course(57152,30));

course.add(new Course(57173,30));

course.add(new Course(57289,30));

return course;

}

}

APPENDIX C

(a)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Per.** | **Room** | **1** | **2** | **3** | **4** | **5** | **6** |
| **/Day** | **(Capacity)** |
| **1st** | UC Mc.(445) | 15110(800) | **03121(480)** | 21120(830) | 21259(460) | 79104(600) | 09105(560) |
|  | D2210(278) | • | • | • | • | • | • |
|  | DH2315(258) | • | • | • | • | • | • |
|  | PH 100(234) | • | 09344(60) | • | 42401(180) | • | • |
|  | HH1000(126) | • | 03201(60) | • | • | 15381(150) | **80226(180)** |
|  | MM 103(115) | • |  | • | 42101(180) | • | • |
|  | MMA14(110) | • |  | • | • | • | • |
|  | DH1212(107) | 15451(150) |  | • | • | 03325(60) |  |
|  | DH 1112(99) | • |  | 15410(150) | 03301(60) | • |  |
|  | HH B103(96) | • | 03330(60) | • | • | 09219(60) | 03401(60) |
|  | HH B131(96) | 21600(70) | • | • | 09221(60) | • | • |
|  | SH 124(95) | • |  | 03231(60) | • |  |  |
|  | GHC4307(75) | 09507(60) |  | • | 57480(30) |  |  |
|  | PH 125C(70) | • |  |  |  |  |  |
|  | WEH5403(65) | 57152(30) |  |  |  |  |  |
|  | DH A310(60) |  | 57173(30) |  |  |  | 82271(30) |
|  | GHC4215(53) |  |  |  |  |  |  |
|  | PH A18A(50) |  |  | 09231(60) |  | 88377(50) | 88412(50) |
|  | PH A18B(50) |  |  | • |  | • | • |
|  | PH A18C(50) |  |  | • |  |  |  |
|  | SH 214(45) |  |  |  |  |  |  |
|  | SH 219(45) |  |  |  |  |  |  |
|  | WEH5302(40) | 15110 |  |  |  |  |  |
|  | WEH6423(35) |  |  |  |  |  |  |
|  | WEH8427(35) |  |  |  |  |  |  |
|  | BH 235A(35) |  |  |  |  |  |  |
|  | BH 235B(35) |  |  |  |  |  |  |
|  | BH 237B(35) |  |  |  |  |  |  |
|  | BH 255A(35) |  |  |  |  |  |  |
|  | DH 1211(35) |  |  |  |  |  |  |
|  | DH 1217(35) |  |  |  |  |  |  |
|  | WEH5320(30) |  |  |  |  |  |  |
|  | DH 1117(30) |  |  | 15410 | 42101 |  |  |
|  | GHC4301(28) |  |  |  |  |  |  |
|  | WEH5304(20) |  |  |  |  |  | 80226 |
| **2nd** | UC Mc.(445) | 70122(200) | 21122(460) | 36225(220) | 36201(400) | 82141(120) | 85102(110) |
|  | DH 2210(278) | **15123(150)** | • | 21228(130) | • | **21241(250)** | 33106(270) |
|  | DH 2315(258) | • | • | 24351(90) | • | • | • |
|  | PH 100(234) | 24302(90) | 73347(100) | 33211(60) | 24424(90) | 73100(100) | 36220(90) |
|  | HH 1000(126) | 21476(70) | 24322(90) | 33331(60) | 33231(60) | 24451(90) | • |
|  | MM 103(115) | 21369(70) | • | 88302(50) | 85211(50) | • | 42444(90) |
|  | MM A14(110) | • | 33111(300) |  | 88122(50) | 85421(50) | • |
|  | DH 1212(107) | 09518(60) | • |  | 21355(70) | 21341(70) | 85241(50) |
|  | DH 1112(99) | • | • |  | • | • |  |
|  | HH B103(96) | 21476 |  | 48210(60) | 33301(60) | 33341(60) | 33338(60) |
|  | HH B131(96) | 48315(60) | • | • | • | • | • |
|  | SH 124(95) | • |  |  | 33445(60) |  |  |
|  | GHC4307(75) |  | 21370(70) |  | • |  |  |
|  | PH 125C(70) |  | • |  |  |  |  |
|  | WEH5403(65) |  | 09711(60) |  |  |  |  |
|  | DH A310(60) |  | • |  |  |  |  |
|  | GHC4215(53) |  |  |  |  |  |  |
|  | PH A18A(50) | 73150(50) | 76321(50) | 80383(50) |  | 85219(50) | 85370(50) |
|  | PH A18B(50) | • | • | • |  | • | • |
|  | PH A18C(50) |  |  | 48240(60) |  |  |  |
|  | SH 214(45) |  |  | • |  |  |  |
|  | SH 219(45) |  |  | • |  |  |  |
|  | WEH5302(40) |  |  |  |  |  |  |
|  | WEH6423(35) |  |  |  |  |  |  |
|  | WEH8427(35) |  |  |  |  |  |  |
|  | BH 235A(35) |  |  |  |  |  |  |
|  | BH 235B(35) |  |  |  |  |  |  |
|  | BH 237B(35) |  |  |  |  |  |  |
|  | BH 255A(35) |  |  |  |  |  |  |
|  | DH 1211(35) |  |  |  |  |  |  |
|  | DH 1217(35) |  |  |  |  |  |  |
|  | WEH5320(30) |  |  |  |  |  |  |
|  | DH 1117(30) |  |  |  |  |  |  |
|  | GHC4301(28) |  |  |  |  |  |  |
|  | WEH5304(20) |  |  |  |  |  |  |
| **3rd** | UC Mc.(445) | **15212(150)** | 85102(200) | 06323(180) | 21127(200) | 06423(180) | 06221(180) |
|  | DH 2210(278) | 18220(90) | 09217(90) | 21111(100) | 12335(90) | **21256(100)** | 76270(100) |
|  | DH 2315(258) | 09106(90) | 06422(90) |  |  | 12355(90) | 82171(90) |
|  | PH 100(234) | 18491(90) | 18450(90) | 18342(90) | 18320(90) |  |  |
|  | HH 1000(126) | 48550(60) | 51271(60) | 21257(50) | 70100(50) | 70207(50) | 70371(50) |
|  | MM 103(115) | 73359(50) | 73270(50) | 67250(50) | 67306(50) | 67371(50) | 70414(50) |
|  | MM A14(110) |  | 36350(50) | 73253(50) | 70492(50) | 70440(50) |  |
|  | DH 1212(107) | 73310(50) |  |  | 36225(50) |  | 33124(50) |
|  | DH 1112(99) |  |  |  |  |  |  |
|  | HH B103(96) |  |  | 12212(90) | 06321(90) | 18290(90) | 18240(90) |
|  | HH B131(96) |  |  | • | • | • | • |
|  | SH 124(95) |  |  |  |  |  |  |
|  | GHC4307(75) |  |  |  |  |  |  |
|  | PH 125C(70) |  |  |  |  |  |  |
|  | WEH5403(65) |  |  |  |  |  |  |
|  | DH A310(60) |  |  |  |  |  |  |
|  | GHC4215(53) |  |  |  |  |  |  |
|  | PH A18A(50) | 36463(50) | 73497(50) |  |  |  | 70391(50) |
|  | PH A18B(50) | • | • | 36309(50) |  | 36220(50) | • |
|  | PH A18C(50) |  |  | • |  | • |  |
|  | SH 214(45) |  |  |  |  |  |  |
|  | SH 219(45) |  |  |  |  |  |  |
|  | WEH5302(40) |  |  |  |  |  |  |
|  | WEH6423(35) |  |  |  |  |  |  |
|  | WEH8427(35) |  |  |  |  |  |  |
|  | BH 235A(35) |  |  |  |  |  |  |
|  | BH 235B(35) |  |  |  |  |  |  |
|  | BH 237B(35) |  |  |  |  |  |  |
|  | BH 255A(35) |  |  |  |  |  |  |
|  | DH 1211(35) |  |  |  |  |  |  |
|  | DH 1217(35) |  |  |  |  |  |  |
|  | WEH5320(30) |  |  |  |  |  |  |
|  | DH 1117(30) |  |  |  |  |  |  |
|  | GHC4301(28) |  |  |  |  |  |  |
|  | WEH5304(20) |  |  |  |  |  |  |

(b)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Per.** | **Room** | **1** | **2** | **3** | **4** | **5** | **6** |
| **/Day** | **(Capacity)** |
| **1st** | UC Mc.(445) | 15110(800) | **03121(480)** | 21120(830) | 21259(460) | 79104(600) | 09105(560) |
|  | D2210(278) | • | • | • | • | • | • |
|  | DH2315(258) | • | • | • | • | • | • |
|  | PH 100(234) | • | 09344(60) | • | 42401(180) | • | • |
|  | HH1000(126) | • | 03201(60) | • | • | 15381(150) | **80226(180)** |
|  | MM 103(115) | • |  | • | 42101(180) | • | • |
|  | MMA14(110) | • |  | • | • | • | • |
|  | DH1212(107) | 15451(150) |  | • | • | 03325(60) |  |
|  | DH 1112(99) | • |  | 15410(150) | 03301(60) | • |  |
|  | HH B103(96) | • | 03330(60) | • | • | 09219(60) | 03401(60) |
|  | HH B131(96) | 21600(70) | • | • | 09221(60) | • | • |
|  | SH 124(95) | • |  | 03231(60) | • |  |  |
|  | GHC4307(75) | 09507(60) |  | • | 57480(30) |  |  |
|  | PH 125C(70) | • |  |  |  |  |  |
|  | WEH5403(65) | 57152(30) |  |  |  |  |  |
|  | DH A310(60) |  | 57173(30) |  |  |  | 82271(30) |
|  | GHC4215(53) |  |  |  |  |  |  |
|  | PH A18A(50) |  |  | 09231(60) |  | 88377(50) | 88412(50) |
|  | PH A18B(50) |  |  | • |  | • | • |
|  | PH A18C(50) |  |  | • |  |  |  |
|  | SH 214(45) |  |  |  |  |  |  |
|  | SH 219(45) |  |  |  |  |  |  |
|  | WEH5302(40) | 15110 |  |  |  |  |  |
|  | WEH6423(35) |  |  |  |  |  |  |
|  | WEH8427(35) |  |  |  |  |  |  |
|  | BH 235A(35) |  |  |  |  |  |  |
|  | BH 235B(35) |  |  |  |  |  |  |
|  | BH 237B(35) |  |  |  |  |  |  |
|  | BH 255A(35) |  |  |  |  |  |  |
|  | DH 1211(35) |  |  |  |  |  |  |
|  | DH 1217(35) |  |  |  |  |  |  |
|  | WEH5320(30) |  |  |  |  |  |  |
|  | DH 1117(30) |  |  | 15410 | 42101 |  |  |
|  | GHC4301(28) |  |  |  |  |  |  |
|  | WEH5304(20) |  |  |  |  |  | 80226 |
| **2nd** | UC Mc.(445) | 70122(200) | 21122(460) | 36225(220) | 36201(400) | 82141(120) | 85102(110) |
|  | DH 2210(278) | **15123(150)** | • | 21228(130) | • | **21241(250)** | 33106(270) |
|  | DH 2315(258) | • | • | 24351(90) | • | • | • |
|  | PH 100(234) | 24302(90) | 73347(100) | 33211(60) | 24424(90) | 73100(100) | 36220(90) |
|  | HH 1000(126) | 21476(70) | 24322(90) | 33331(60) | 33231(60) | 24451(90) | • |
|  | MM 103(115) | 21369(70) | • | 88302(50) | 85211(50) | • | 42444(90) |
|  | MM A14(110) | • | 33111(300) |  | 88122(50) | 85421(50) | • |
|  | DH 1212(107) | 09518(60) | • |  | 21355(70) | 21341(70) | 85241(50) |
|  | DH 1112(99) | • | • |  | • | • |  |
|  | HH B103(96) | 21476 |  | 48210(60) | 33301(60) | 33341(60) | 33338(60) |
|  | HH B131(96) | 48315(60) | • | • | • | • | • |
|  | SH 124(95) | • |  |  | 33445(60) |  |  |
|  | GHC4307(75) |  | 21370(70) |  | • |  |  |
|  | PH 125C(70) |  | • |  |  |  |  |
|  | WEH5403(65) |  | 09711(60) |  |  |  |  |
|  | DH A310(60) |  | • |  |  |  |  |
|  | GHC4215(53) |  |  |  |  |  |  |
|  | PH A18A(50) | 73150(50) | 76321(50) | 80383(50) |  | 85219(50) | 85370(50) |
|  | PH A18B(50) | • | • | • |  | • | • |
|  | PH A18C(50) |  |  | 48240(60) |  |  |  |
|  | SH 214(45) |  |  | • |  |  |  |
|  | SH 219(45) |  |  | • |  |  |  |
|  | WEH5302(40) |  |  |  |  |  |  |
|  | WEH6423(35) |  |  |  |  |  |  |
|  | WEH8427(35) |  |  |  |  |  |  |
|  | BH 235A(35) |  |  |  |  |  |  |
|  | BH 235B(35) |  |  |  |  |  |  |
|  | BH 237B(35) |  |  |  |  |  |  |
|  | BH 255A(35) |  |  |  |  |  |  |
|  | DH 1211(35) |  |  |  |  |  |  |
|  | DH 1217(35) |  |  |  |  |  |  |
|  | WEH5320(30) |  |  |  |  |  |  |
|  | DH 1117(30) |  |  |  |  |  |  |
|  | GHC4301(28) |  |  |  |  |  |  |
|  | WEH5304(20) |  |  |  |  |  |  |
| **3rd** | UC Mc.(445) | **21256(100)** | 85102(200) | 06323(180) | 21127(200) | 06423(180) | 06221(180) |
|  | DH 2210(278) | 18220(90) | 09217(90) | 21111(100) | 12335(90) |  | 76270(100) |
|  | DH 2315(258) | 09106(90) | 06422(90) |  |  | 12355(90) | 82171(90) |
|  | PH 100(234) | 18491(90) | 18450(90) | 18342(90) | 18320(90) |  |  |
|  | HH 1000(126) | 48550(60) | 51271(60) | 21257(50) | 70100(50) | 70207(50) | 70371(50) |
|  | MM 103(115) | 73359(50) | 73270(50) | 67250(50) | 67306(50) | 67371(50) | 70414(50) |
|  | MM A14(110) |  | 36350(50) | 73253(50) | 70492(50) | 70440(50) |  |
|  | DH 1212(107) | 73310(50) |  | **15212(150)** | 36225(50) |  | 33124(50) |
|  | DH 1112(99) |  |  | • |  |  |  |
|  | HH B103(96) |  |  | 12212(90) | 06321(90) | 18290(90) | 18240(90) |
|  | HH B131(96) |  |  | • | • | • | • |
|  | SH 124(95) |  |  |  |  |  |  |
|  | GHC4307(75) |  |  |  |  |  |  |
|  | PH 125C(70) |  |  |  |  |  |  |
|  | WEH5403(65) |  |  |  |  |  |  |
|  | DH A310(60) |  |  | 15212 |  |  |  |
|  | GHC4215(53) |  |  |  |  |  |  |
|  | PH A18A(50) | 36463(50) | 73497(50) |  |  |  | 70391(50) |
|  | PH A18B(50) | • | • | 36309(50) |  | 36220(50) | • |
|  | PH A18C(50) |  |  | • |  | • |  |
|  | SH 214(45) |  |  |  |  |  |  |
|  | SH 219(45) |  |  |  |  |  |  |
|  | WEH5302(40) |  |  |  |  |  |  |
|  | WEH6423(35) |  |  |  |  |  |  |
|  | WEH8427(35) |  |  |  |  |  |  |
|  | BH 235A(35) |  |  |  |  |  |  |
|  | BH 235B(35) |  |  |  |  |  |  |
|  | BH 237B(35) |  |  |  |  |  |  |
|  | BH 255A(35) |  |  |  |  |  |  |
|  | DH 1211(35) |  |  |  |  |  |  |
|  | DH 1217(35) |  |  | 15212 |  |  |  |
|  | WEH5320(30) |  |  |  |  |  |  |
|  | DH 1117(30) |  |  |  |  |  |  |
|  | GHC4301(28) |  |  |  |  |  |  |
|  | WEH5304(20) |  |  |  |  |  |  |