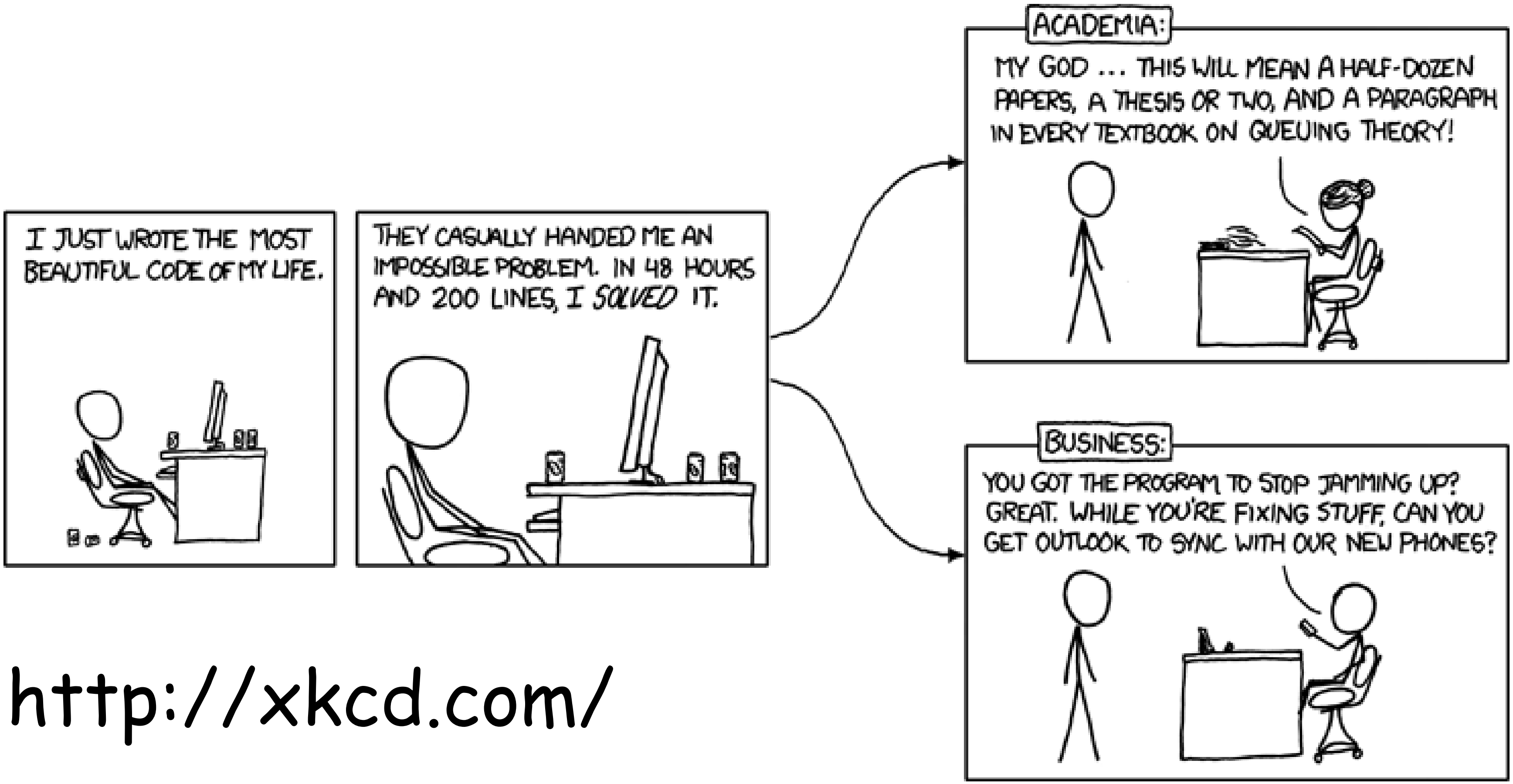
CSC 422/522 Fall 2014

Dr. Wendy Myrvold, ECS 552, wendym@cs.uvic.ca



http://xkcd.com/

Announcements

Powerpoint slides will be posted on the class web pages:

http://webhome.cs.uvic.ca/~wendym/422.html

Or on connex if they contain material that cannot be placed on the web.

Welcome to CSC 422/522!

Office hours:

Let me know either at the end of class or by e-mail what time you would like to come by so that I don't have to be there when nobody wants to see me.

TWF 11:30am - 12:20pm.

Tuesdays 1:30pm: when no dept. meeting.

WF: 1:30pm (until all questions are answered).

Or by appointment.

Outline

- Who is the instructor?
- My research interests.
- Logistics for CSC 422/522- the critical points are included on the course outline and class web pages.
- Don't worry about taking notes today

About me:

B.Sc. : Computer Science, McGill University, 1983

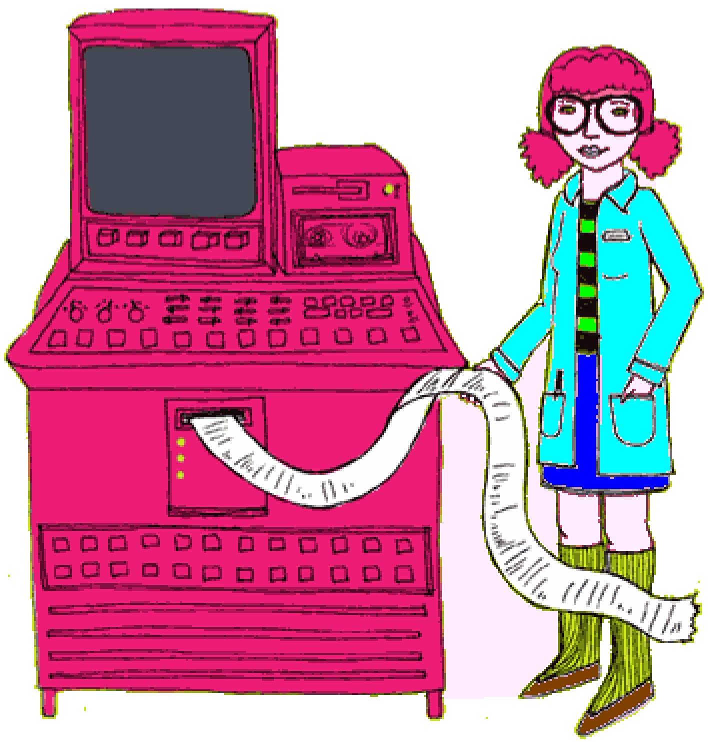
M.Math. : Combinatorics and Optimization, University of Waterloo, 1984

Ph.D. in Computer Science: Waterloo, 1988

University of Victoria: started in 1988, currently a full professor

by Mark A. Hicks, illustrator.

Currently have 64 CPU's that can be used for long computations (provided by NSERC).



From: Gurl Guide to programming.

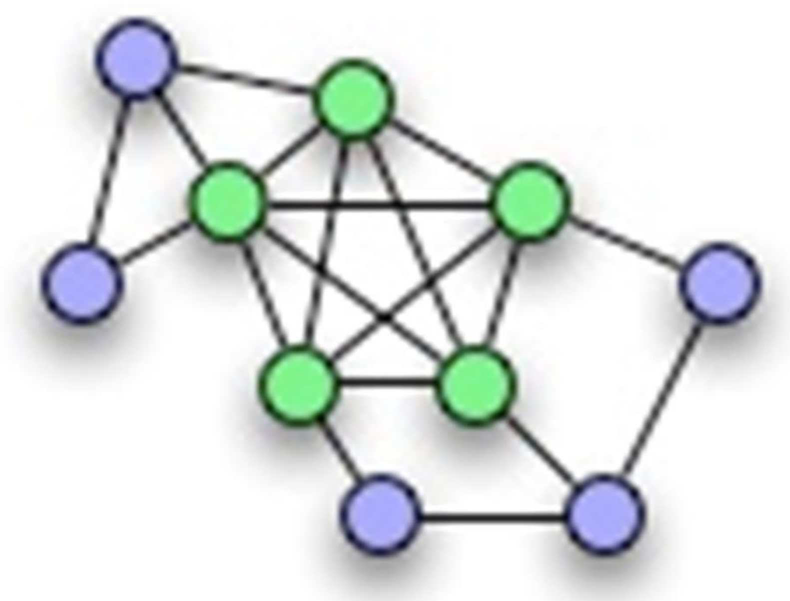

CCM

Denis Savard

Bring your parents to work day at Google.

My Research: Large Combinatorial Searches

Clique: Set of vertices which are pairwise adjacent



Keller graph with dimension d:

vertices which are numbered with each of the 4^d d-digit numbers, digits are to 0, 1, 2, or 3.
Two vertices are adjacent if their labels differ in at least two positions, and in at least one position the difference in the labels is 2 mod 4.

Examples (Dimension 5):

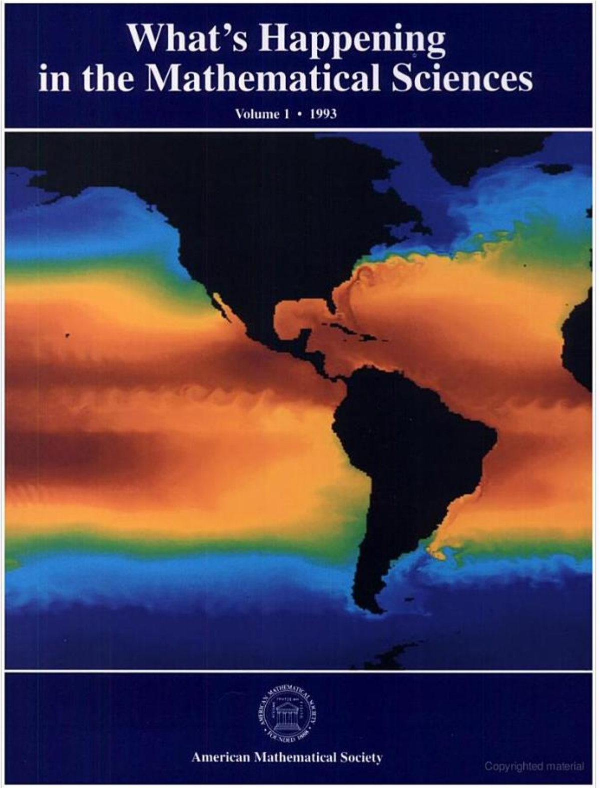
1 0 1 2 0	0 3 1 2 0	0 1 3 2 0
2 0 3 2 0	1 2 0 3 1	0 1 3 0 0
Adjacent	NOT adjacent	NOT adjacent

A complete resolution of the Keller maximum clique problem. Jennifer Debroni, John D. Eblen, Michael A. Langston, Wendy Myrvold, Peter W. Shor, Dinesh Weerapurage, SODA, 2011.

“In a sense, these cases require only patience- and maybe a high speed computer the size of a major galaxy.

No one in his right mind, and no mathematicians either, would set our to sort through 2^{128} possible tilings to check the case of d=7.”

p. 24, Barry Cipra and Paul Zorn



Finishing the Keller conjecture only requires the answer to whether the clique order for dimension 7 is 128 or less than 128.

Determining if it was 127 or less than 127 took only 3 days on 64 CPU's.

Determining that the maximum clique order is 124 took 109 days on 64 CPU's.

Funding for CPU's was provided by:

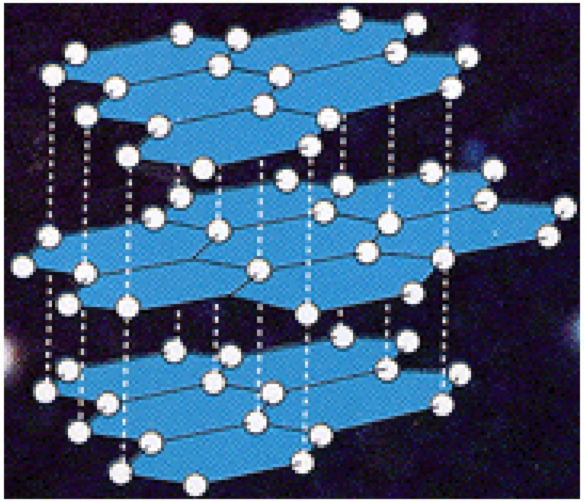
NSERC
CRSNG

Double checking:

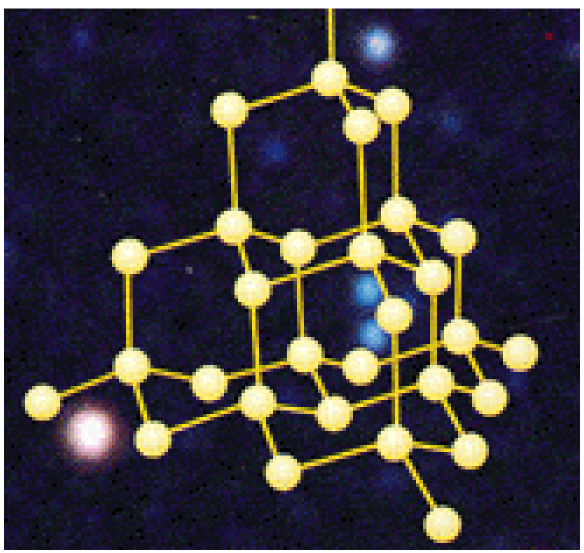
8192 CPU's

Applications of Graph theory to chemistry

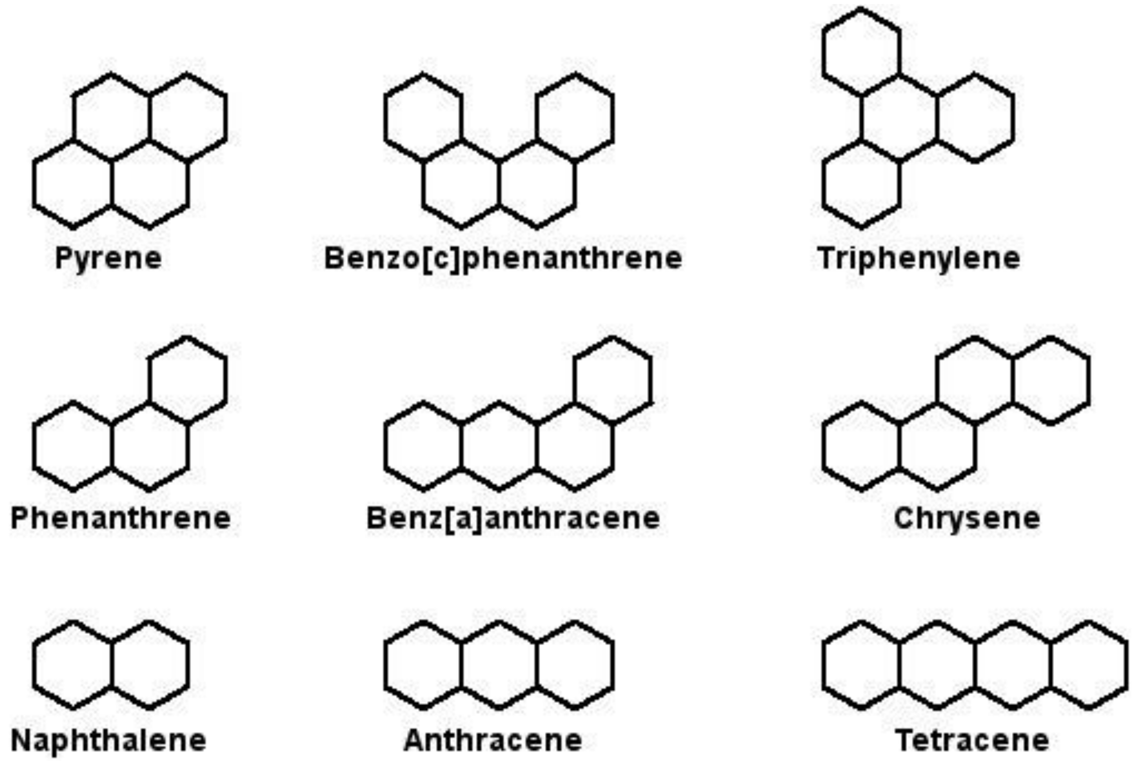
Working with Patrick Fowler (chemist)



Graphite

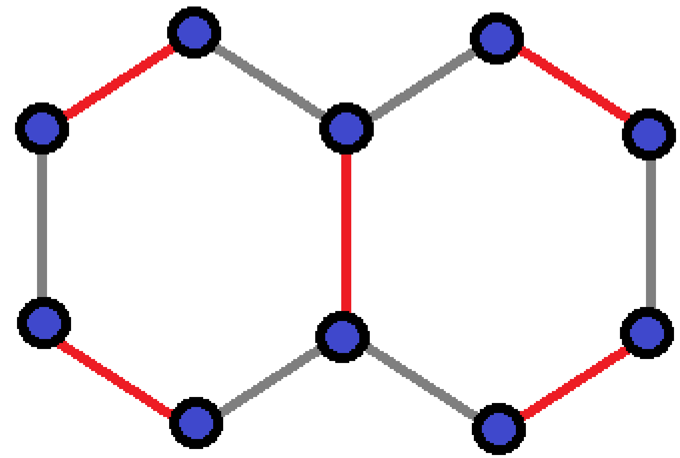


Diamond

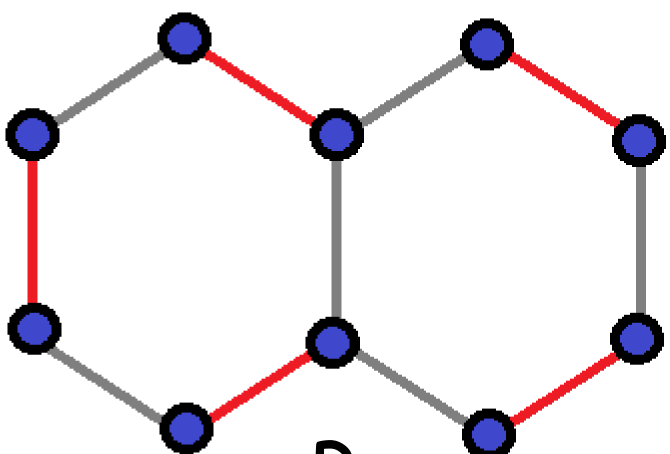


Benzenoids

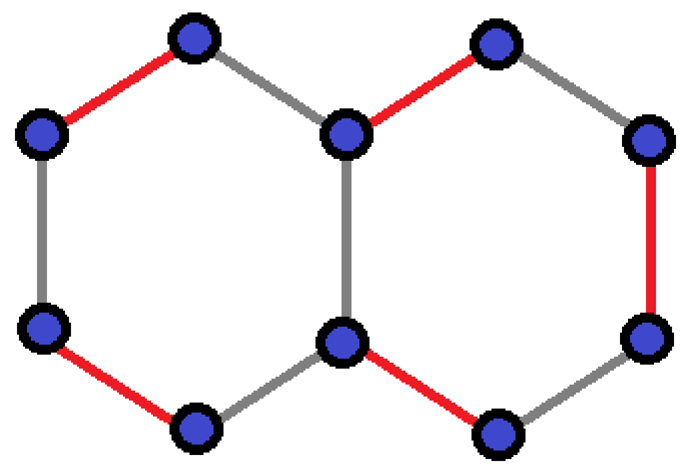
The graph for naphthalene has 3 perfect matchings:



A

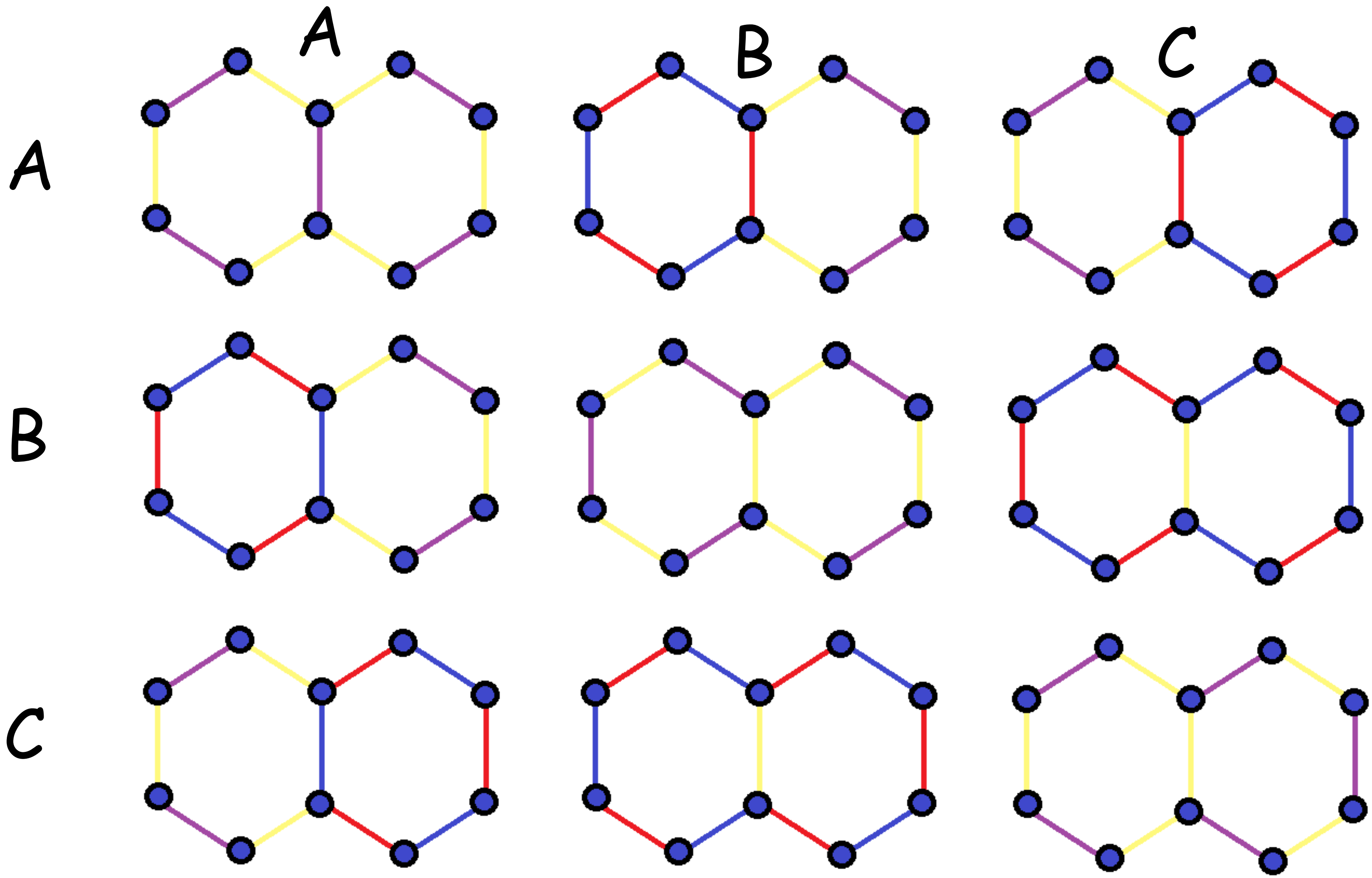


B

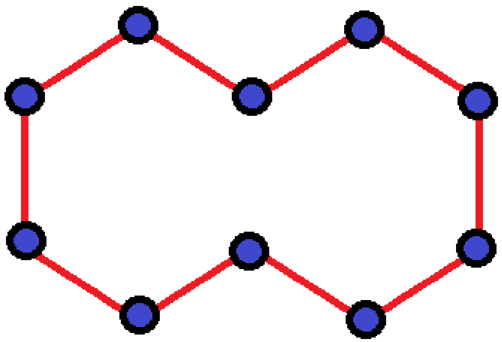


C

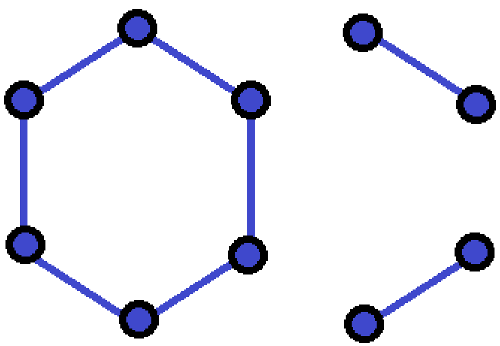
Randić current model: Consider ordered pairs of perfect matchings.



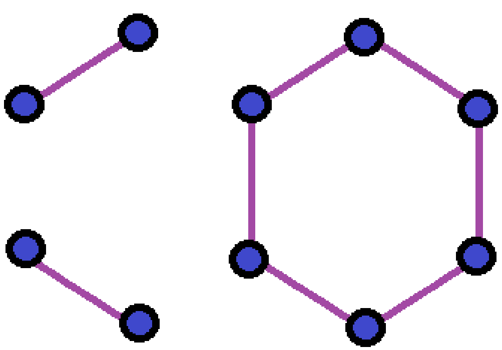
Conjugated Circuits:



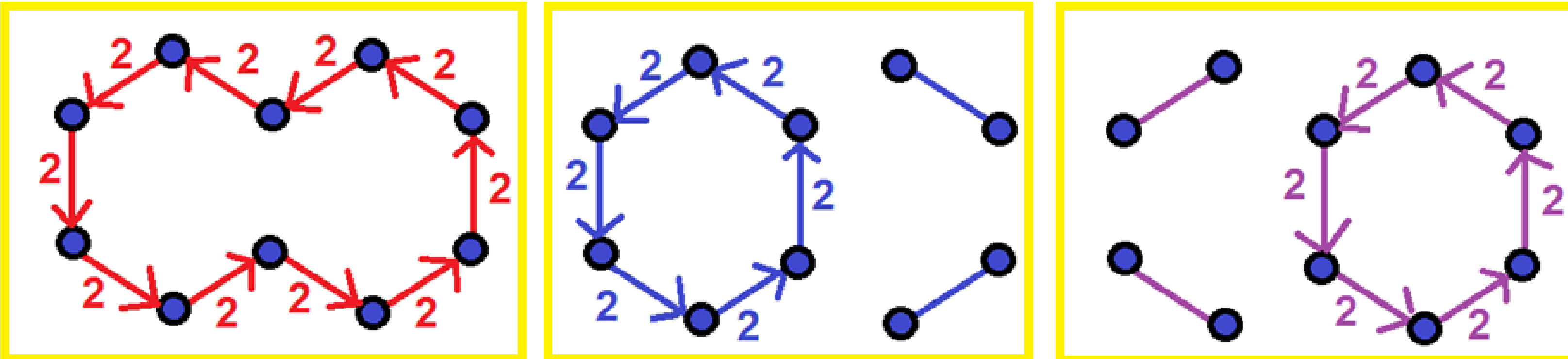
Occurs 2 times
(BC, CB).

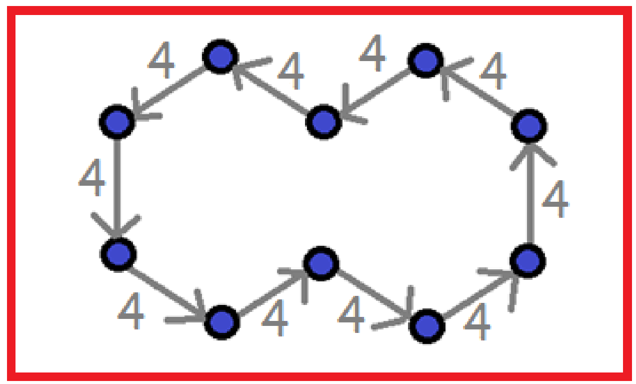


Occurs 2 times.
(AB, BA)



Occurs 2 times.
(AC, CA)



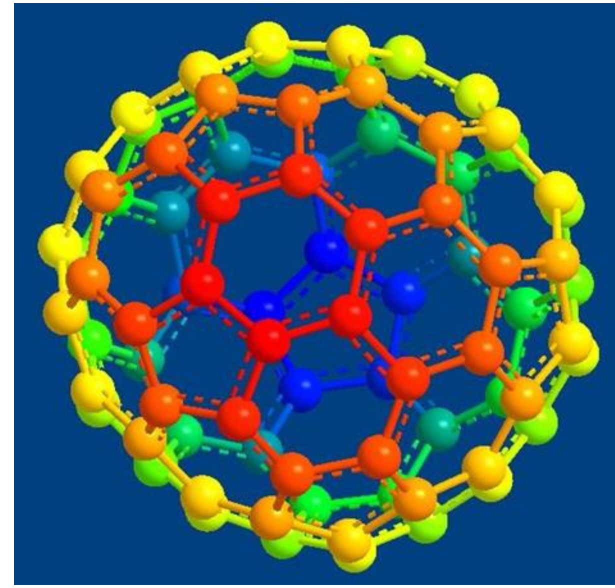


Milan Randić

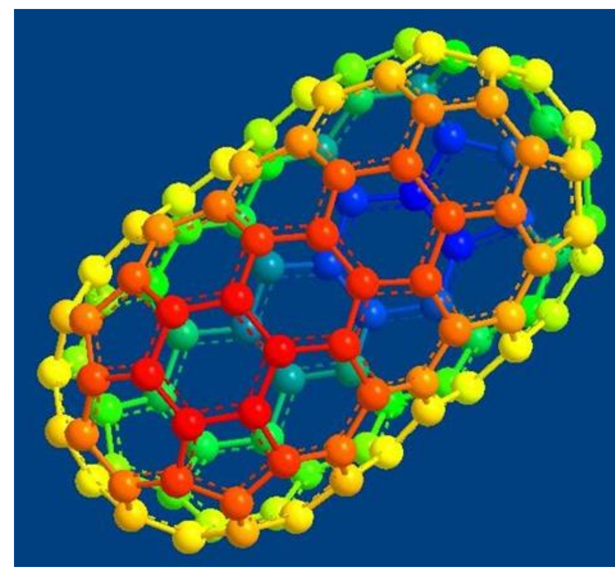
Current flow: counterclockwise in 4n+2 cycles and clockwise in 4n cycles.

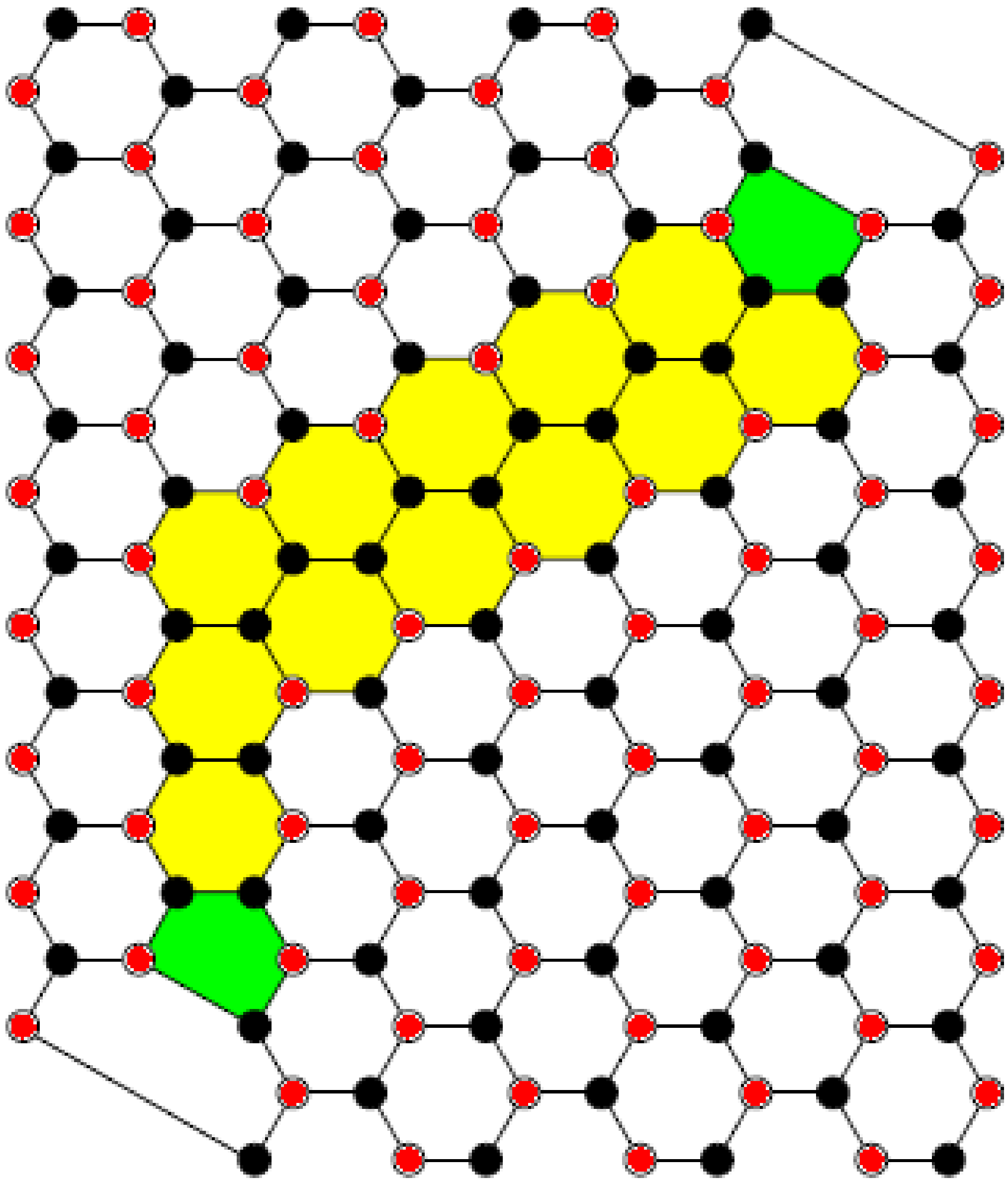
Sum the currents for each pair of matchings to get current estimate.

Fullerenes are all-carbon molecules that correspond to 3-regular planar graphs with all face sizes equal to 5 or 6.



The Nobel Prize in Chemistry 1996 was awarded jointly to Robert F. Curl Jr., Sir Harold W. Kroto and Richard E. Smalley *"for their discovery of fullerenes"*.





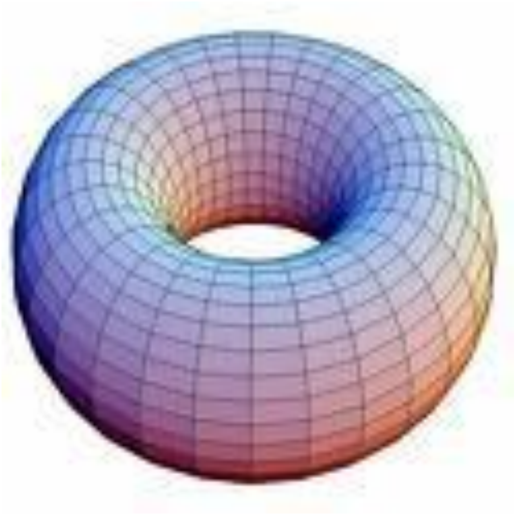
Pentagons cause grief for some hexagons.

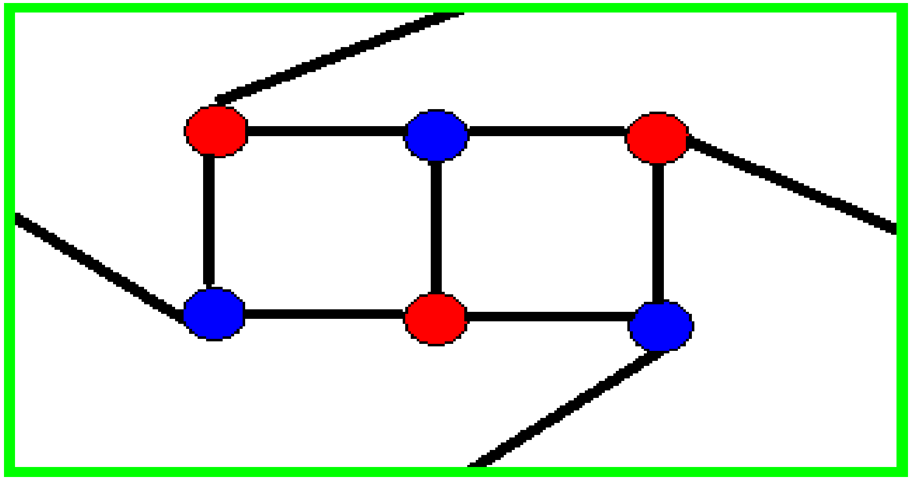
Yellow hexagons- only 2 independent set vertices.

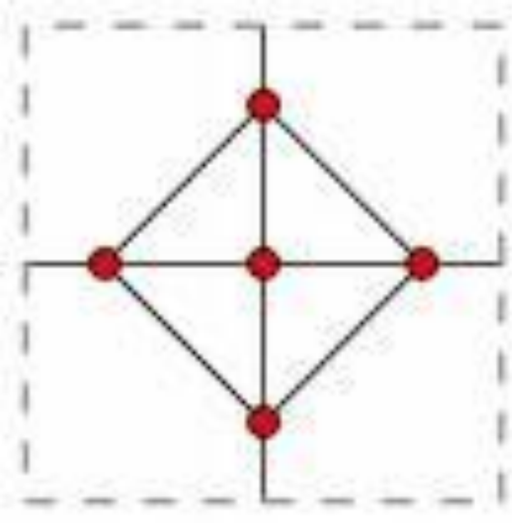
Linear time algorithm for maximum independent set of a fullerene: joint work with Sean Daugherty.

Topological Graph Theory:

Algorithms and Obstructions







Torus Obstructions Found So Far:

n/m:	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
8 :	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0
9 :	0	2	5	2	9	17	6	2	5	0	0	0	0	0	0	0	0	0	0
10 :	0	15	9	35	40	190	170	102	76	21	1	0	1	0	0	0	0	0	0
11 :	5	2	49	87	270	892	1878	1092	501	124	22	4	1	0	0	0	0	0	0
12 :	1	12	6	201	808	2698	6688	6372	1933	482	94	6	2	0	0	0	0	0	0
13 :	0	0	12	19	820	4967	12781	16704	7182	1476	266	52	1	0	0	0	0	0	0
14 :	0	0	0	9	38	2476	15219	24352	16298	3858	808	215	19	0	0	0	0	0	0
15 :	0	0	0	0	0	33	3646	22402	20954	8378	1859	708	184	5	0	0	0	0	0
16 :	0	0	0	0	0	0	20	2689	17469	10578	3077	1282	694	66	1	0	0	0	0
17 :	0	0	0	0	0	0	0	0	837	8099	4152	1090	1059	368	11	0	0	0	0
18 :	0	0	0	0	0	0	0	0	0	133	2332	1471	511	639	102	1	0	0	0
19 :	0	0	0	0	0	0	0	0	0	0	0	393	435	292	255	15	0	0	0
20 :	0	0	0	0	0	0	0	0	0	0	0	0	39	100	164	63	2	0	0
21 :	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	63	1	0	0
22 :	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	22	0	0
23 :	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
24 :	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

COMBINATORIAL ALGORITHMS GROUP
University of Victoria

http://www.cs.uvic.ca/~wendym/cag

Our research interests include:

Graph Theory and Graph Algorithms
Combinatorics
Combinatorial Algorithms
Computational Geometry
Randomized Algorithms
Computational Complexity
Network Reliability
Topological Graph Theory
Computational Biology
Cryptography
Design Theory

Join our listserv to get information about conferences and research talks.

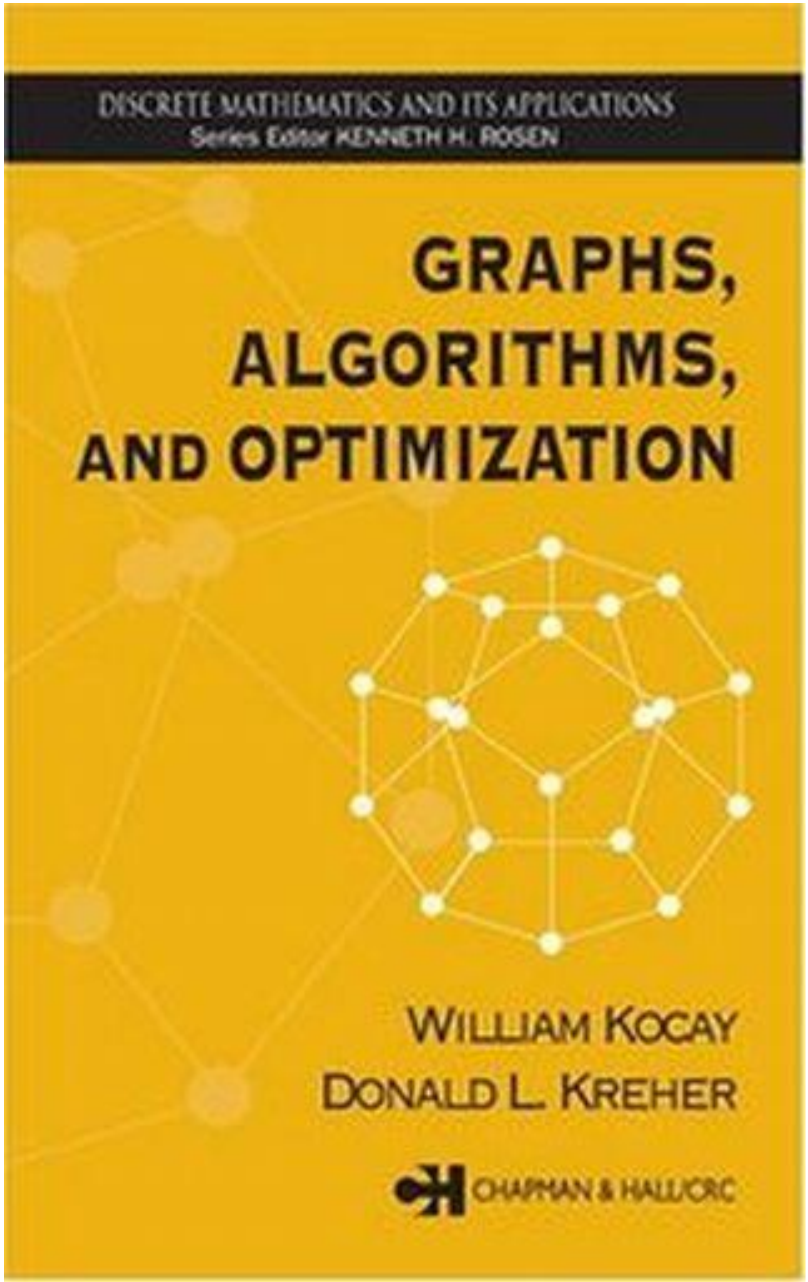
Undergrads are welcome to all events.

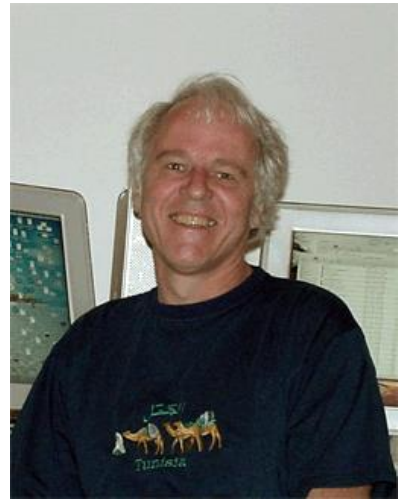
Course description:

This course provides an introduction to graph theory and graph algorithms. We will start with basic definitions in order to make the class accessible to all. The algorithms studied range from classical polynomial time algorithms for problems such as network flows to those geared towards dealing with intractible problems such as finding a maximum independent set in a graph. The material also includes cutting edge research tactics for solving real world problems. The class is especially valuable for students requiring graph theory and combinatorics as a tool for research in areas such as networks, database, computer graphics, and software engineering.

Course objectives:

- To provide a solid foundation in graph theory and algorithms.
- To teach some useful algorithms and algorithm design tactics.
- To develop research skills which include:
  - Background literature search,
  - Formal writing for graph theory topics (as required for theses, conference or journal papers), and
  - Programming graph algorithms.
- To intrigue and excite students about graph theory research topics.
- To take students to the leading edge of graph theory research.





Text: Graphs, Algorithms, and Optimization by William Kocay, and Donald L. Kreher Chapman and Hall/CRC Press, 2004.

Other references will be provided if we deviate from the text.

Students with a disability

Please let me know as soon as possible how I can accommodate your disability.

It's sometimes possible to go beyond what is first offered by the disability center.

Parents of young children

Let me know if you require accommodation because of the school strike.

Grading scheme:

Component			Weight
Small Assignments	8-10	~weekly	30
Small Pop Quizzes	8-10	~weekly	20
Literature Review Project		Oct. 14	20
Programming Project		Dec. 9	30

New Grading System (effective Summer 2014)

- Instructor will submit grades in percentages.
- The University will use the following Senate approved standardized grading scale to assign letter grades.
- Both the percentage mark and the letter grade will be recorded on the academic record and transcripts.

F	D	C	C+	B-	B	B+	A-	A	A+
0-49	50-59	60-64	65-69	70-72	73-76	77-79	80-84	85-89	90-100

For graduate students:

B- or lower is unacceptable work revealing some deficiencies in knowledge, understanding or techniques.

Assignments (30%):

- 8-10 equally weighted small assignments, No late assignments.
- Your lowest assignment grade will be dropped when computing your assignment average.

If necessary due to limitations of TA resources, a random selection of question might be chosen for marking. Students are strongly advised to submit answers to all of the assignment questions.

Exams (20%)

- 8-10 equally weighted small pop quizzes that are during a class slot.
- Your lowest quiz mark will be dropped.
- Start: week of Sept. 23.
- No quizzes during reading break week (Nov. 10-14).
- Students who arrive to class late and miss the start of a quiz will not be provided with any extra time to finish the quiz. Come to class on time!

Literature Review Project (20%)
Due: Tues. Oct. 14, beginning of class.

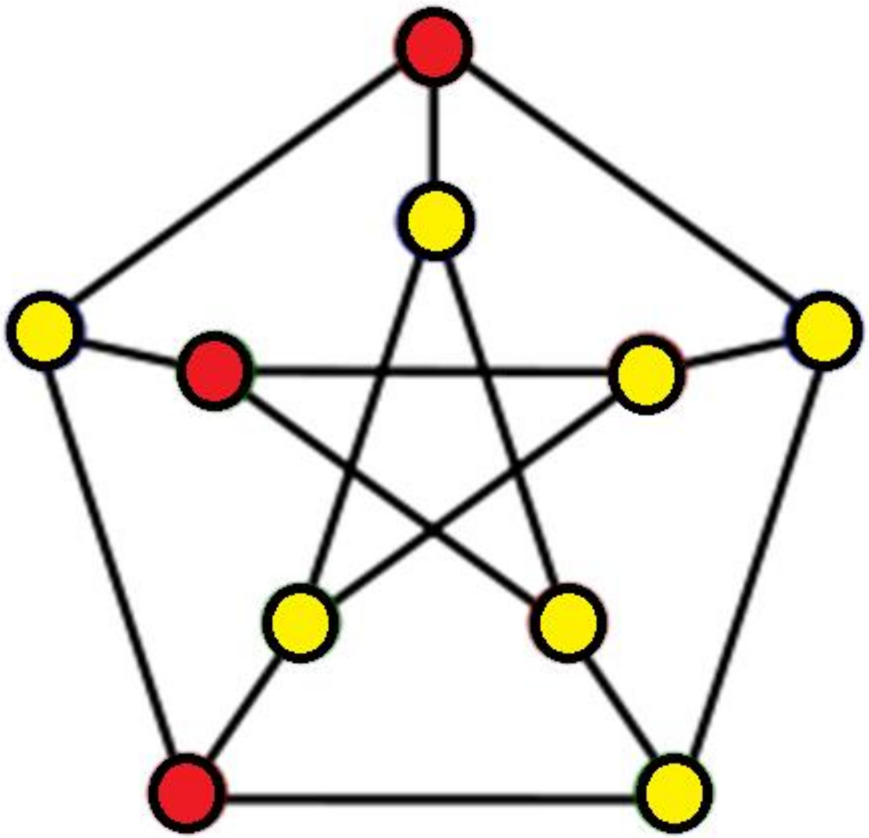
- Choose a pre-approved subdomain of graph algorithms.
- Write a paper that defines the problem considered and summarizes some papers in the area. More substantial for graduate students (CSC 522).
- Students who exceed expectations can get bonus marks.
- Late submissions: Tues. Oct. 21 with a 10% late penalty.

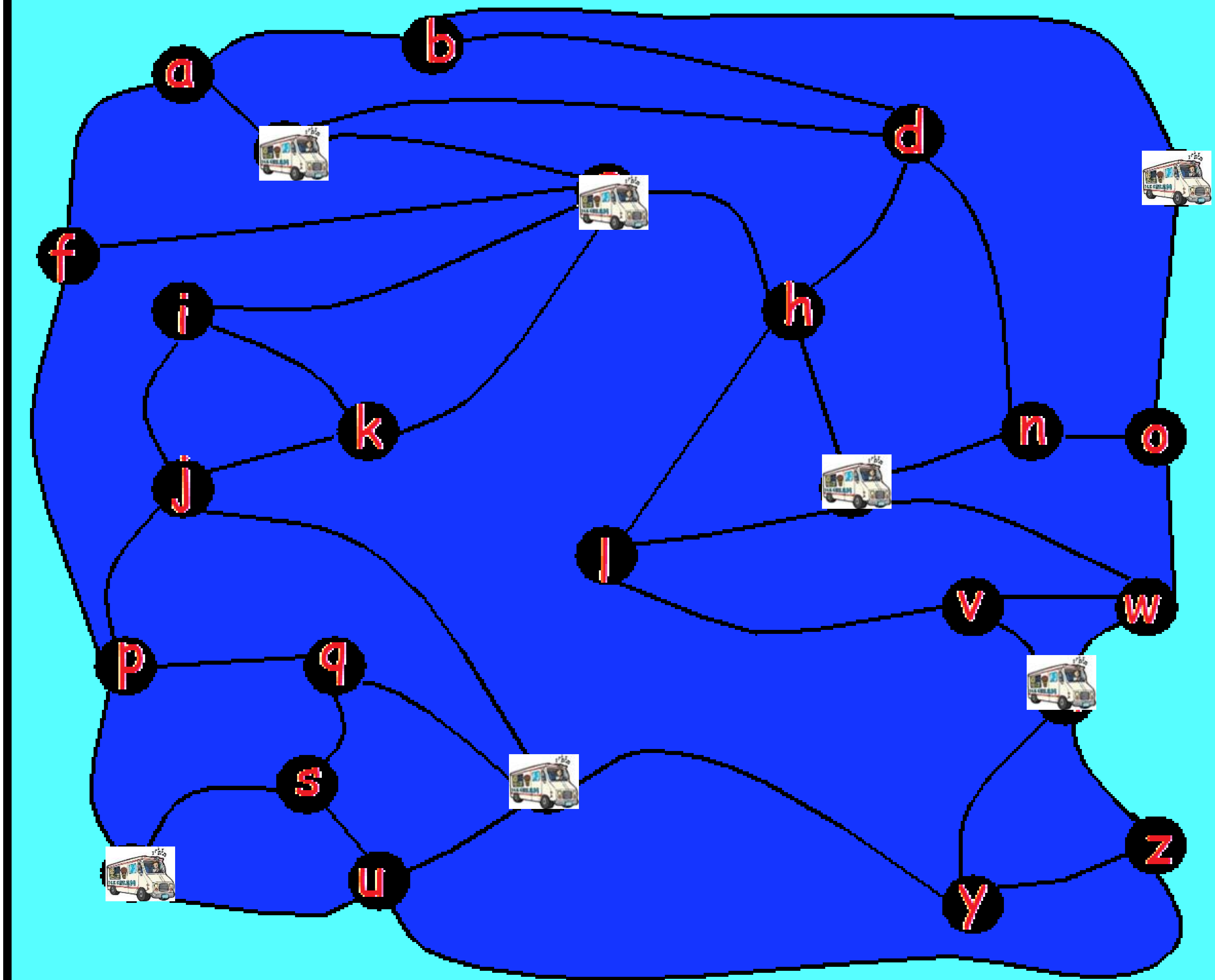
Programming Project (30%)

Due: Tues. Dec. 9 by 11pm.

- Design and implement an algorithm (or for CSC 522 students, 2 algorithms) for a hard problem in graph algorithms.
- Students who exceed expectations can get bonus marks.
- Final submission: a paper that describes the algorithm, and the program(s).
- Late submissions: **Tues. Dec. 16** at 11pm with a 10% late penalty.

A *dominating set* of a graph G is a subset D of the vertices of G such that every vertex v of G is either in the set D or v has at least one neighbour that is in D.



A Map of the Town of Iceberg

CSC 422/522: Class project

Dominating Set Challenge

In spite of more than 2,000 papers on dominating sets, not much has been done algorithmically to search for and evaluate practical algorithms.

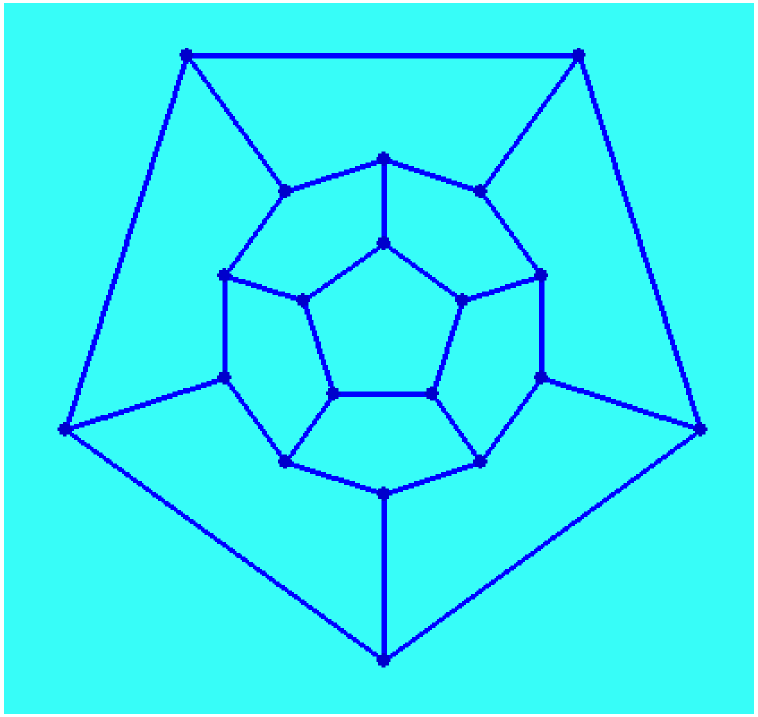
In CSC 425/520 in the spring, students collected a large selection of interesting test graphs for this problem:
http://webhome.cs.uvic.ca/~wendym/425.html

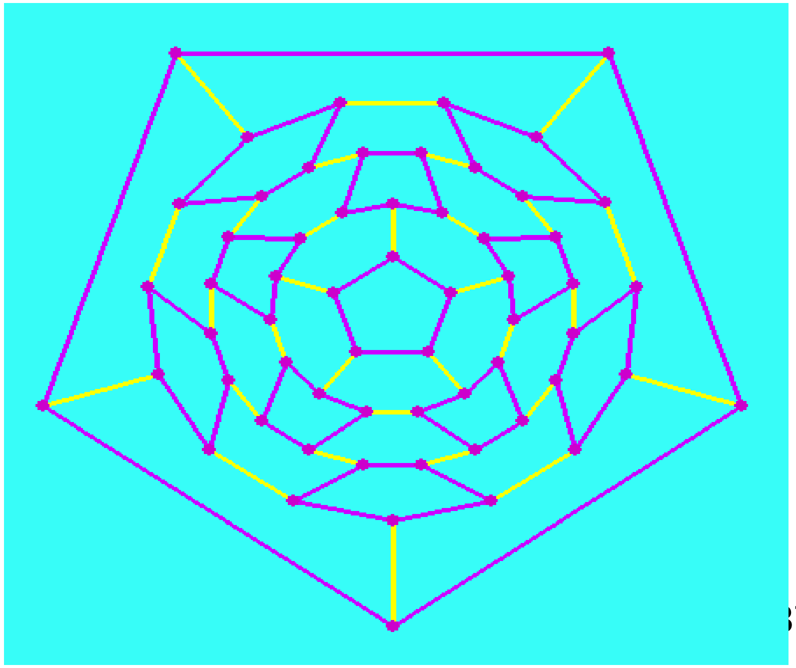
Open problems?:

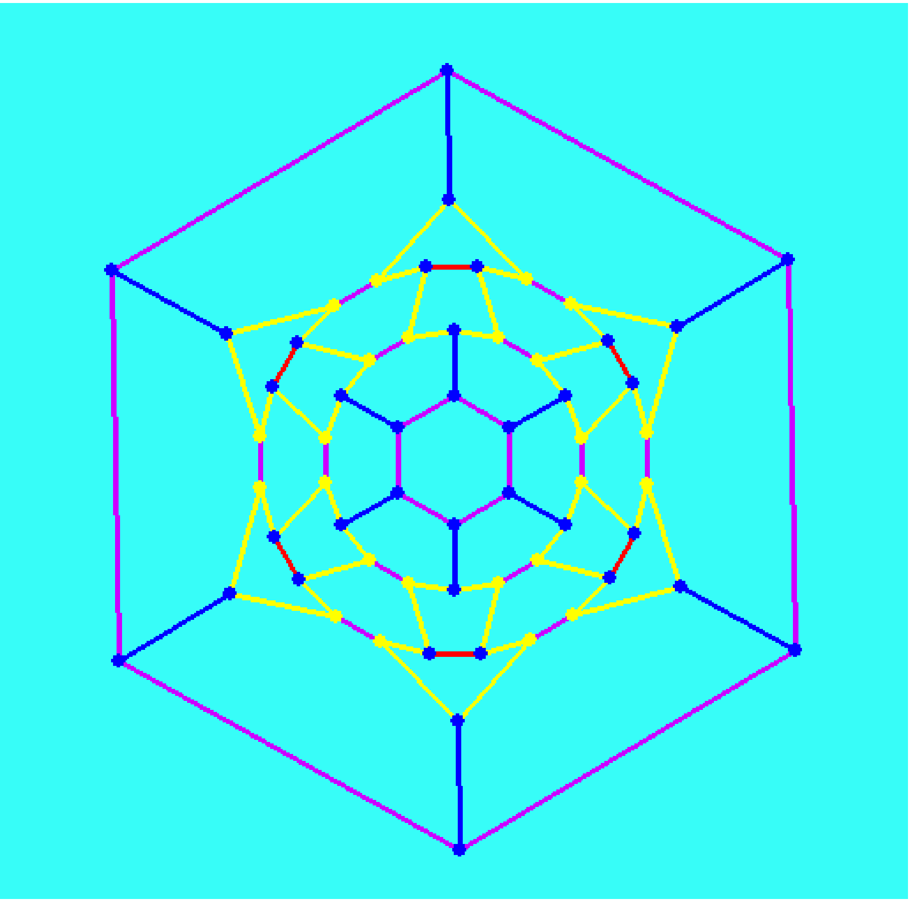
Lower bound	Upper bound	Graph name	Number of vertices	Degrees	Input file
22	27	Kneser (9,4)	126	5	ikneser_9_4
14	20	Kneser (10,4)	210	15	ikneser_10_4
10	17	Kneser (11,4)	330	35	ikneser_11_4
10	12	Kneser (12,4)	495	70	ikneser_12_4
10	11	Queen graph: 20	400	57-75	iqueen_20
11	12	Queen graph: 22	484	63-83	iqueen_22
12	13	Queen graph: 24	576	69-91	iqueen_24
13	14	Queen graph: 26	676	75-99	iqueen_26
58	64	Hypercube: 9	512	9	ihyper_9
71	73	Football Pool problem: 6	729	12	ifootball_6

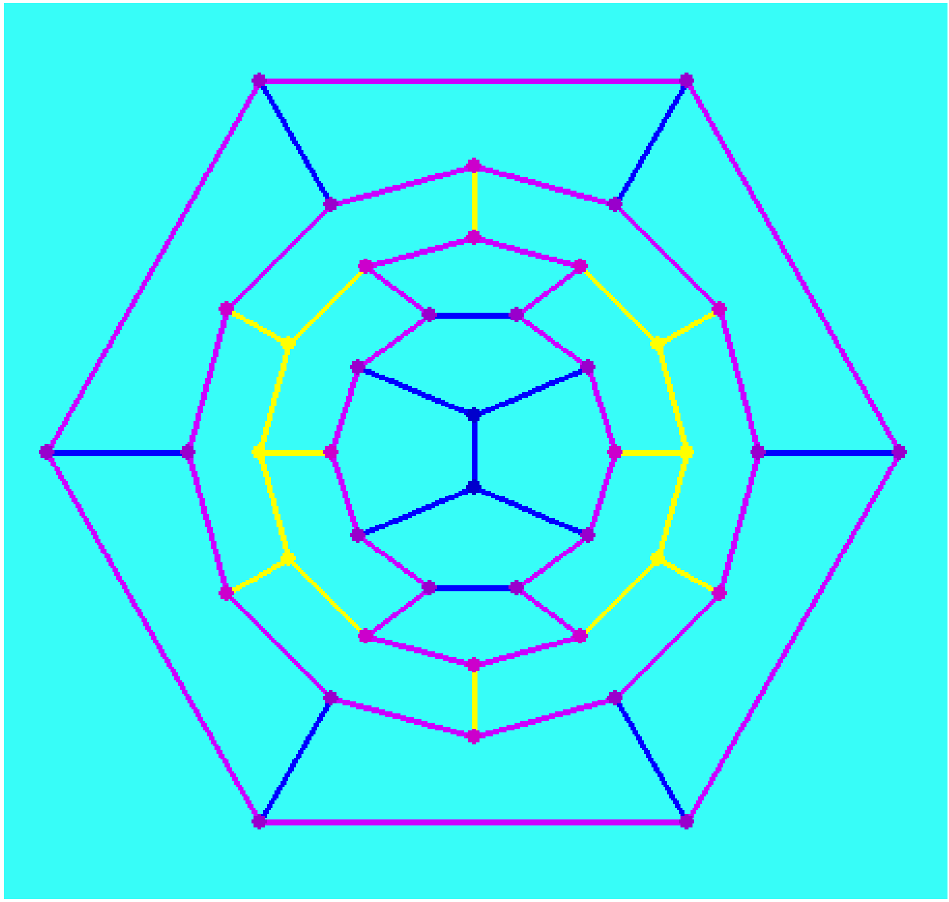
Fullerenes

- Correspond to 3-regular planar graphs.
- All faces are size 5 or 6.
- Euler's formula: exactly 12 pentagons.









n	LB	#LB	#LB+1	#LB+2	Seconds: Adj. list
40	10	1	21	18	0.156
42	11	1	44	0	0.104
44	11	0	55	34	0.532
46	12	6	110	0	0.544
48	12	1	109	89	2.62
50	13	6	265	0	2.54
52	13	0	270	167	10.58
54	14	19	561	0	10.38
56	14	1	470	453	51.46
58	15	23	1182	0	42.11
60	15	0	1014	798	183.7

Some conjectures for fullerenes:

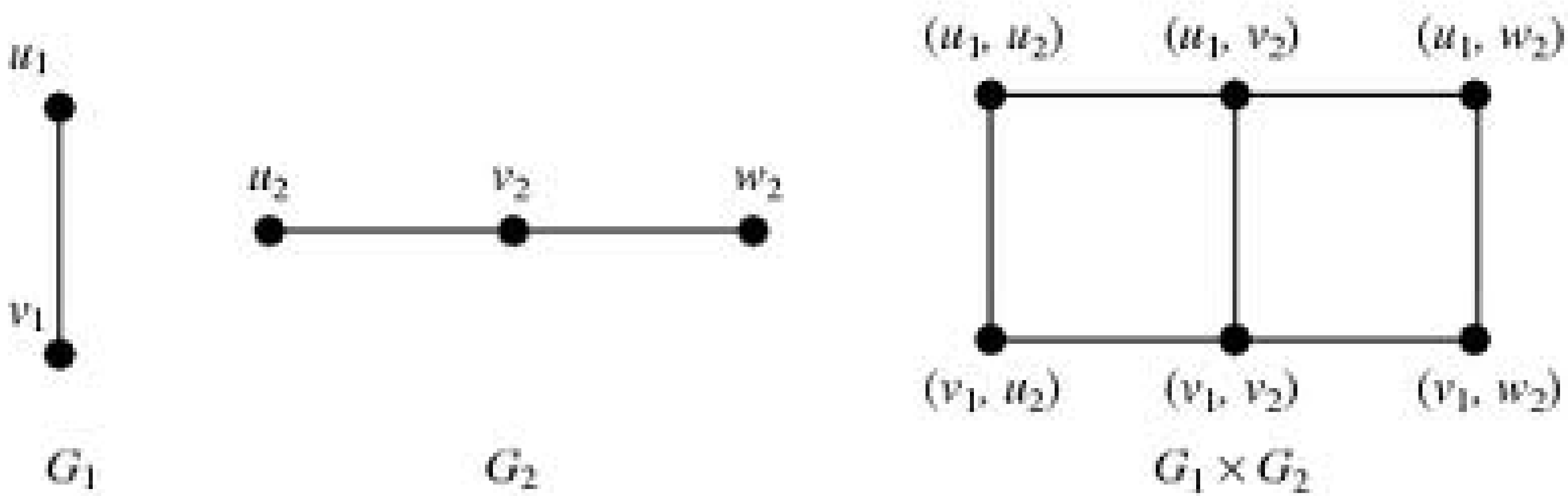
If n is divisible by 4 then the minimum dominating set order is either n/4, n/4 +1, or n/4+2. Can we characterize the cases that are n/4?

If n is not divisible by 4 (n is congruent to 2 mod 4) then the minimum dominating set order is $\left\lceil \frac{n}{4} \right\rceil$ or $\left\lceil \frac{n}{4} \right\rceil$ +1.

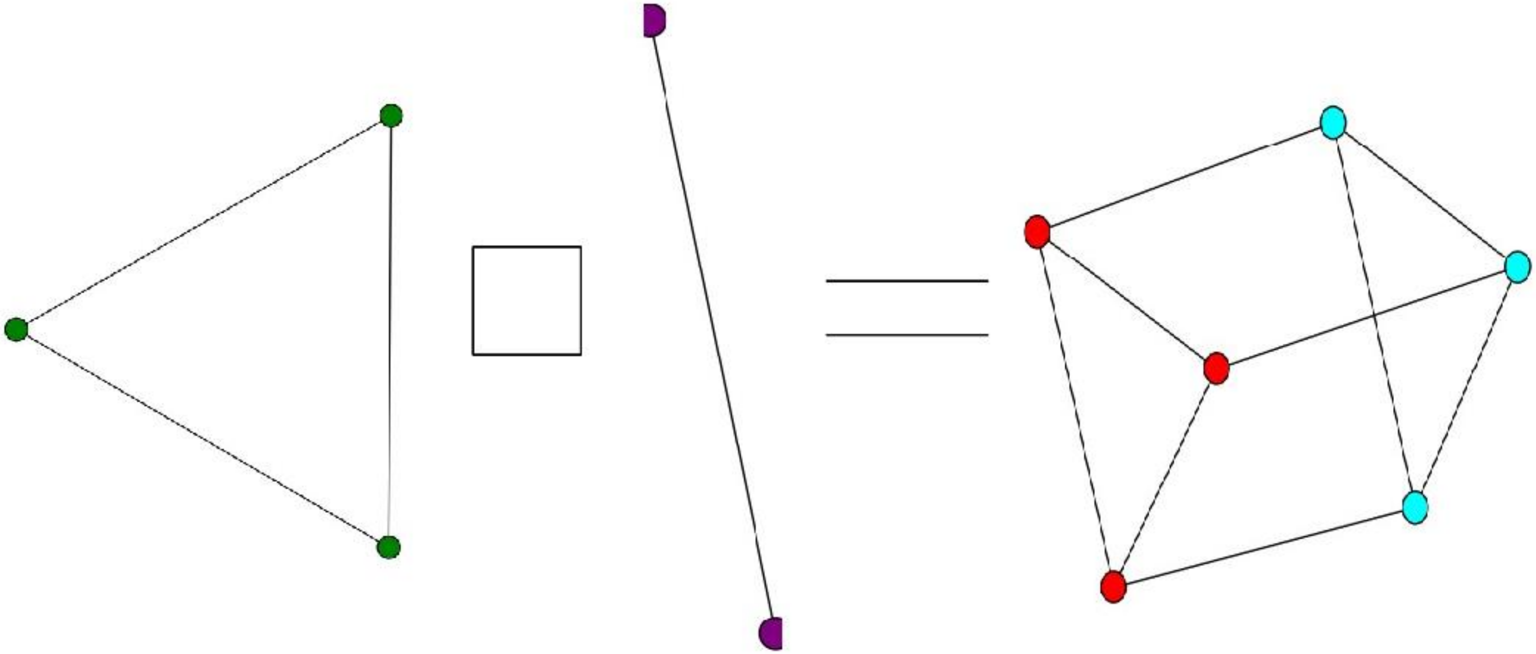
There is a linear time (or maybe $O(n^2)$ time) algorithm for finding a minimum size dominating set of a fullerene.

The Cartesian product, $G \square H$, of graphs G and H is a graph F such that

1. $V(F) = V(G) \times V(H)$; and
2. any two vertices (u,u') and (v,v') are adjacent in F if and only if either:
   u = v and u' is adjacent with v' in H, or
   u' = v' and u is adjacent with v in G.

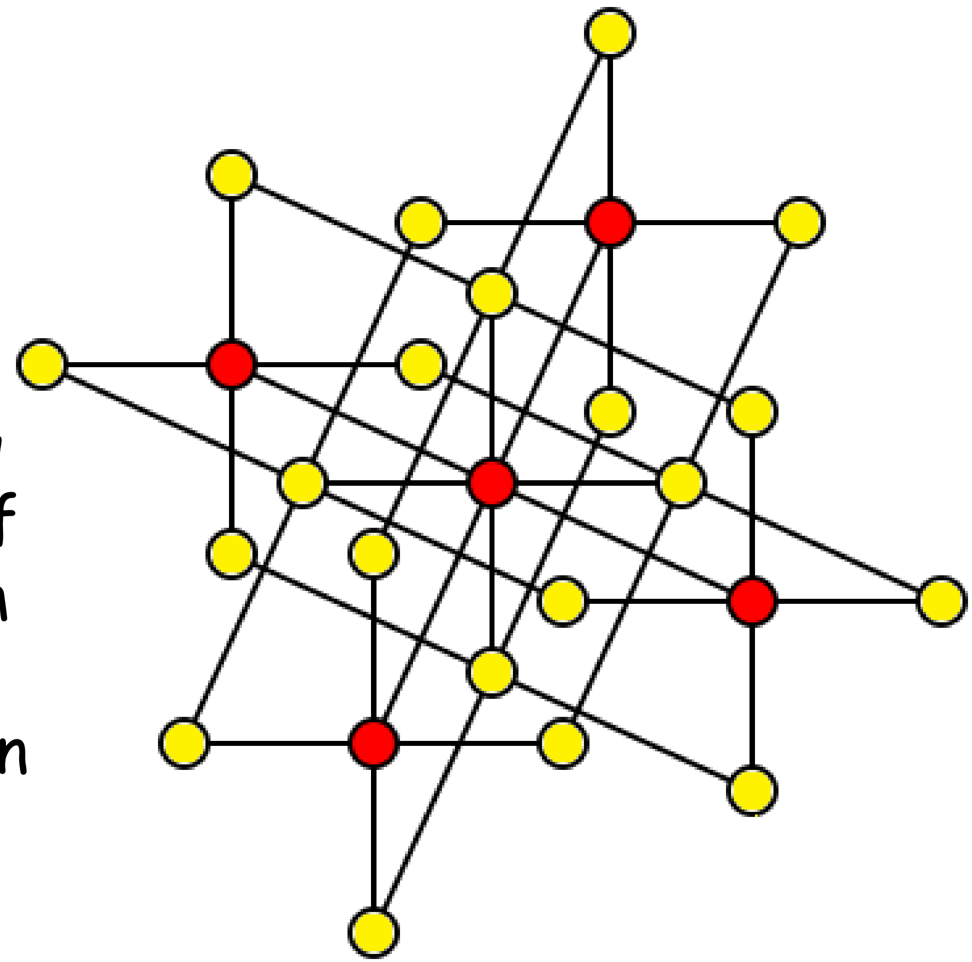


http://mathworld.wolfram.com/GraphCartesianProduct.html



http://cnx.org/content/m34835/latest/?collection=col10523/latest

Vizing's conjecture concerns a relation between the domination number and the cartesian product of graphs. This conjecture was first stated by Vadim G. Vizing (1968), and states that, if $\gamma(G)$ denotes the minimum number of vertices in a dominating set for G, then $\gamma(G \square H) \geq \gamma(G)\gamma(H)$.



Conjecure predicts ≥ 1 for this graph so it is not tight.

http://en.wikipedia.org/wiki/Vizing's_conjecture

A recent survey paper:

Brešar, Boštjan; Dorbec, Paul; Goddard, Wayne; Hartnell, Bert L.; Henning, Michael A.; Klavžar, Sandi; Rall, Douglas F. Vizing's conjecture: a survey and recent results. J. Graph Theory 69 (2012), no. 1, 46-76.