THE UNIVERSITY OF MELBOURNE

CHEN20010

Material and Energy Balances

# LECTURE 01

Monday 3 March 2025

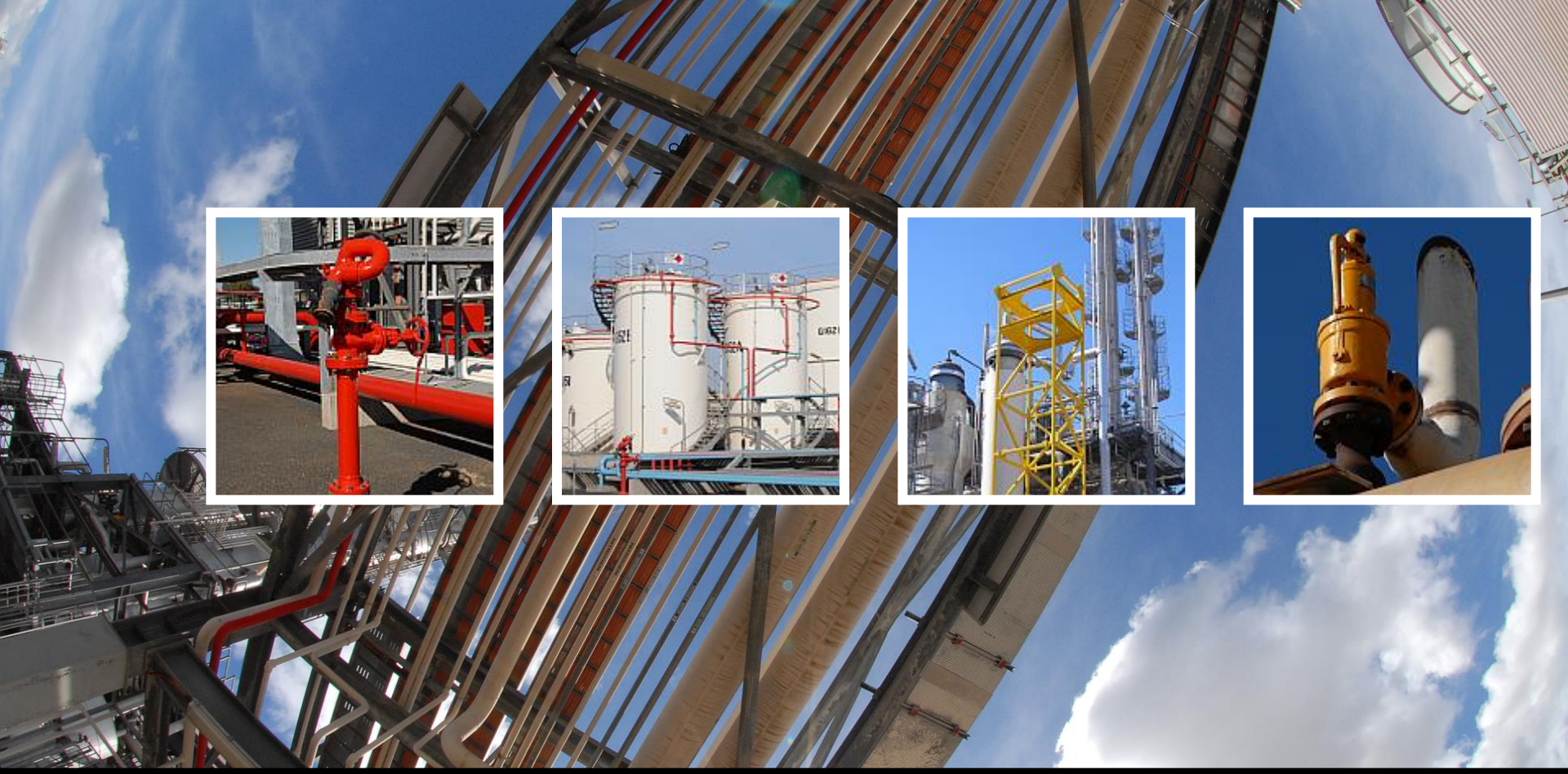
## Introduction to the Subject

## What are Material and Energy Balances ?


This is …

# CHEN20010

## Material and Energy Balances



CHEN20010 Material and Energy Balances

# What are Material and Energy Balances ?

THE UNIVERSITY OF MELBOURNE

Lecturers :

**Dr Catherine Sutton**
Email: ccsutton@unimelb.edu.au
Room 328, Level 3 (by appointment)
Chemical Engineering Building 1

**Dr George Chen**
Email: gechen@unimelb.edu.au
Room 327, Level 3 (by appointment)
Chemical Engineering Building 1

Email etiquette:

- Please include your name, student number, and that it is for CHEN20010 Material and Energy Balances
- Please do NOT send separate emails to both of us

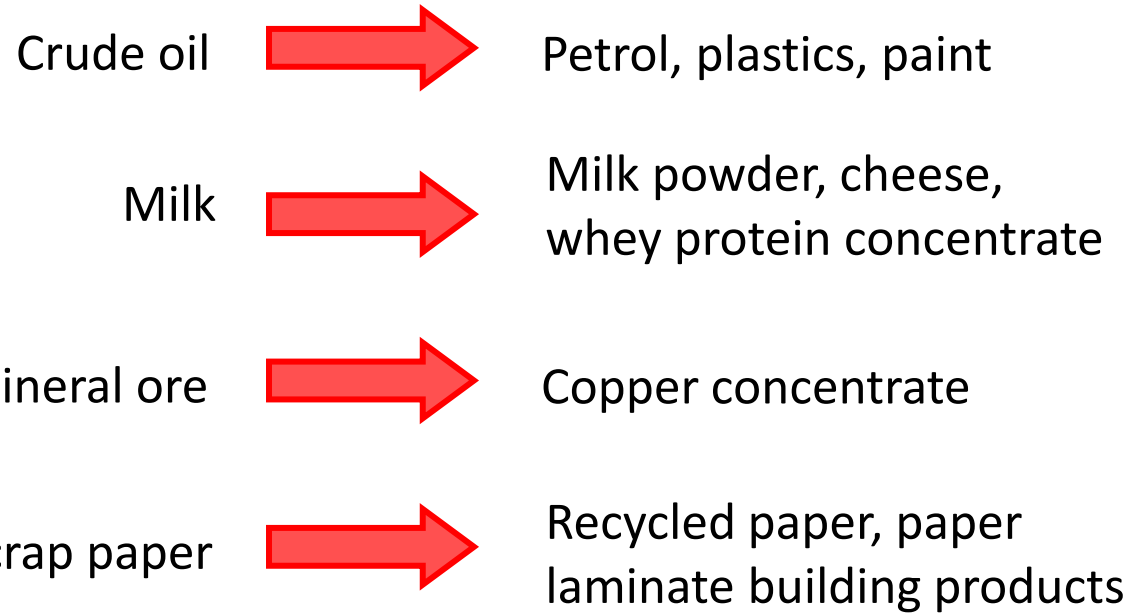
Note that ***content*** questions should go on the Discussion Board

## In this subject we will learn about :

- different systems of units of measurement.
- basic chemical engineering flow sheet calculations.
- material balances with and without chemical reactions.
- concepts of energy, enthalpy, heat capacity, latent heat, heats of reaction and adiabatic operation.
- energy balances with and without chemical reactions.
- simultaneous material and energy balances.
- manufacturing processes and process safety.

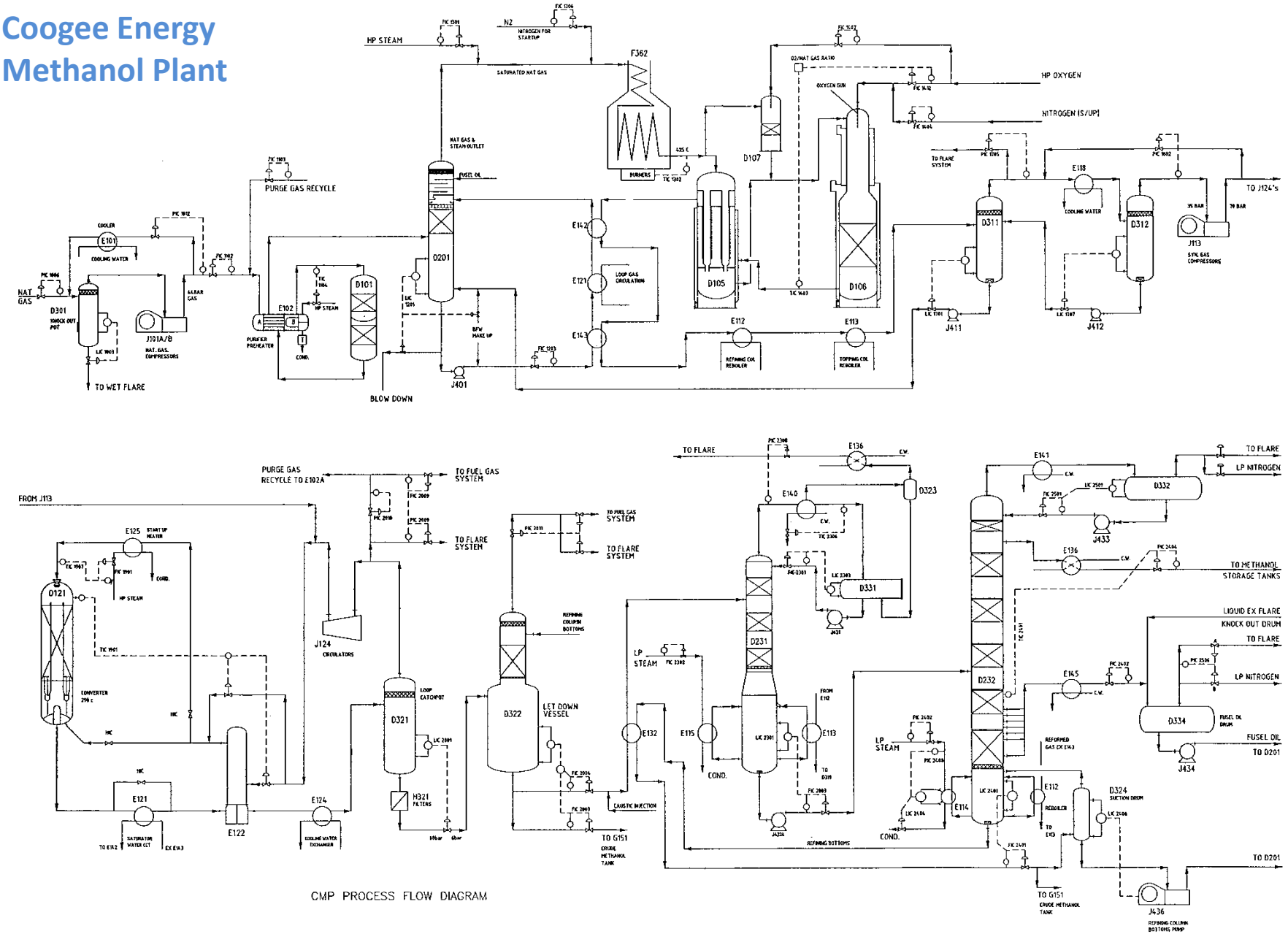
# What is chemical engineering ?

Chemical engineering is the profession in which knowledge of mathematical, chemical and biological sciences, gained by study, experience, and practice, is applied with judgment to develop processes that take one or more raw material and turn them safely and economically into more useful products.



# Coogee Methanol Plant

# Coogee Energy
# Methanol Plant




CMP PROCESS FLOW DIAGRAM

# What do chemical engineers do ?

Chemical engineers take crude oil and turn it into:

- unleaded petrol
- lubricants
- diesel
- aviation gasoline
- paints
- coatings
- plastics
- synthetic materials

# What do chemical engineers do ?

Chemical engineers take raw milk and turn it into:

- homogenised and pasteurised milk
- low-fat milk
- cream
- butter
- cheese (all types, e.g., soft and hard)
- yoghurt
- whey protein concentrate
- skim milk powder
- skim milk concentrate

# What do chemical engineers do ?

Chemical engineers work in the following industries:

- petrochemical
- food and beverage
- minerals
- pulp and paper
- pharmaceutical
- utilities
- oil and gas
- banking
- glass and ceramics
- computer

# Let’s consider milk

We need to process milk so that it is safe to drink.

Consumers also want milk with a defined fat content – e.g., 3.0 % fat.

# The Pasteurization Process

This process kills most of the microorganisms that otherwise might make us sick.

The microorganisms are killed by heating the milk to about 72$^{o}$C for 15 to 20 seconds.

The chemical engineering challenge is to ensure that this is done correctly.

Not hot enough – the bugs don't die.

Too hot – the bugs die but the milk tastes off.

Hot, but not for long enough – the bugs don't die.

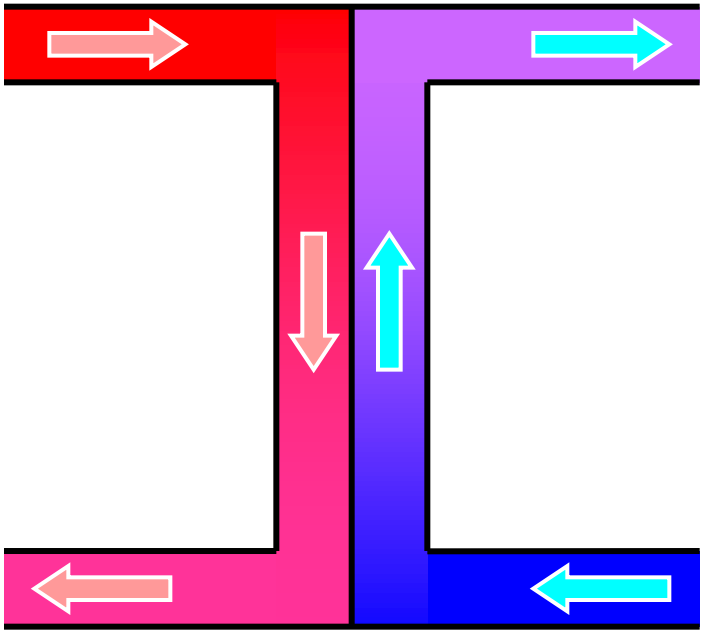
Hot, but for too long – the milk tastes off.

**How can we ensure that the microorganisms are killed but that the milk doesn't taste revolting?**

A heat exchanger is used to transfer heat from the hot stream to the cold stream.

The hot stream cools and the cold stream heats.

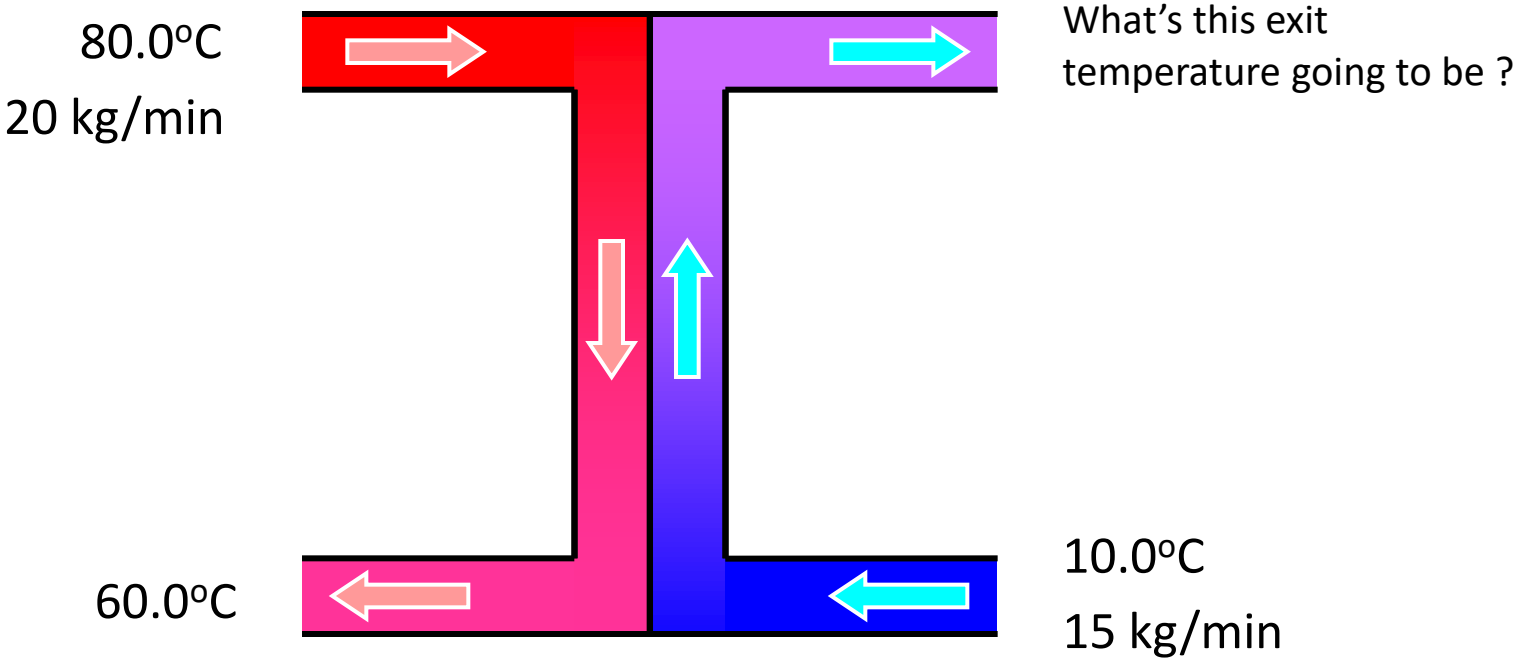
But by how much ?



The exit temperatures of the hot and cold streams will depend on a number of factors:

- flow rate of the cold stream
- flow rate of the hot stream
- inlet temperature of the cold stream
- inlet temperature of the hot stream
- design of the heat exchanger.

A heat exchanger is used to transfer heat from the hot stream to the cold stream.

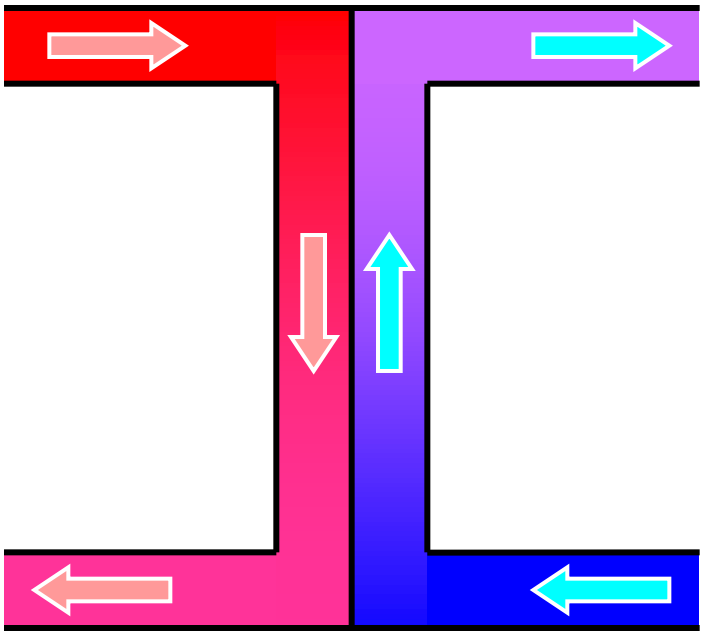



$$\begin{pmatrix}\text{Energy lost}\\ \text{by hot stream}\end{pmatrix} = \begin{pmatrix}\text{Energy gained}\\ \text{by cold stream}\end{pmatrix}$$

Every 1 kilogram of water gives up 4.2 kJ of energy for every 1°C drop in temperature.

Every 1 kilogram of milk gains 3.8 kJ of energy for every 1°C increase in temperature.

A heat exchanger is used to transfer heat from the hot stream to the cold stream.

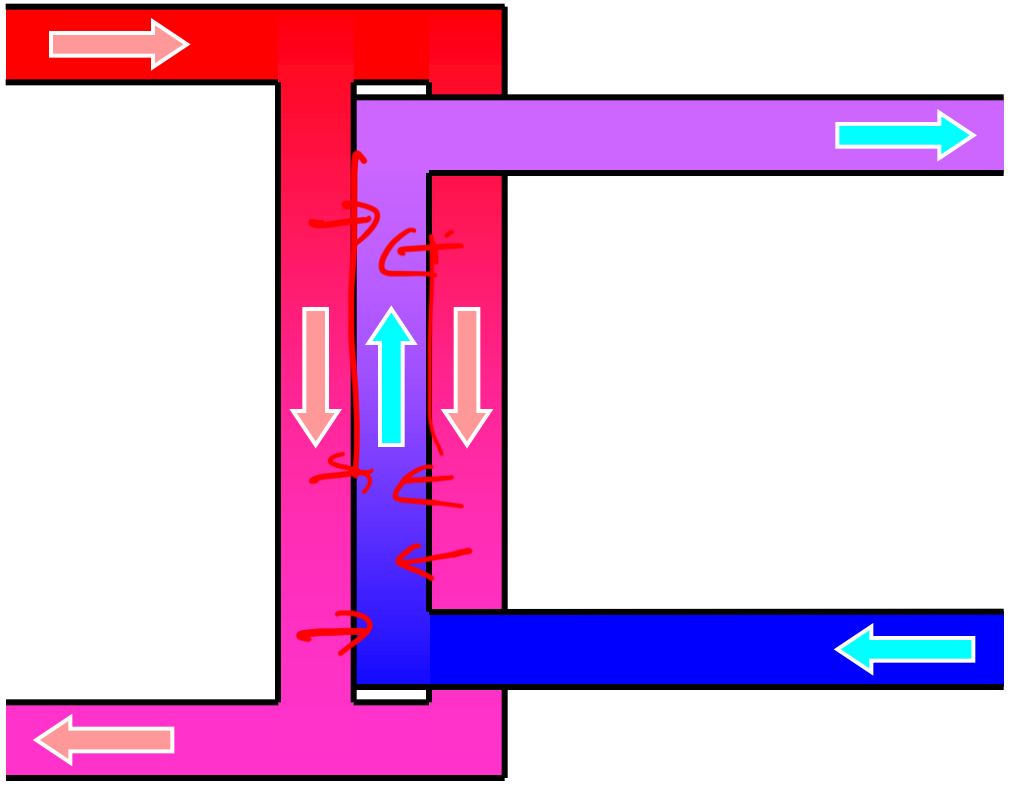



$$\begin{pmatrix}\text{Energy lost}\\ \text{by hot stream}\end{pmatrix} = \begin{pmatrix}\text{Energy gained}\\ \text{by cold stream}\end{pmatrix}$$

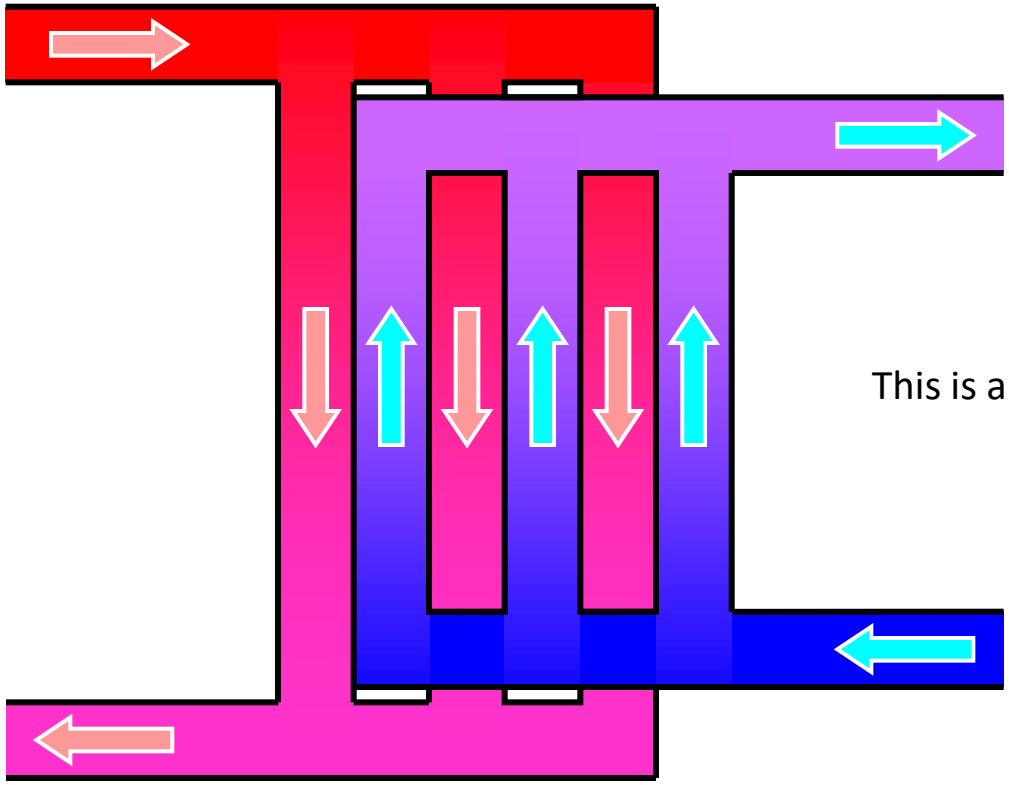
Every 1 kilogram of water gives up 4.2 kJ of energy for every 1°C drop in temperature.

Every 1 kilogram of milk gains 3.8 kJ of energy for every 1°C increase in temperature.

A heat exchanger is used to transfer heat from the hot stream to the cold stream.

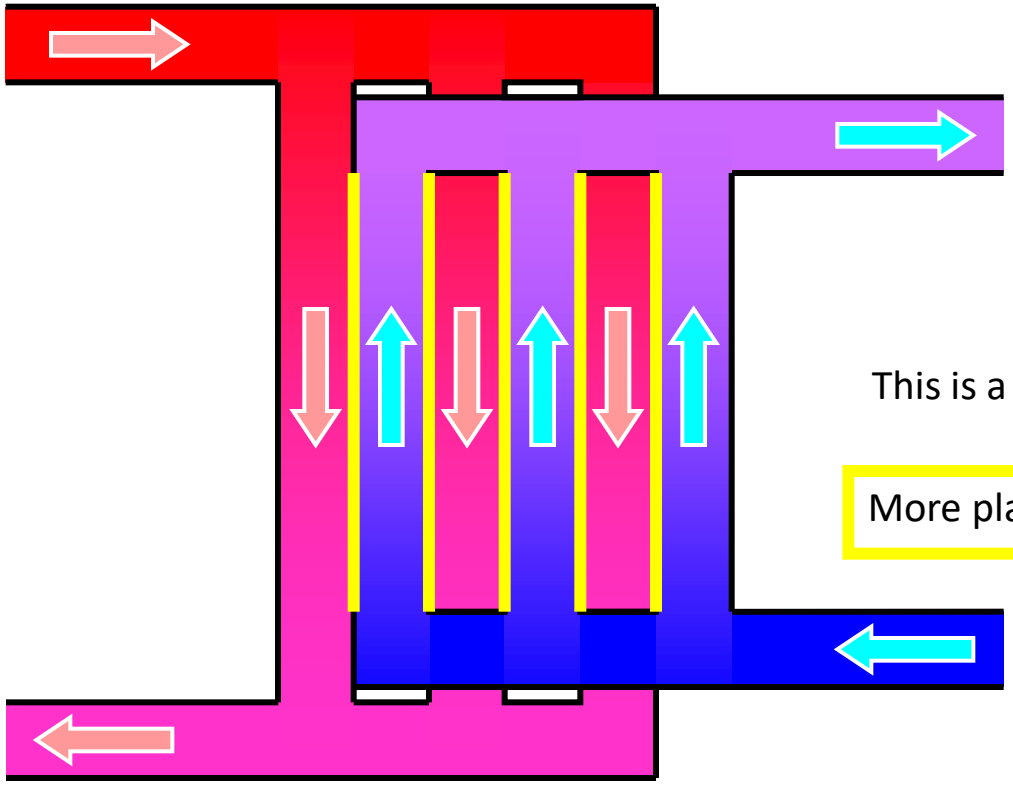


A heat exchanger is used to transfer heat from the hot stream to the cold stream.



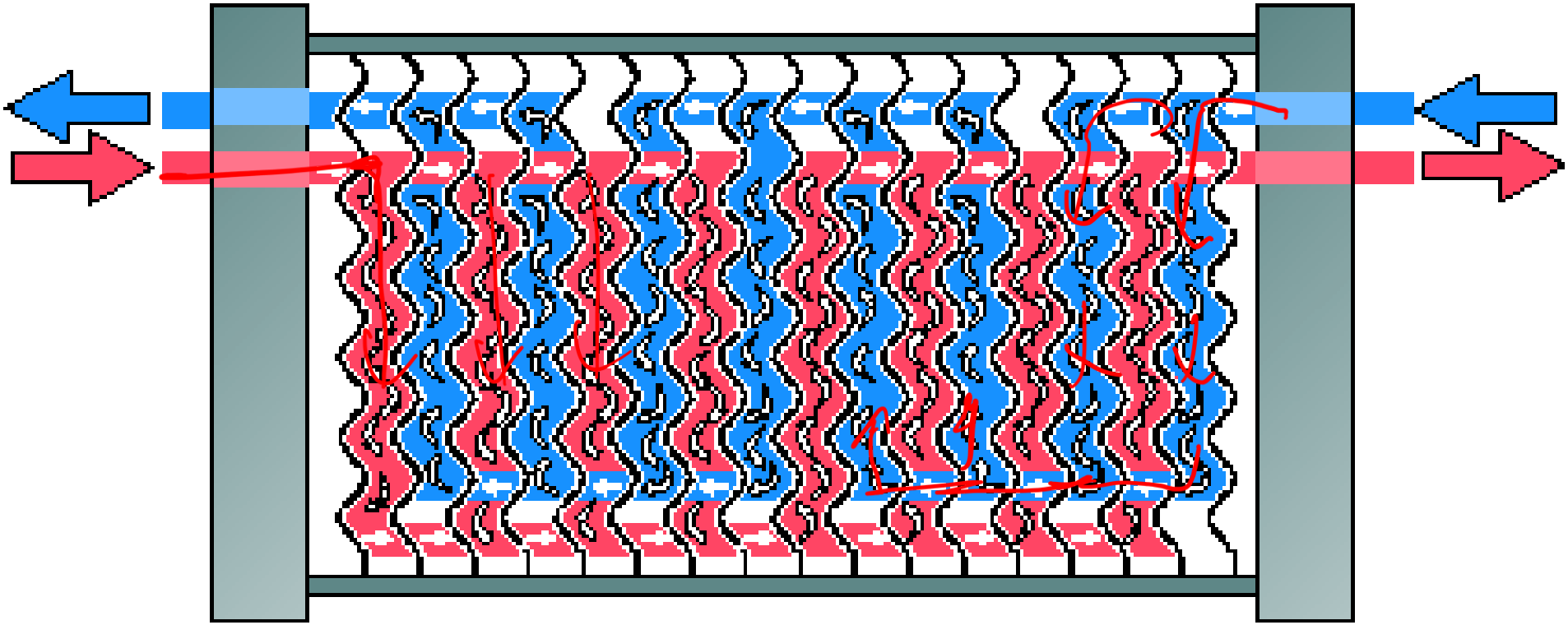
This is a plate heat exchanger.

A heat exchanger is used to transfer heat from the hot stream to the cold stream.



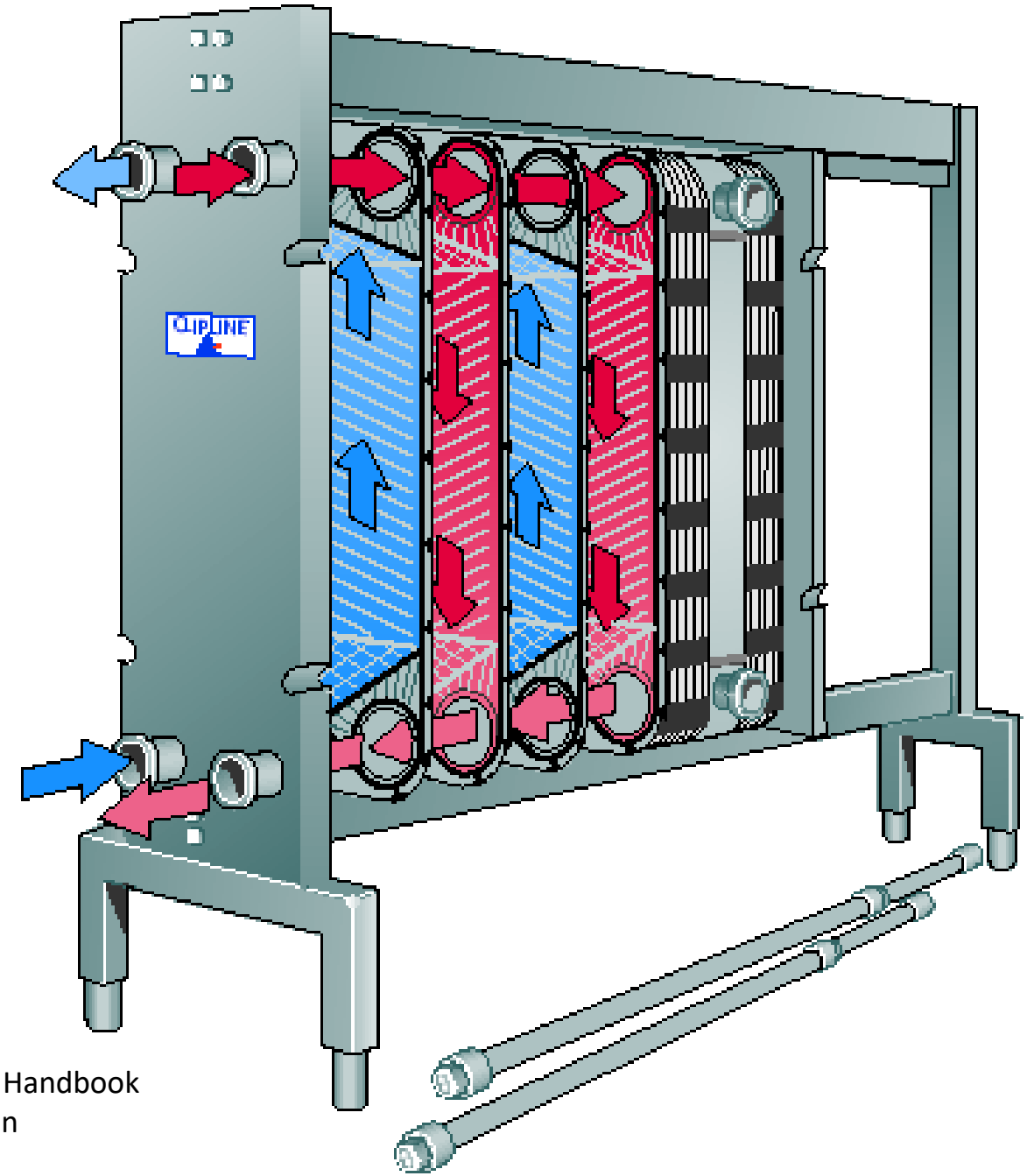
This is a plate heat exchanger.

More plates increases the heat transfer area.

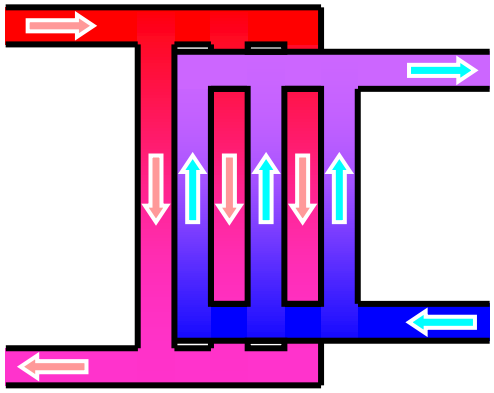


Dairy Processing Handbook
Tetra Pak, Sweden

A plate heat exchanger consists of a stack of thin corrugated plates pressed together to form a series of flow channels for the liquids to pass through.  Heat is exchanged between the two fluids across the plates (heat transfer area).




Dairy Processing Handbook
Tetra Pak, Sweden



The chemical engineer has to address some important design questions:

How many plates will the heat exchanger need?

How big will each plate need to be?

How thick should the plates be?

How far apart should be plates be?

What material should the plates be made of?

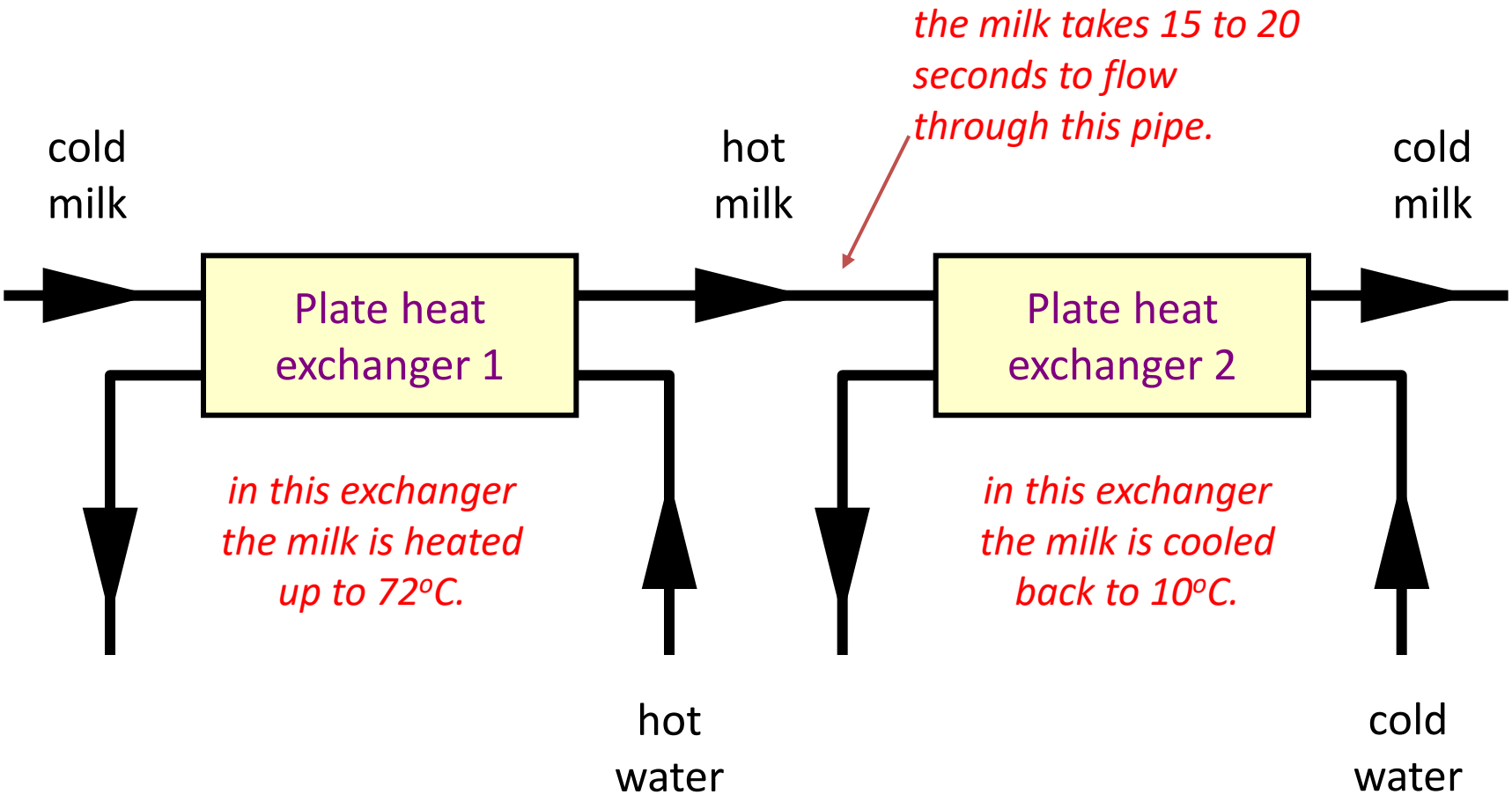
How should the heat exchanger be cleaned and how often?

What happens if the exchanger fails and water leaks into the milk?

What happens if the supply of hot water fails?

What happens if the temperature of the hot water drops?

How can we be sure that the maximum temperature of the milk reaches the desired value?

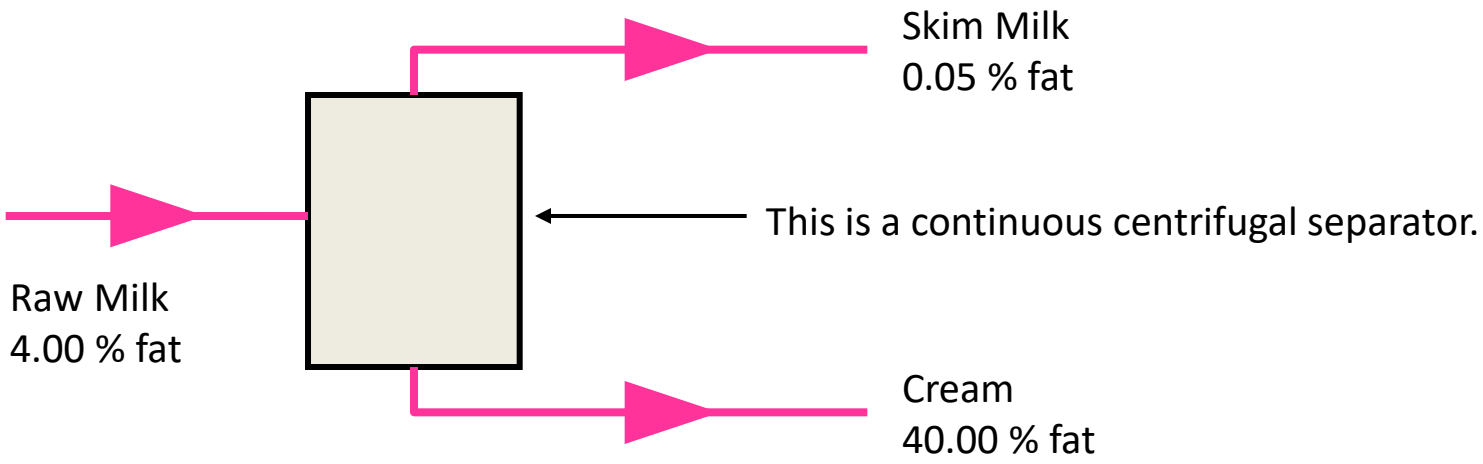

cold milk
hot milk
cold milk
the milk takes 15 to 20 seconds to flow through this pipe.
Plate heat exchanger 1
Plate heat exchanger 2
in this exchanger the milk is heated up to 72°C.
in this exchanger the milk is cooled back to 10°C.
hot water
cold water

# The Standardization Process

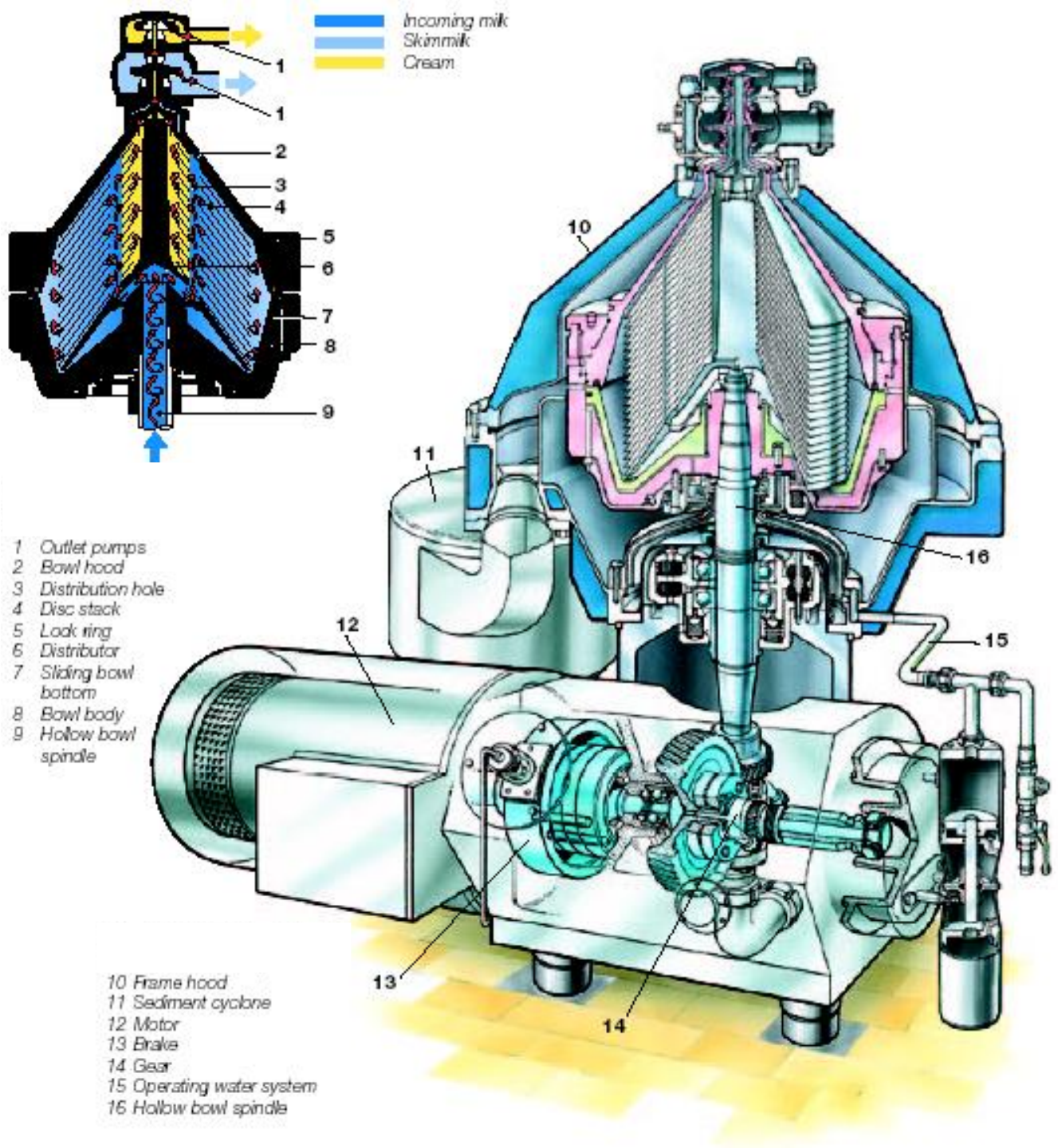
This process ensures that the processed milk has a constant fat content no matter what the actual fat content of the raw milk is.

Let's suppose that we want to produce a milk with a fat content of 3.00 %.

We will use a separator to remove nearly all the fat content from the milk.

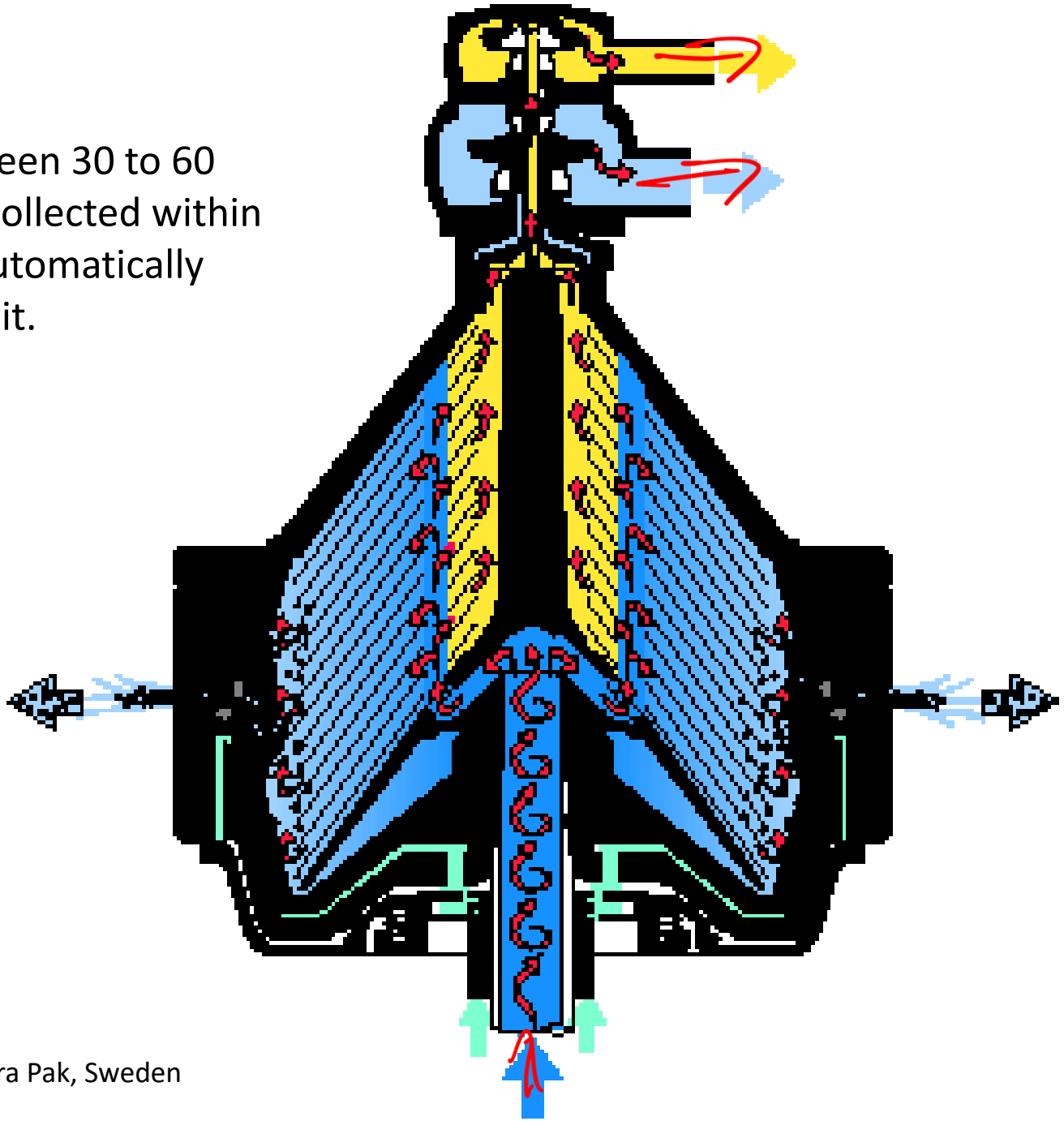


Continuous centrifugal separator  are used to separate cream, skim milk and solid particles.




Dairy Processing Handbook
Tetra Pak, Sweden

At intervals of between 30 to 60 minutes the solids collected within the separator are automatically ejected from the unit.



Dairy Processing Handbook Tetra Pak, Sweden

Separation is achieved by exploiting the differing properties possessed by the components to be separated.

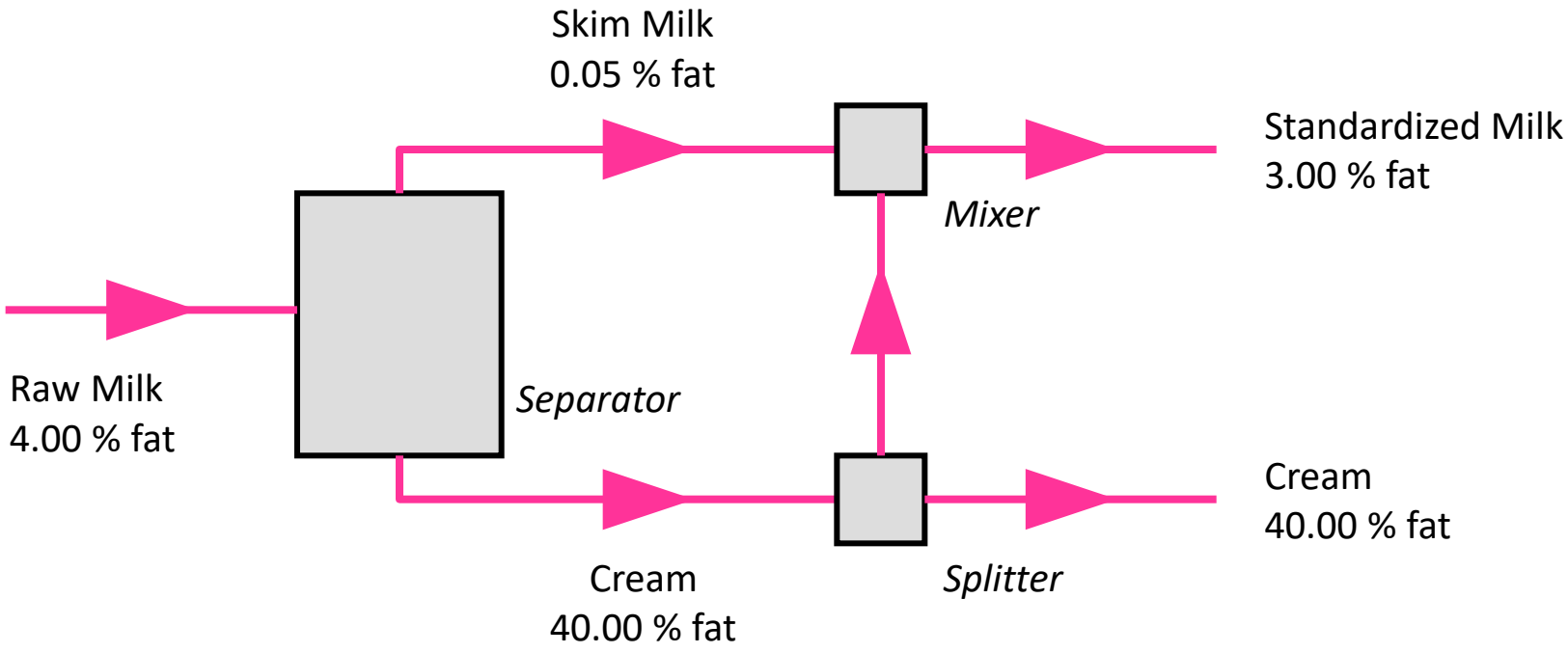
This separator works because the skim milk and the fat have different densities.

# The Standardization Process

This process ensures that the processed milk has a constant fat content no matter what the actual fat content of the raw milk is.

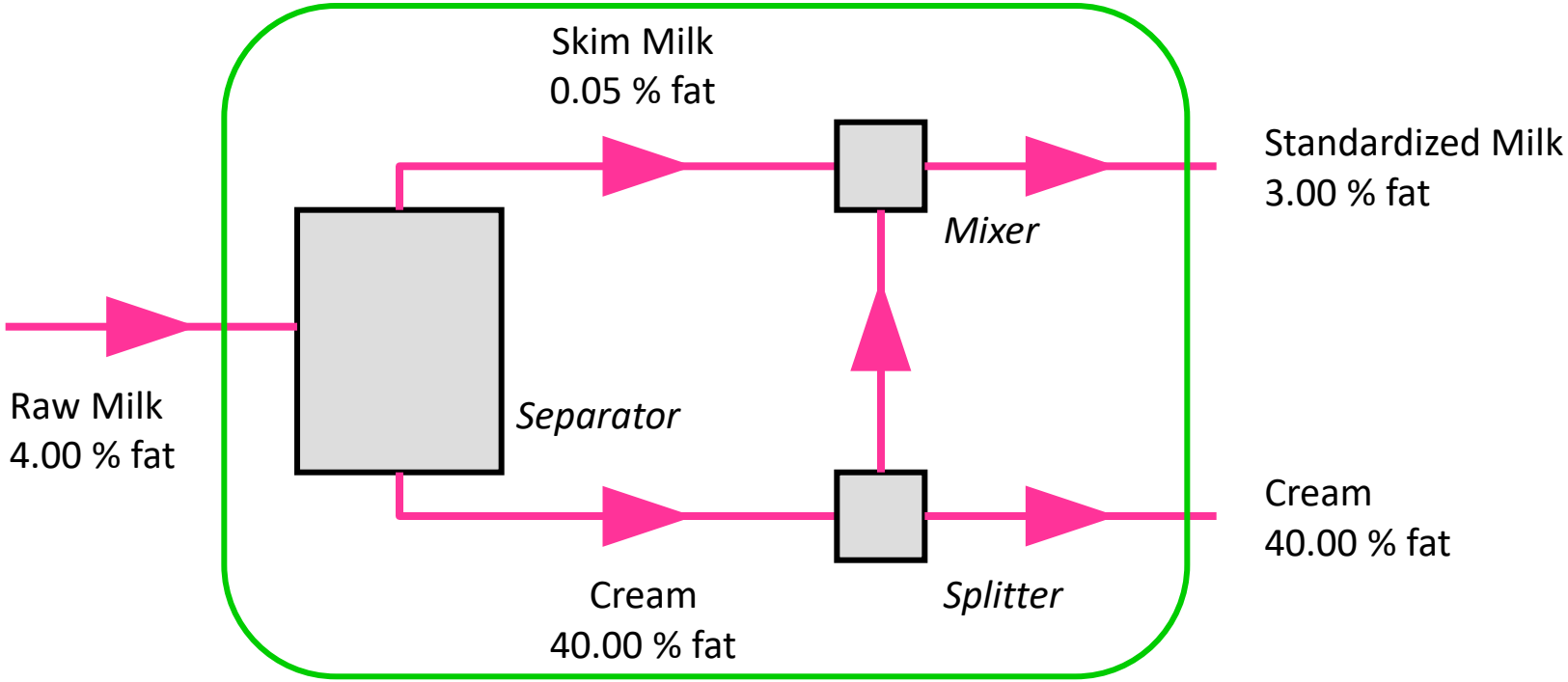
Let's suppose that we want to produce a milk with a fat content of 3.00 %.

But we want milk with a fat content of 3.00 % not 0.05 % or 40 % !!



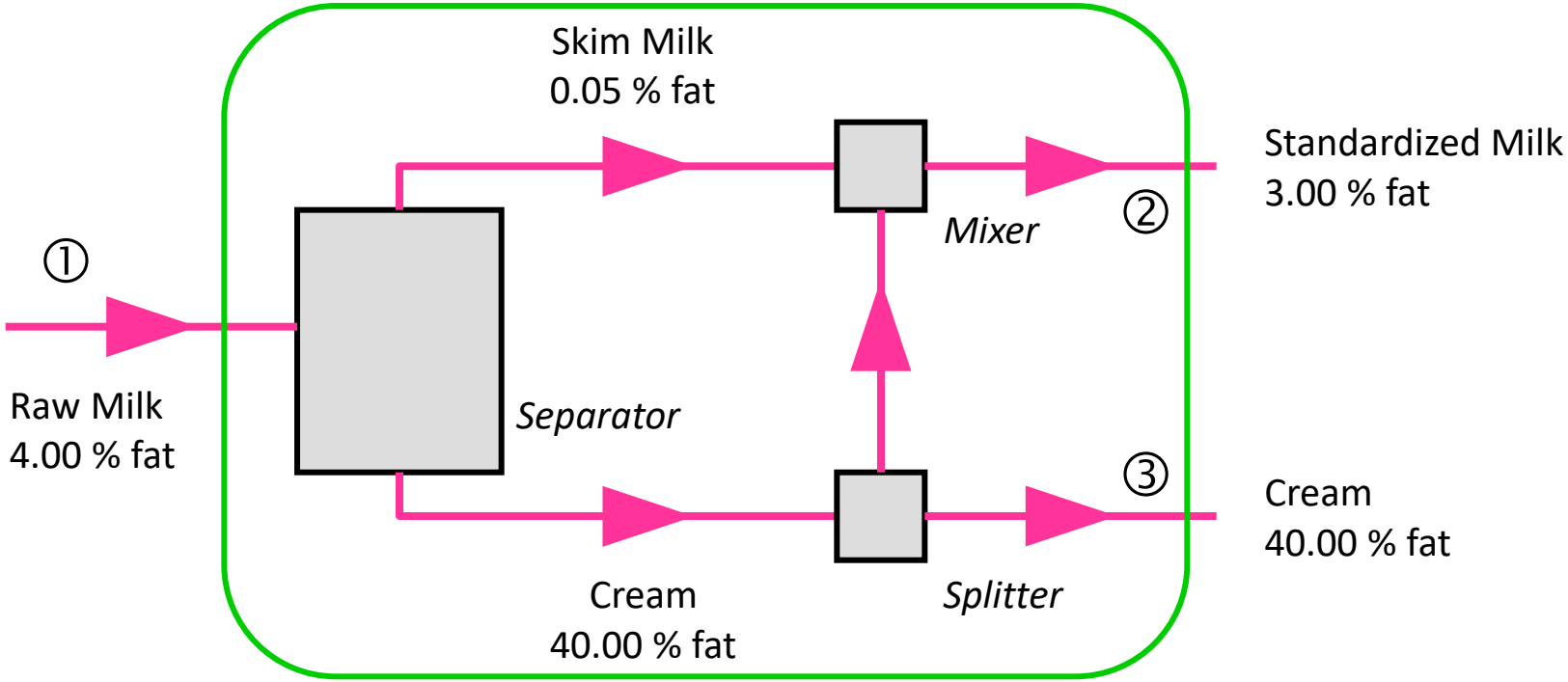
# The Standardization Process

How much standardized milk will we get for every 100 kg of raw milk processed?



# The Standardization Process

How much standardized milk will we get for every 100 kg of raw milk processed?

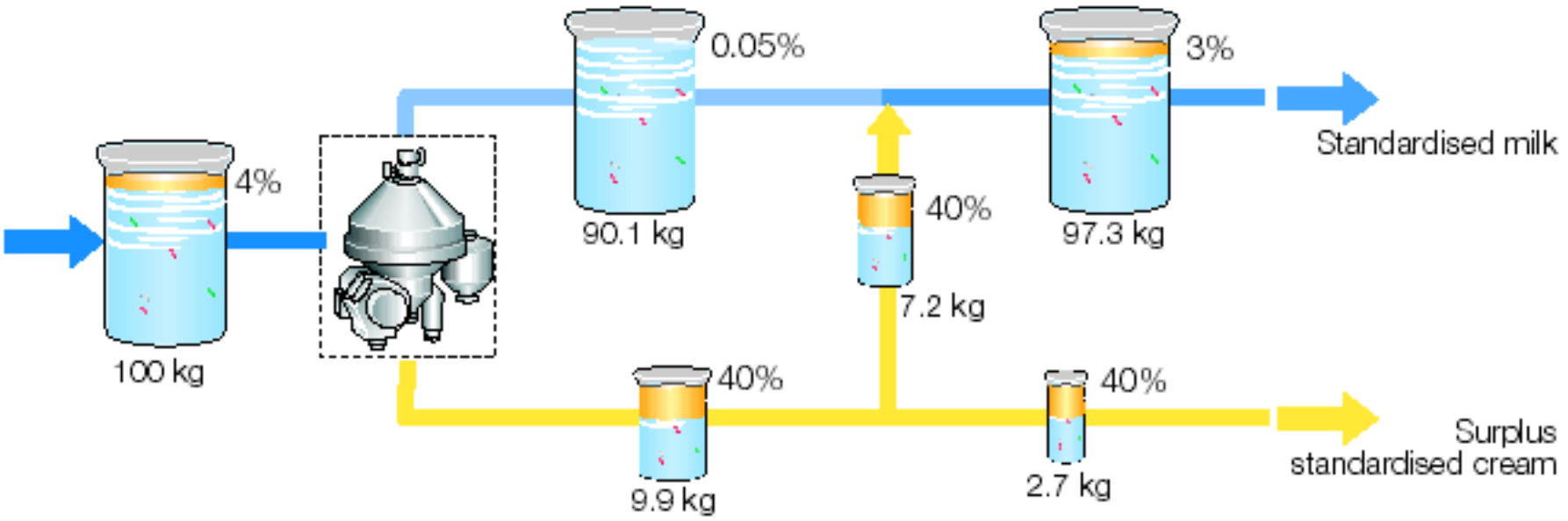


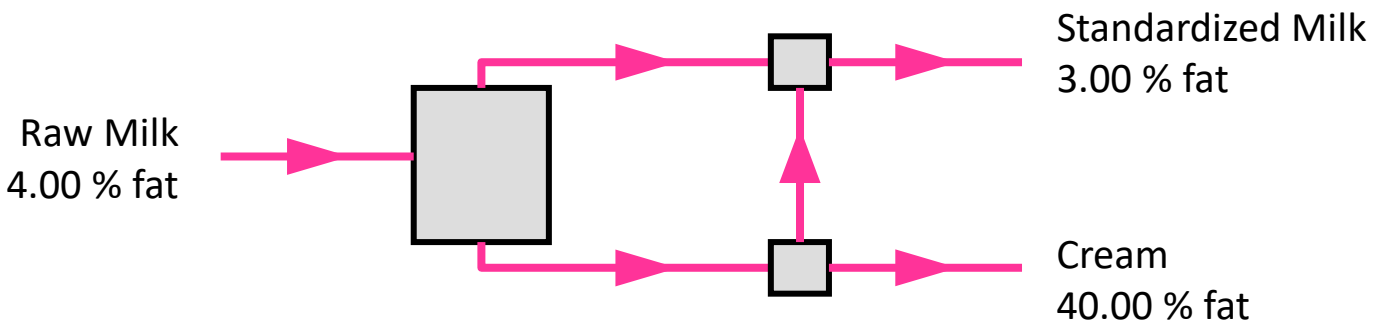

$$(\text{total mass entering}) = (\text{total mass leaving}) \qquad F_1 = F_2 + F_3$$

$$(\text{mass of fat entering}) = (\text{mass of fat leaving}) \qquad 0.04\,F_1 = 0.03\,F_2 + 0.40\,F_3$$

But we know that $F_1 = 100.0$ kg  So, $F_2 = 97.3$ kg  and  $F_3 = 2.7$ kg

# The Standardization Process






The chemical engineer has to address some important design questions:

What should the diameters of the connecting pipes be?

Should they be all of the same diameter?

How should the splitter and mixer be designed?

What material should the pipes be made of?

What type of weld should be used to join the pipe segments together?

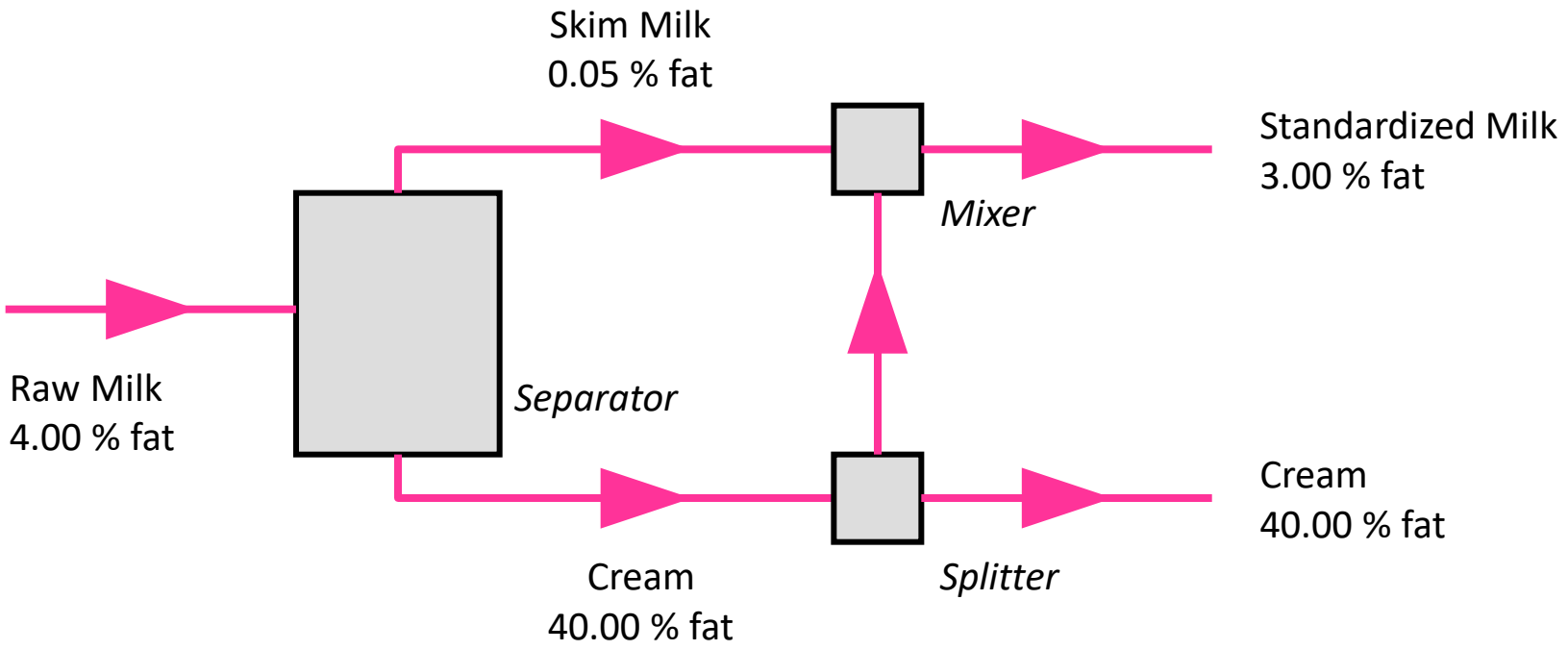
How should be the equipment be cleaned and how often?

What happens if the fat content of the raw milk decreases (or increases)?

What happens if the the fat content of the product needs to be changed to 2.00 %?

How is the fat content of the standardized milk controlled?

# Block Flow Diagrams




Equipment such as distillation columns, heat exchangers, pumps, compressors, mixers, splitters and chemical reactors are represented by blocks. Groups of equipment may also be represented by blocks.

The arrowed lines represent streams – anything that flows in a pipe, duct or channel or on a conveyor belt.

# Lectures

There will be 3 on-campus lectures every week.  Each lecture will be recorded.

These lectures have been optimised for in-person attendance.  Students who only watch on-line will not get the full educational experience and may be disadvantaged.  Technology sometimes fails and lectures might not be recorded.

# Tutorial/Workshops

In-person tutorial/workshops will run throughout the semester, starting in Week 2.

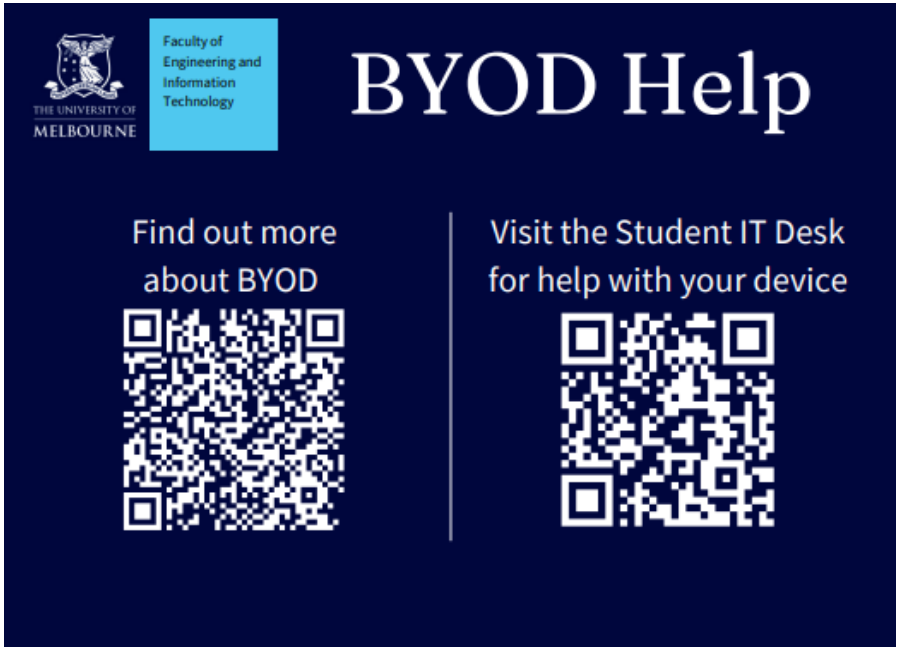
Attendance is not compulsory except in oral presentation weeks. You are **strongly encouraged to attend** the sessions.

The aim educational aim of these sessions is to provide additional support to students who might need it.

These sessions are an opportunity to engage about any topic related to the subject.

Help will be available in these sessions, particularly with MATLAB.

# Tutorial/Workshops: Bring Your Own Device




# Exercise Sheets

Each Module has an exercise sheet that covers the topics from the Module.

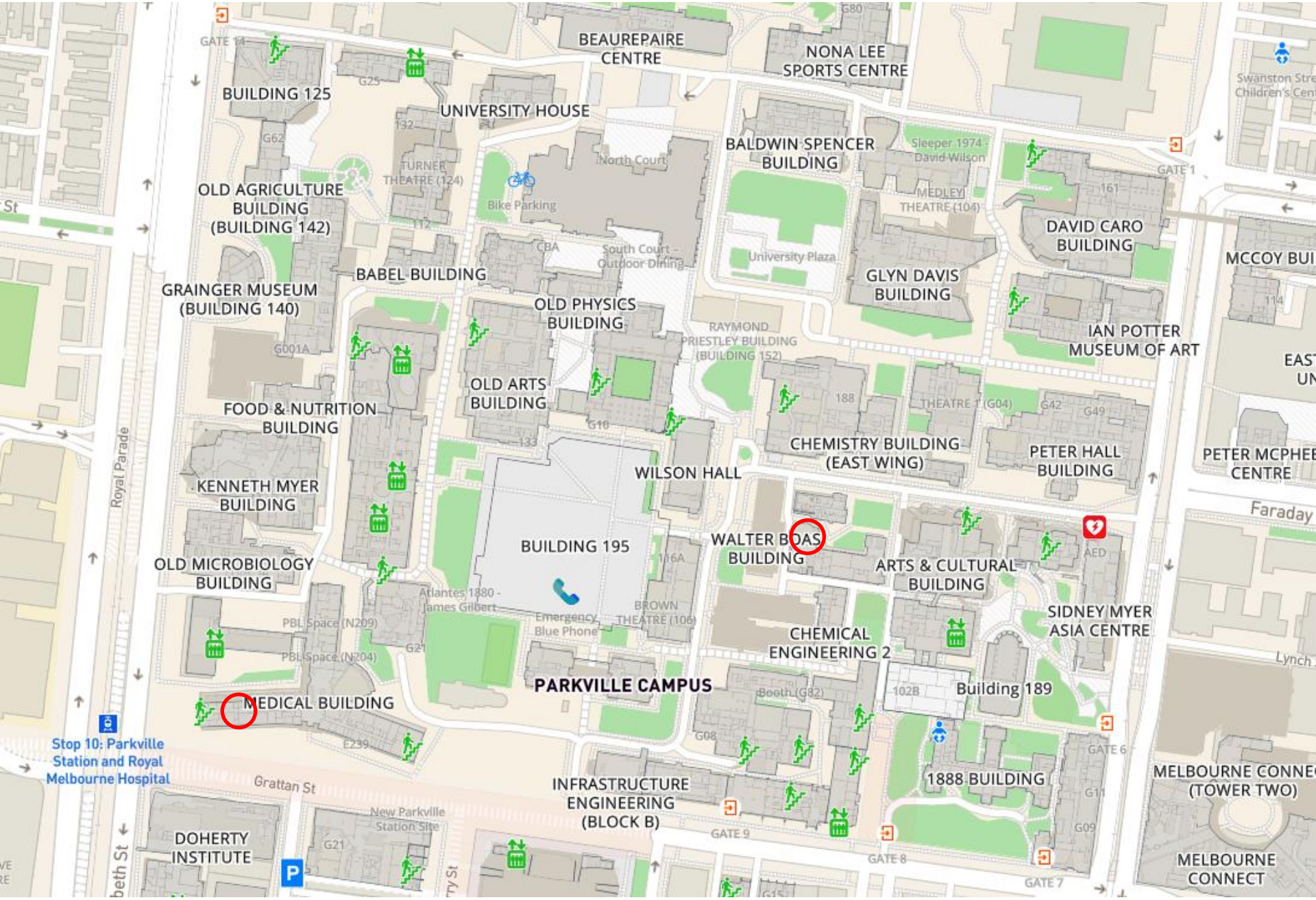
- Numerical answers available at the same time so you can check if you have the correct answer

Solutions will be made available at the end of the week.

- Full written worked solutions
- Video solutions of many problems

# Timetable – Lectures

| | Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|---|
| 8:00 | | | | | |
| 9:00 | | | | | |
| 10:00 | | | Lecture | | |
| 11:00 | | | | | |
| 12:00 | Lecture | | | | |
| 13:00 | Lecture | | | | |
| 14:00 | | | | | |
| 15:00 | | | | | |
| 16:00 | | | | | |
| 17:00 | | | | | |


BEAUREPAIRE CENTRE
NONA LEE SPORTS CENTRE
BUILDING 125
UNIVERSITY HOUSE
BALDWIN SPENCER BUILDING
OLD AGRICULTURE BUILDING (BUILDING 142)
TURNER THEATRE (124)
North Court
Bike Parking
MEDLEY THEATRE (104)
DAVID CARO BUILDING
BABEL BUILDING
CBA
South Court - Outdoor Dining
University Plaza
GLYN DAVIS BUILDING
GRAINGER MUSEUM (BUILDING 140)
OLD PHYSICS BUILDING
RAYMOND PRIESTLEY BUILDING (BUILDING 152)
IAN POTTER MUSEUM OF ART
OLD ARTS BUILDING
FOOD & NUTRITION BUILDING
THEATRE 1 (G04)
CHEMISTRY BUILDING (EAST WING)
PETER HALL BUILDING
WILSON HALL
KENNETH MYER BUILDING
Royal Parade
BUILDING 195
WALTER BOAS BUILDING
ARTS & CULTURAL BUILDING
AED
OLD MICROBIOLOGY BUILDING
Atlantes 1880 - James Gilbert
Emergency Blue Phone
BROWN THEATRE (106)
PBL Space (N209)
PBL Space (N204)
SIDNEY MYER ASIA CENTRE
CHEMICAL ENGINEERING 2
PARKVILLE CAMPUS
MEDICAL BUILDING
Booth (G82)
Building 189
Stop 10: Parkville Station and Royal Melbourne Hospital
Grattan St
INFRASTRUCTURE ENGINEERING (BLOCK B)
1888 BUILDING
New Parkville Station Site
DOHERTY INSTITUTE
GATE 9
GATE 8
GATE 7
GATE 6
MELBOURNE CONNECT (TOWER TWO)
MELBOURNE CONNECT
Faraday
PETER MCPHEE CENTRE

# Timetable – Tutorials

| | Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|---|
| 8:00 | | | | | |
| 9:00 | Tutorial Workshop | | | | |
| 10:00 | | | Lecture | | |
| 11:00 | | Week 2: replacement Tutorial Workshop | | | |
| 12:00 | Lecture | | | | |
| 13:00 | Lecture | Week 2: replacement Tutorial Workshop | Tutorial Workshop | | |
| 14:00 | | | | | |
| 15:00 | Tutorial Workshop | | | Tutorial Workshop | |
| 16:00 | | | | | |
| 17:00 | | | | | |

# Assessment

| | | |
|---|---|---|
| 1) Oral presentation | Released : 14 March<br>Presentations : 31 March to 10 April | 10 % |
| 2) MATLAB Assignment 1 | Released : 31 March<br>Due : 14 April | 10 % |
| 3) Laboratory 1 | Classes : 7 April to 19 April<br>Due : 14 days after lab class | 10 % |
| 4) MATLAB Assignment 2 | Released : 5 May<br>Due : 26 May | 10 % |
| 5) Laboratory 2 | Classes : 5 May to 9 May<br>Due : 14 days after lab class | 10 % |
| 6) 2-hour exam* | End-of-semester exam period | 50 % |

You must pass the exam to pass the subject.

# MATLAB

MATLAB is an incredibly useful tool that has many uses for chemical engineers. Throughout this subject you will be provided with a range of exercises that are designed to both develop your skills in solving material and energy balances, but also to develop your skills in using MATLAB.

MATLAB is available for students to download and install on their own computers. Please ensure that MATLAB is installed prior to the end of Week 1.

Full instructions for installing MATLAB on both Windows and Mac are available at: https://studentit.unimelb.edu.au/software

**There will be two MATLAB assignments to be completed during the semester.**

# MATLAB

## Software for students

Search for software...

### Downloadable software

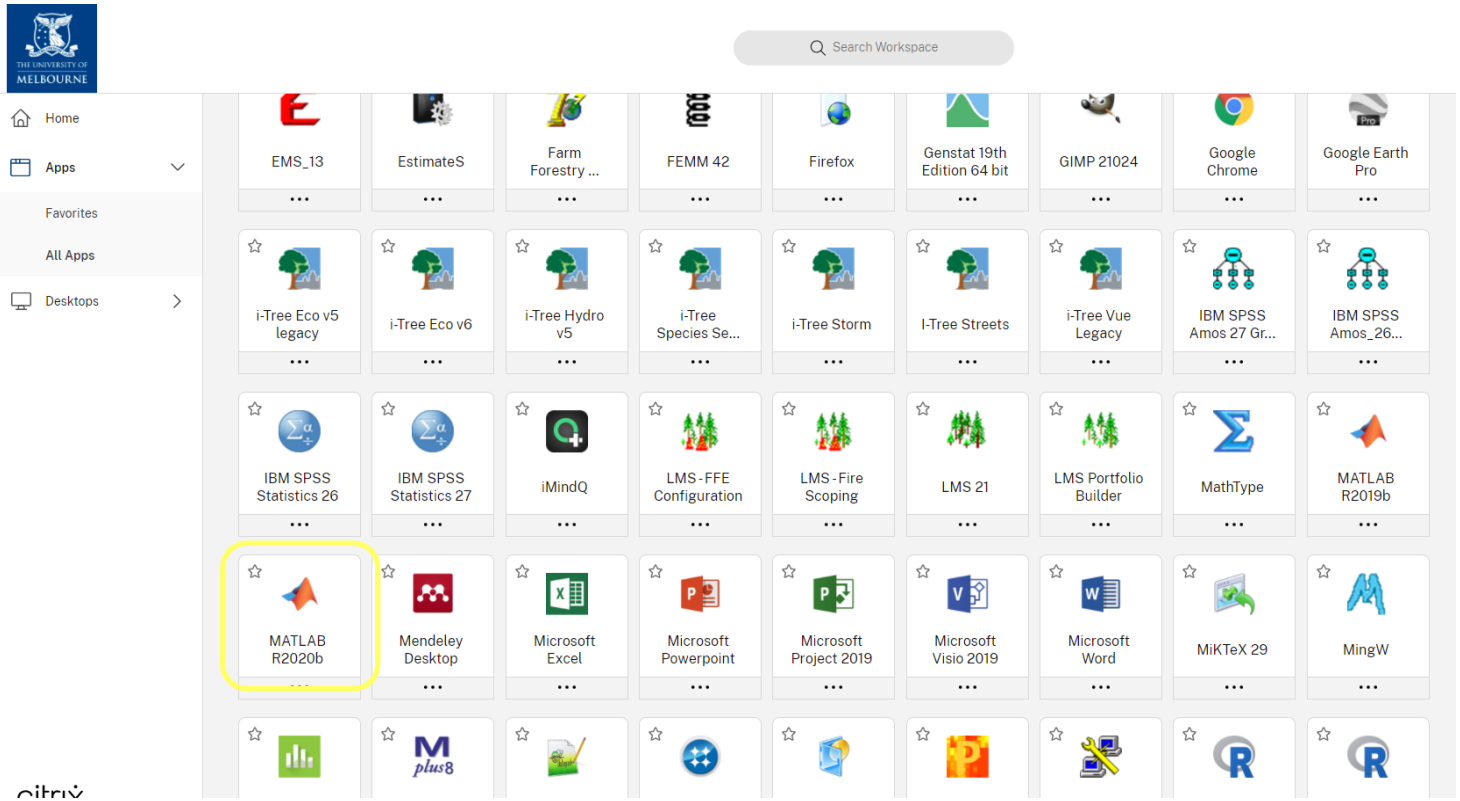
This software is available to install on your personal device. This is a comprehensive list of all software offered by The University of Melbourne.

Click on the tiles for further information on how to obtain/download it.

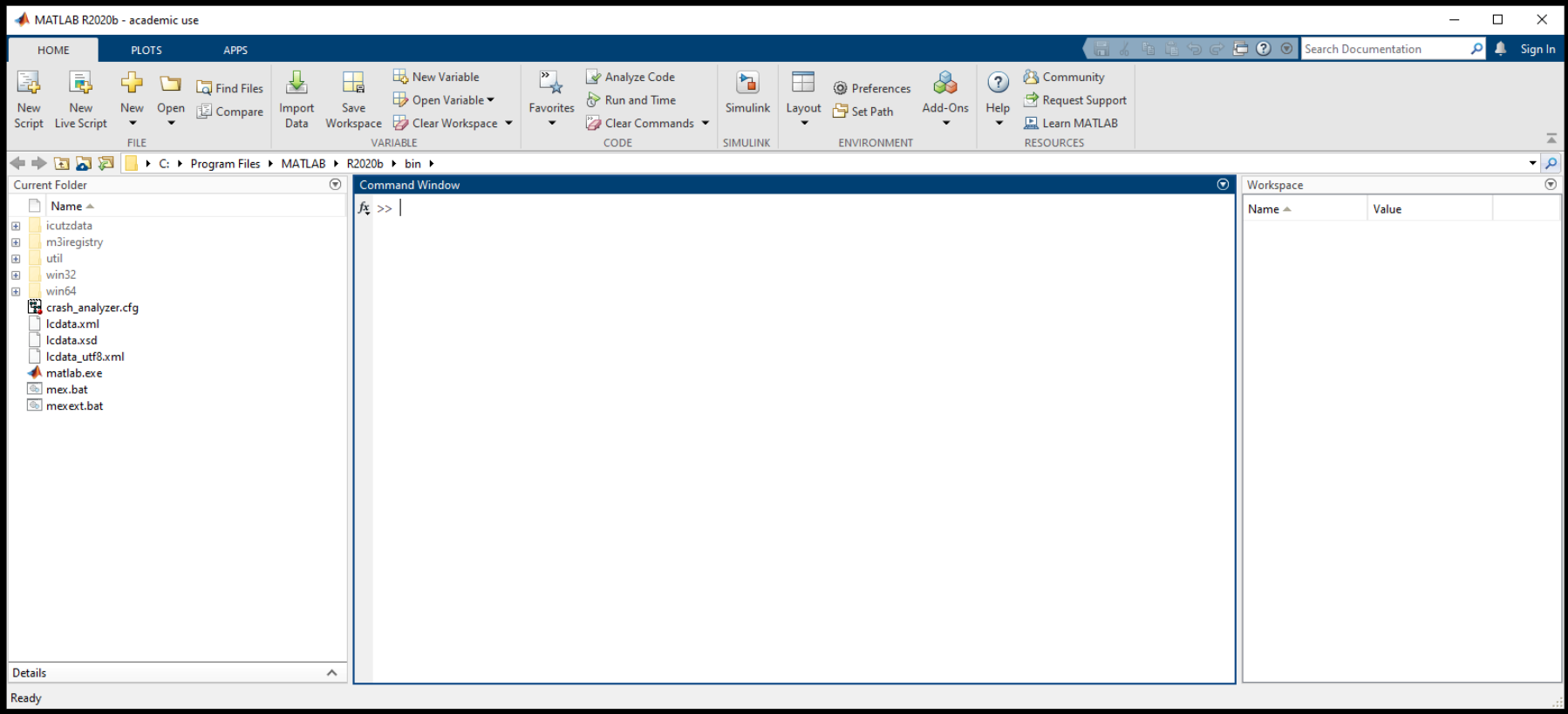
| | | | |
|---|---|---|---|
| **Adobe Creative Cloud** Graphic design and video editing software by Adobe | **AutoDesk suite** AutoCAD, 3DS Max, Revit, Maya and more | **ArcGIS** Geographic Information System by ESRI | **AspenONE** Engineering software suite |
| **EndNote X9** Reference management software | **Genstat** Statistical program for data analysis. | **Google Workspace** Online collaborative productivity suite | **LabVIEW** System Design Platform by National Instruments |
| **LastPass** Secure Password Manager | **Lean Library** E-Library resource access browser plugin | **LTSpice** Circuit (SPICE) Simulation Software | **MATLAB** Programming environment for scientists and engineers |
| **Mendeley** Reference management software | **Microsoft Project Professional** for Windows | **Microsoft Access** (v. 2016) for Windows | **Microsoft Visio Professional** (v. 2016 & 2019) for Windows |
| **Visual Studio** Code, Community & Enterprise (v. 2019) | **Microsoft Office 365** Word, Excel, PowerPoint, Outlook and more | **Minitab** Statistical analysis software | **Citrix Workspace** Access myUniApps natively |
| **NVivo** | **R and R Studio** | **SAS** | **UniMelb VPN** |

# MATLAB

Installing the software on your own computer is recommended; however, you can also run MATLAB remotely through myUniApps. If you do this, it is important that you save your all your working files (scripts, figures etc.) to your local computer hard drive so that you don't accidentally lose them.



# MATLAB


MATLAB R2020b - academic use
HOME
PLOTS
APPS
Search Documentation
Sign In
New Script
New Live Script
New
Open
Find Files
Compare
FILE
Import Data
Save Workspace
New Variable
Open Variable
Clear Workspace
VARIABLE
Favorites
Analyze Code
Run and Time
Clear Commands
CODE
Simulink
SIMULINK
Layout
Preferences
Set Path
Add-Ons
ENVIRONMENT
Help
Community
Request Support
Learn MATLAB
RESOURCES
C: ▸ Program Files ▸ MATLAB ▸ R2020b ▸ bin ▸
Current Folder
Name
icutzdata
m3iregistry
util
win32
win64
crash_analyzer.cfg
lcdata.xml
lcdata.xsd
lcdata_utf8.xml
matlab.exe
mex.bat
mexext.bat
Details
Command Window
>>
Workspace
Name
Value
Ready

# Oral Presentations

You will work in a team of 3 or 4 to deliver a 15 to 20 minute presentation on a topic which will be assigned to you.

Topics will generally either discuss a safety incident or the manufacture of some product.

You will be required to prepare a PowerPoint presentation and then to present to the rest of your workshop group.

The oral presentations will take place during the workshops in Weeks 5 and 6 in your tutorial class.

It is a requirement to pass the oral presentation that you attend your tutorial class in both Weeks 5 and 6.

# Laboratory Classes

All students will be required to complete 2 laboratory classes – one in April and one in May. You should have been allocated to a class via your Timetable.

In-person attendance is required of all students for both classes. Students must attend a class to gain a mark in the laboratory assignment.

Students who miss a lab session due to illness will have their lab class rescheduled. Please apply for Special Consideration to do so.

Safety is of paramount importance in the laboratory. You will receive a full safety briefing before the laboratory classes.

All students must complete the on-line **FEIT HSW Student Induction** including the test.

# Web Site

http://www.lms.unimelb.edu.au

This site is the main resource for this subject. It contains:

PowerPoint slides
Lecture recordings
Exercise sheets and solutions
Laboratory Information
MATLAB information
Additional material

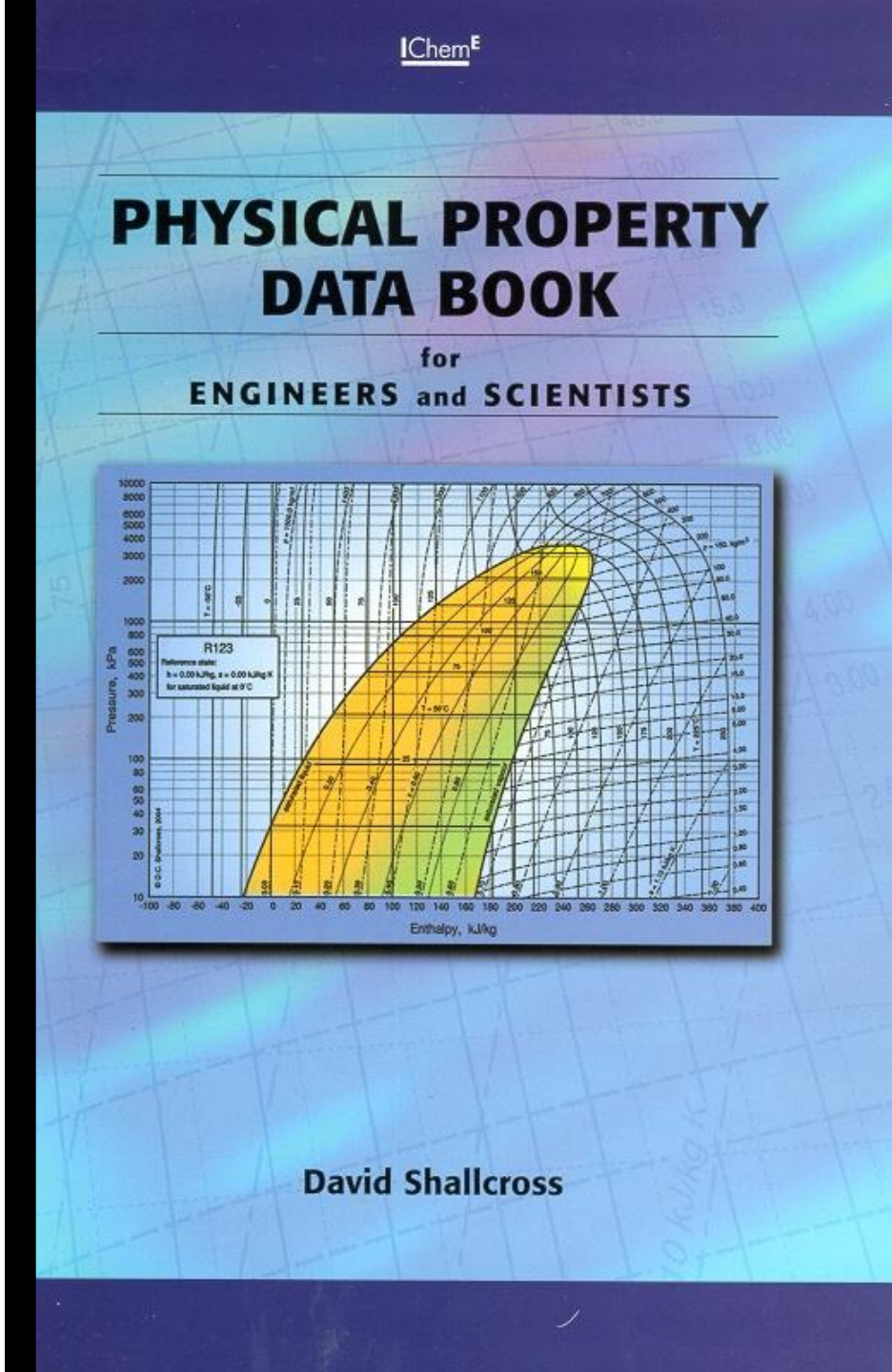
# Course Notes

Lecture slides will be made available for the subject on the Canvas web page.

# Physical Property Data Book

You should have a copy of this book.

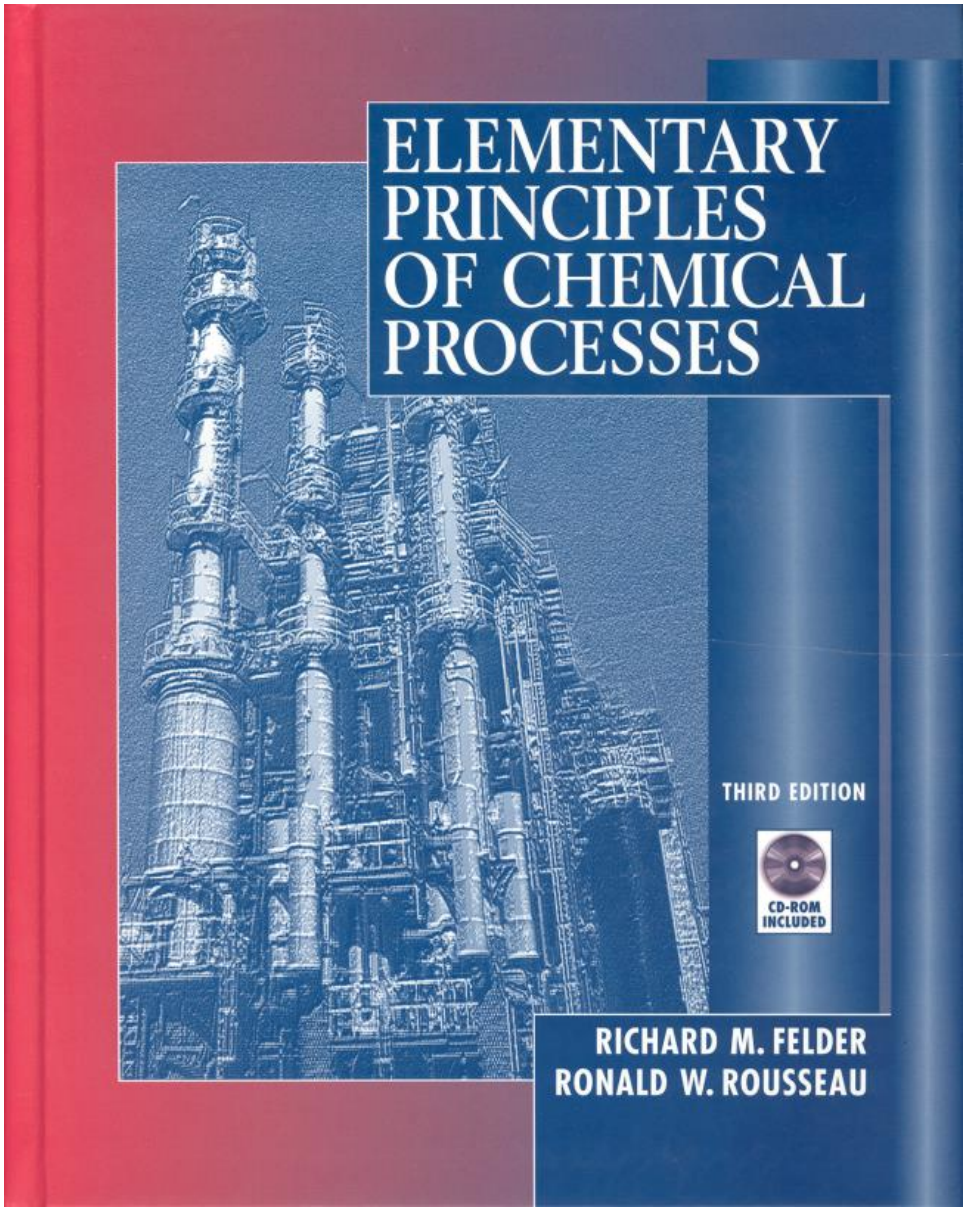
https://icheme.myshopify.com/products/physical-property-data-book-for-engineers-and-scientists?_pos=1&_sid=3051d2858&_ss=r



# Text Books

Felder and Rousseau, “Elemental Principles of Chemical Processes”
(includes CD)

You do not need to have this book but it is still a useful addition to your professional library.



# Safety Shares

Each lecture will start with a safety share – these are not assessable but they may keep you alive.

# E-mails

E-mails may be used to communicate with the class.  Please check your unimelb e-mail accounts regularly.

You will receive at least one e-mail every week for this subject, so please follow these.

# Study Commitments

In order to pass this subject to the best of your abilities you must attend all lectures, complete all exercise sheets and spend on average 5 to 7 hours per week in private study. That's 10 hours of total time commitment every week and 170 hours over the ENTIRE semester. This time could be spent in reviewing lectures, doing the exercise sheets and additional problems and studying for the exam.

The 5 to 7 hours per week of private study should commence in the first week.

# FEIT Extensions and Special Consideration

- Short extensions up to 3 working days
- Extensions between 4 and 10 working days
- Special consideration and extensions of more than 10 working days

- You can also register for ongoing support, such as an Academic Adjustment Plan (AAP)

Please see the LMS page “FEIT Extensions and Special Consideration”

# Use of Formative Artificial Intelligence Systems

There is no valid reason why you would need to make use of generative artificial intelligence systems such as ChatGPT to create any assessment items in this subject.

The use of any formative artificial intelligence system by students in this subject would be considered academic misconduct, and may result in significant penalties.

# Unauthorised Sharing of Subject Material

Under no circumstances may any subject material be shared on the internet on sites such as Chegg, CourseHero or Studoc. This includes slides, notes, exercise sheets, exercise solutions, assignments and other forms of assessment.

Sharing material on websites breaches copyright and the intellectual property rights of the University.

The unauthorised sharing of material may be considered academic misconduct and those students responsible may face significant penalties if found guilty of misconduct.

# Contract Cheating

Contract cheating is getting someone else to do your assignment for you – whether you pay them or not.

Contract cheating is serious academic misconduct and can have serious consequences.

Contract cheating agencies have been known to blackmail students into paying >$10k to not disclose the cheating.

These people do not care about you or your learning – they just want to take your money.

# Keys to Success in this Subject

Keep up with the lectures – do not allow yourself to get behind.

Keep up with the weekly exercise sheets – if you put in 5 to 7 hours a week in working on these sheets you should be fine.

Attend the weekly workshops to ask questions, see what other students are doing and share concerns.

Do not miss the due dates for the lab class reports or the oral presentation.

You cannot hope to pass this subject by simply studying just the week before the exam.

If you don’t understand something then ask for help – send us an e-mail.


THE UNIVERSITY OF

MELBOURNE