24CGP059
Product Design

Semester 2 2024/25 In-Person Exam paper

This examination is to take place in-person at a central University venue under exam conditions. The standard length of time for this paper is **2 hours**.

You will not be able to leave the exam hall for the first 30 or final 15 minutes of your exam. Your invigilator will collect your exam paper when you have finished.

Help during the exam

Invigilators are not able to answer queries about the content of your exam paper. Instead, please make a note of your query in your answer script to be considered during the marking process.

If you feel unwell, please raise your hand so that an invigilator can assist you.

You may use a calculator for this exam. It must comply with the University's Calculator Policy for In-Person exams, in particular that it must not be able to transmit or receive information (e.g. mobile devices and smart watches are **not** allowed).

You **MUST** answer **QUESTION 1** (10 marks) and **TWO** further questions (25 marks each).

Candidates should show full working for all calculations and derivations if required.

This question (Q1) is **COMPULSORY**

1. (a) Describe the technology you try to develop in your research or PDP project in this academic year. Describe a potential chemical, biochemical, bioengineering product with application of this technology. [2 marks]

   (b) The company intends to offer you an opportunity to develop the product you proposed in (a). Describe six key steps you would follow in the new product development process and identify two specific methods or recourses you would consider for each step. [6 marks]

   (c) After completing these six steps, your product has been approved for further manufacturing and market launch. Compare one major difference and one key relationship between chemical product design and chemical process design. [2 marks]

Answer **TWO** further questions

2. A greyscale printing process involves the use of a lithographic ink, comprising:
   - pigment
   - natural oil
   - polymer resin and
   - solvent, methylene chloride, which is carcinogenic and an inhalation hazard.

   The pigment is typically a colloidal carbon; the oil contains fatty acids with multiple double bonds which are cross-linked in the presence of oxygen to make the ink permanent. The solvent and resin affect the ink's rheology. The solvent also removes ink from selected regions of the plate, releasing fumes during the printing process; the same solvent is used to clean the presses, releasing more fumes.

   Various stakeholders have been interviewed to determine their needs for a pollution-free printing process. A summary of their responses is contained in the list (Q2: Needs). You need to provide the needs number when you answer questions.

   (a) Propose an additional stakeholder for the project and provide three more needs for that person. [5 marks]

   (b) Identify any contradictory or redundant needs and organise the needs statements into a structured list, based on the desired functional properties of the chemical product. [10 marks]

   (c) Rephrase, combine and interpret three of the three-star needs and provide a short justification for each of these selections. [5 marks]

   (d) A proposed solution is to find a solvent to replace methylene chloride. Describe the one method without experiments that could be used to identify a suitable replacement with the same solubility as methylene chloride. Formulate six other possible target metrics that would need to be achieved for the new selected solvent. [5 marks]

Continued/…

Q2 Continued/…

Q2: Needs for a printing process with reduced solvent emissions

Lithographic press operator

O1	The ink spreads really easily over the lithographic plate surface.
O2	The ink doesn't half stink, so it's not much fun cleaning up afterwards.
O3	We have to wear protective gloves to do the cleaning. Sometimes I forget.
O4	The ink has a runny consistency so that it's easy to handle. Not too thin though.
O5	Charging the ink onto the presses needs to be done carefully and it takes a long time.
O6	It's a dirty job.
O7	I've been talking to our shop steward about improving the working conditions.
O8	We need to wash our hands to protect yourself from illnesses at a break.
O9	Typically, print runs last a few hours and then we have to clean the presses at the end of each shift.
O10	People don't do this job for very long.
O11	We've tried other inks, but some seem to stick to the litho plates and are hard to remove.
O12	I need a holiday.

Press manager

M1	The ink is expensive and we leave too much excess on the presses
M2	I'm worried that we'll be prosecuted for having volatile organics in the atmosphere.
M3	The cleaning process produces a lot of chemical waste, which is expensive to dispose of.
M4	Waste ink is also a problem for disposal, but there isn't too much of that.
M5	We've tried some alternative formulations, but they gave poor print quality.
M6	I've heard about water soluble inks.
M7	We always buy our inks from a local supplier.
M8	We haven't changed the materials since I've been here.
M9	New presses are very expensive and there's a long pay back time.

Customer

C1	We need a rapid turnaround on any jobs we submit for printing.
C2	High and consistent print quality is required.
C3	If the costs go up, we'll find an alternative printer.
C4	We've sent back some sales brochures, because they were printed in the wrong colours.
C5	We read newspapers every day during our breakfast.

Scientific consultant

S1	We need to control the surfactant properties of the ink to give high quality products.
S2	We've always chosen an ink formulation with an organic solvent.
S3	The pigment size distribution and morphology are critical.
S4	My daughter's just gone to Loughborough to do Chemical Engineering.
S5	The solvent reduces the ink viscosity which makes it easier to distribute on the litho plates.
S6	The solvent isn't expensive, but we use quite a lot for cleaning purposes.
S7	The expensive part is getting rid of the waste.
S8	I've never talked to anyone on the shop floor.

You should use the reference numbers given above to identify the needs statements in your answers.

3. In order to describe the right specifications of chemical products, calculations are commonly used to compare different chemical products and guide their design. The Cross equation is:

$$\mu_a = \mu_\infty + \frac{\mu_0 - \mu_\infty}{1 + \alpha\left(\dot{\gamma}\right)^n}$$

(a) Briefly explain the meaning of each symbol. What is the theoretical background of the equation? [6 marks]

(b) Describe under what circumstances a Cross equation fluid apparently displays (i) power law, and (ii) yield stress behaviour. [6 marks]

(c) Explain why concentrated emulsions show shear thinning behaviour. Can this be related to the theory behind the Cross model? [6 marks]

(d) What unique feature of emulsions do you consider to be of most interest to designers of chemical products? Provide three products with three different functions based on these features. [7 marks]

4. (a) (i) Provide two examples of companies for each of three different levels of innovation and adaptation and describe how the development approach affects their product portfolios. [6 marks]

(ii) Describe the six methods of building and organising process development and product development teams in these companies. Point out the advantages and disadvantages of different organisational structures. [6 marks]

(b) (i) Since the introduction of insulin almost a century ago, more than 80 peptide drugs have reached the market for a wide range of diseases, including diabetes, cancer, osteoporosis, multiple sclerosis, HIV infection and chronic pain. In this perspective, we summarize key trends in peptide drug discovery and development. If it is your responsibility to design a process for the manufacture of a therapeutic peptide for clinical applications, please evaluate the use of the liquid phase methods for small- and large-scale manufacturing of peptides as biopharmaceuticals. [4 marks]

(ii) After an amputation, some people experience pain in the part of the limb that's no longer there. This sensation is phantom limb pain. The pain is real. The phantom part refers to the location of the pain: the missing limb or part of the limb (such as fingers or toes). Phantom limb pain ranges from mild to severe and can last for seconds, hours, days or longer. It may occur after a medical amputation (removing part of a limb with surgery). It can also happen after accidental amputation, when you lose a finger, toe or other body part. Briefly evaluate 9 possible treatments and/or healthcare product(s) to relieve the phantom pain. [9 marks]

END OF PAPER

Dr H Yang, Dr T Sun