THE UNIVERSITY OF MELBOURNE

SCHOOL OF GEOGRAPHY, EARTH AND ENVIRONMENTAL SCIENCES

SEMESTER 2 EXAMINATION, 2021

SUBJECT: MODELLING THE REAL WORLD, EVSC20007

Exam Duration: 2 hours

This paper has 10 pages.

Reading Time: 15 minutes

Uploading Time: 30 minutes

Instructions to Students:

This assessment consists of four sections, Section A, Section B, Section C, Section D. The exam has a total of 120 marks. **Each Section has 2 questions, each worth 15 marks (30 marks in total) and it is suggested that you spend 30 minutes on each Section.** The marks available for each question are proportional to the suggested completion times.

Please ensure that answer all Sections, photograph and upload your solutions through gradescope – indicating the Section that each answer belongs to.

Paper to be held by Baillieu Library - YES

SECTION A (30 marks in total as indicated)

A1. (15 marks)

a. Describe the steps you would follow when creating a model of a system. **(5 marks)**

b. The following stock and flow diagram presents several complex feedbacks. Describe two of the feedback loops, giving their sign and describing their implications for the company and its decision making processes. Demonstrate that the logic holds by a clear example. **(10 marks)**

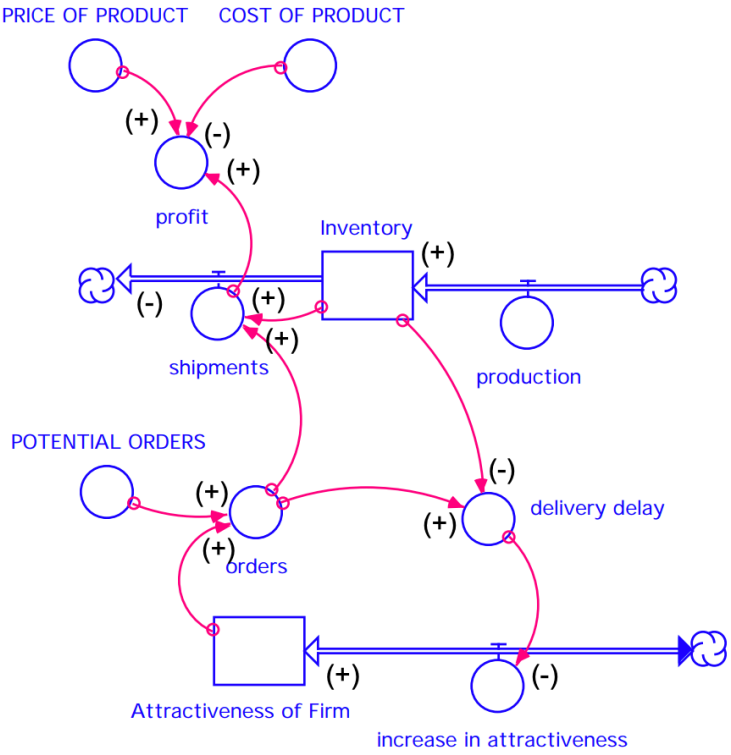
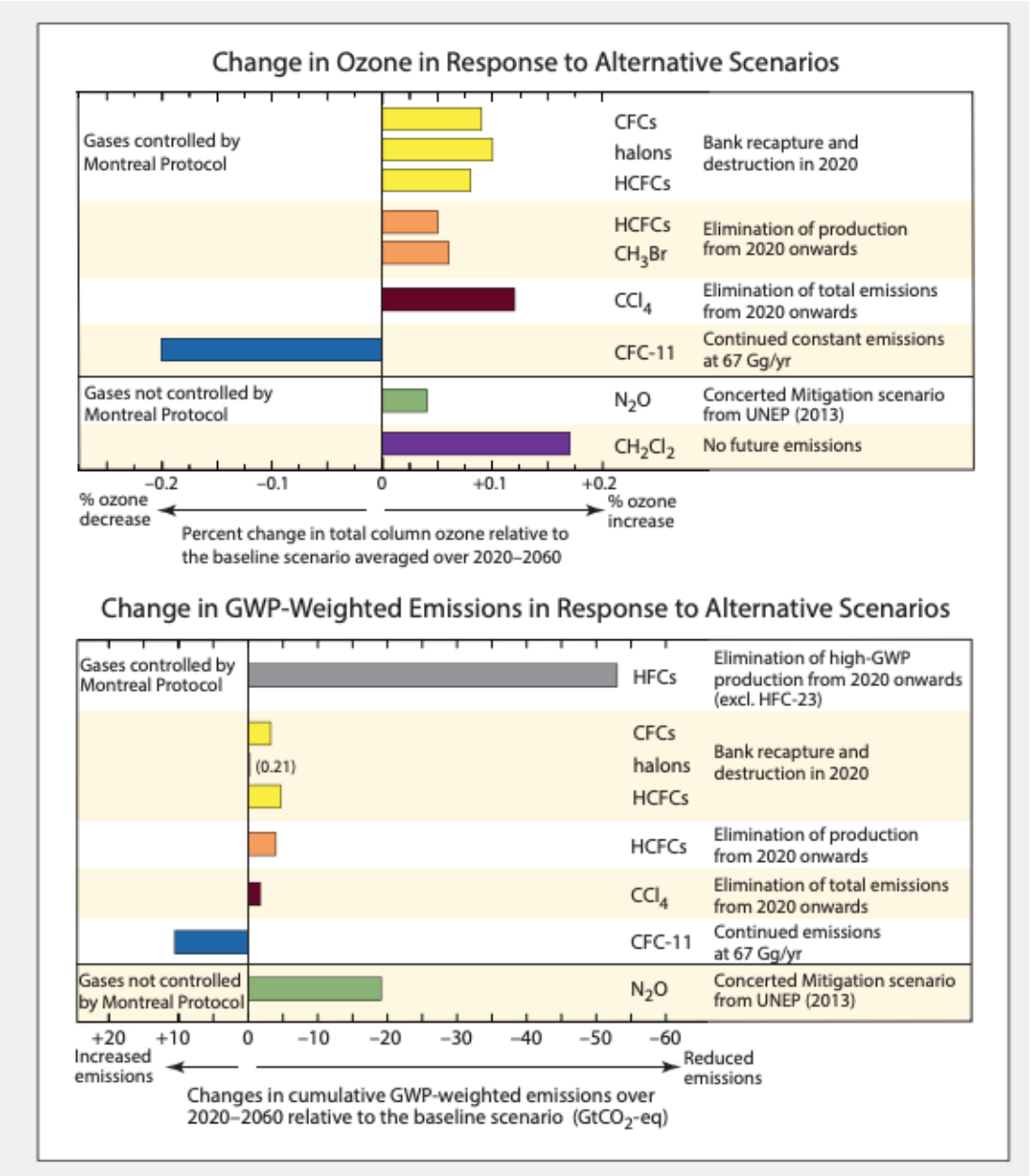


Figure 7: Stock-and-Flow Diagram of Basic Mechanism of a Company (see Fig. 2)

A2. (15 marks)

a. The ozone hole forms every year in spring when the sunlight returns to the Antarctic because of introduced chlorine to the stratosphere (10-50 km altitude where the ozone layer exists). Chlorine has been introduced via chlorofluorocarbons (CFCs) and halons (fire retardants) that have been now banned for some years under the international Montreal protocol.

The reason that we are still experiencing Antarctic ozone holes every year is because the CFCs are only destroyed very slowly in the stratosphere by UV light. CFCs are also very effective greenhouse gases, and the Montreal protocol banning CFCs remains the most significant climate action taken to date.



CFCs were replaced by HFCs, which were recently also banned due to them having very high global warming potentials. HCFCs (another replacement gas was proposed to be banned from 2020).

As policy makers are concerned with both ozone depletion and global warming draw a conceptual model that captures the complexity of system from emissions to impacts. Make sure it clearly captures how replacement gases need to consider all possible impacts so that solving one issue doesn't result in another. **(15 marks)**

SECTION B (30 marks in total as indicated)

B1. (15 marks)

You are interested in studying the dynamics of aquatic food chains. As a starting point, you decide to make a simple model of a food chain involving three species: algae, krill and small fish.

You know the following about how these species interact:

- Since algae are photosynthetic, they can grow and reproduce on their own
- Algae form the primary source of food for krill
- Small fish primarily feed on krill

Given that you are after a reasonably simple model, you decide to develop an ordinary differential equation (ODE) model of this system.

a. Write down the state variables you are considering.
(2 marks)

b. List the processes you wish to consider. You may find it helpful to draw a diagram of the system.
(4 marks)

c. Derive the ODEs for the system. You may assume that all interactions follow the law of mass action. Define all your parameters and state any additional assumptions you make.
(7 marks)

d. Briefly explain how you would modify the equations you derived in part c to account for fishing, which removes small fish from the ecosystem.
(2 marks)

B2. (15 marks)

You wish to make a model of how wounds heal to better predict how effective certain treatments are. Over the days after a wound forms, the skin cells surrounding the wound gradually close the wound through two processes:

- **Proliferation**: the division of one cell into two identical cells
- **Migration**: the random movement of cells to nearby locations

a. You decide to make a cellular automata model of wound healing. What are the advantages of using a cellular automata model in this context?
(5 marks)

b. Describe how you would make a cellular automata model of wound healing that incorporates the processes of proliferation and migration. You may assume that the wound is initially circular, with a radius *R*. Please discuss the following in your answer:

- What variables and parameters will you use?
- How will you set the initial conditions?
- What assumptions will you make?
- Briefly describe the rules and heuristics you would use for your model. You may find it helpful to use diagrams to illustrate your points.

(10 marks)

SECTION C (30 marks in total as indicated)

C1. (15 marks)

You and a friend have stumbled upon a short film festival. Unfortunately, there are only two hours remaining in the festival. Immediately you construct a schedule containing all the remaining viewings.

Movie	Start Time	Finish Time	Critic Review Score
1	85	100	2
2	50	70	7
3	15	40	5
4	50	95	7
5	40	75	5
6	95	120	5
7	0	25	6
8	10	35	4
9	85	110	9
10	25	45	9

Note, each person has their own screen meaning you do not need to change location between each movie.
For the questions below, present all steps and calculations required to obtain the solution.

a. Your friend suggests that the best strategy is to view as many of the movies as possible. What is the maximum number of movies that can be attended? Also, which movies were suggested? **(5 Marks):**

b. Having recently attended Modelling the Real World at the University of Melbourne, you instead suggest to your friend that it might be better to maximise your viewing based on the critic review score of the movies. What is the maximum value and which movies are selected? **(10 Marks)**

C2. (15 marks)

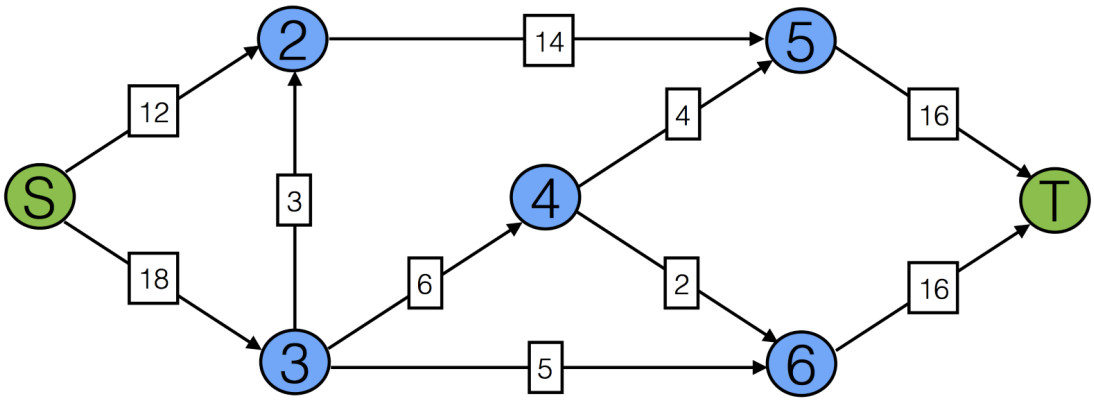
Consider the following rail network, connecting our source city, S, to our destination city, T. This rail network passes through the satellite cities (nodes) denoted 2, 3, 4, 5 and 6. Each arrow denotes the direction in which the cargo can move, with the capacity of each route given by the number in the box.

a. What is the maximum amount of cargo that we can send through our network? Show full working **(10 marks)**

What is the corresponding minimum cut to the network that we could make to completely disrupt the flow of cargo?

b. ? **(5 marks)**

Remember to construct a residual graph and provide it as part of your solution.



SECTION D (30 marks in total as indicated)

D1. (15 marks)

The Department of Environment (DoE) are concerned about vegetation change in public lands of the high plains. Forests are an important carbon sink. These upland areas are also watersheds for major rivers supplying irrigation, hydroelectric power and native animals and plants. Cattle are grazed in some areas under licence, returning profit to some farmers. Cattle create bare ground with their hooves and eating plants, allowing sediment to wash into streams. DoE wish to know how to decide whether to renew cattle grazing licenses.

DoE have some aerial photographs that they think may help with assessing how it has changed over time and some information about the history of land use (was there a fire, was it grazed by cattle, was clearing visible). The air photos can resolve three vegetation types, forest, grassland and shrubland. They suspect that some areas of grassland become shrubland and particularly after fires. They also think that cattle like to graze in fresh, young grasslands, but surprisingly they eat shrubs. Forests were cleared from substantial areas, resulting in grasslands. Trees have returned to some of those grasslands, and it might be that cattle grazing influence this.

a. Describe a first-cut model for this system. Use a diagram. **(5 marks)**

b. Your DoE contact wants to collect more data (air photos) to help with the modelling. But it is a lot of work and there aren't that many air photos, roughly once a decade since the 1940s. They ask whether they should collect more data. One option is to have snapshot data from lots of places. Another is to have high detail on a small number of places, for one time period. Another option is to have several time slices with less detail. From your modelling, which type of data collection would be most useful and why? **(5 marks)**

c. Your contact at DoE explains that one section of the DoE is interested in the long-term dynamics of the system for carbon sequestration and quality and amount of water supply. Another section is concerned to know when and where they should intervene to keep the high plains 'healthy'. Would one model suffice for both uses? What model type would you favour and why. Describe both, if you believe one would not cover both uses. **(5 marks)**

D2. (15 marks)

Land clearing of forest for agriculture, has resulted in 5 fragments of forest near the Wet Tropics World Heritage Area Rainforests. These are isolated from the main forest of 100 000 ha which supports 60 species of frogs. The frogs are poor dispersers across farmland (what the forest has been transformed into). The number of frog species each fragment contains is reported below, along with some other information about the fragments.

	Site	Area (hectares)	species	Distance (km)
1	a	1.0	15	0.5
2	b	5.0	30	1.0
3	c	1.5	22	3.0
4	d	4.0	28	2.8

a. Your colleague, an ecologist, approaches you for help. They want to conserve as many species as possible. They are concerned that those fragments will lose more species. Which fragment do you expect may lose the most species? Explain, drawing on an appropriate model. **(4 marks)**

b. There are funds available to support conservation actions to minimise the number of local extinctions. Actions including building corridors of forest to connect areas, or to increase the size of individual forest fragments. You have no data on the species composition of the individual patches. Which of the forest fragments would be your priority for action and why? **(4 marks)**

c. Explain how data on species composition could assist in the decision process. **(3 marks)**

d. One species the cricket frog, *Litoria smithii*, occurs in the forest fragments. Outline how one might use population ecological information and modelling to justify decisions to best conserve this species. **(4 marks)**

END OF EXAM