UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2019/2020

TITLE OF PAPER:	INDUSTRIAL PHYSICS
COURSE NUMBER:	PHY496
TIME ALLOWED:	THREE HOURS
INSTRUCTIONS:	ANSWER QUESTION 1 AND CHOOSE ANY **THREE** OUT OF THE REMAINING QUESTIONS
	EACH QUESTION CARRIES 25 MARKS
	MARKS FOR EACH SECTION ARE IN THE RIGHT HAND MARGIN
	GIVE CLEAR EXPLANATIONS AND USE CLEAR DIAGRAMS IN YOUR SOLUTIONS. MARKS WILL BE LOST WHERE IT IS NOT CLEAR HOW THE EQUATIONS USED WERE OBTAINED

THIS PAPER HAS SEVEN PAGES INCLUDING THE COVER PAGE

THE LAST PAGE CONTAINS INFORMATION THAT MAY BE USEFUL IN SOME QUESTIONS

IF IN DOUBT, RAISE YOUR HAND AND ASK

DO NOT OPEN THE PAPER UNTIL PERMISSION HAS BEEN GRANTED BY THE CHIEF INVIGILATOR

QUESTION 1: ***COMPULSORY***

(a) Define the following in terms of investment: throughput, net profit and rate of return. **(6 marks)**

(b) Can the payback period be the only method used to determine the viability of an investment? If not, what other considerations must be taken into account in order to make the investment? **(5 marks)**

(c) While searching the Internet, an advert pops out showing and instrument which you think can increase the profitability of your company division. On further research on the instrument you come out with the following information:

- The machine cots E525 000.00.
- The instrument can generate revenue of E87 500.00 per month.
- Monthly cost of inputs is E52 500.00.
- The monthly salary for the machine operator is E15 750.00.
- Annual maintenance costs total E110 000.00.

The company can only spare E250 000.00 that is currently invested where it attracts 10% annual interest and this is available for use towards purchasing the instrument. The balance of E275 000 can be obtained as a loan at 18% annual interest with a condition that it is paid within 5 years.

i. Calculate the monthly payment for the loan. **(3 marks)**
ii. Find the lost income for the company over five years for the amount used as a deposit, and convert it to an average monthly figure. (This lost income is accounted as a cost.) **(2 marks)**
iii. Find the payback period for the investment in the instrument. **(4 marks)**
iv. What argument would you put forward to either or not purchase the instrument? **(2 marks)**

(d) What is the discounting method in capital investment? **(3 marks)**

QUESTION 2

(a) What are the characteristics of Xenon discharge lamps and why are they useful for spectroscopy? **(4 marks)**

(b) Sketch the basic instrument components in their proper orientations of a conventional spectrofluorimeter using a gas discharge lamp (assume diffraction grating based). Briefly explain the purpose of each component and further explain why it would be possible that a interference filter-based fluorometer could actually yield lower detection limits for quantitating a given fluorescence molecule than the spectrofluorometer instrument that you have drawn. **(10 marks)**

(c) Two sets of wavelengths λ_1 and λ_2 in the blue and λ_3 and λ_4 in the red have the same spacing ($\Delta\lambda_{1,2} = \Delta\lambda_{3,4}$). Explain using equations whether a spectrometer system that can barely resolve the two wavelengths λ_1 and λ_2 can be able to resolve the wavelengths λ_3 and λ_4. **(3 marks)**

(d) In atomic emission spectroscopy the intensity increases with temperature, but not necessarily for sodium potassium and lithium. Why is this the case with these elements. **(2 marks)**

(e) The major atomic emission line of potassium is at 766 nm. The potassium is excited by an a hydrogen flame at 2 100°C. The degeneracy of the lower state is 2 and that of the higher one is 4.

i. Determine the ratio of the atoms in the excited state as compared to the lower state at the indicated temperature. **(3 marks)**

ii. How much improvement would be achieved if a much more expensive air-acetylene flame at 2 200°C was used as compared to the hydrogen at 2 100°C. **(3 marks**

QUESTION 3

(a) What is the benefit of a mass spectrometry and what are its major components? **(4 marks)**

(b) In mass spectrometry the full width at half maximum (FWHM) is usually considered to be of importance. Explain with illustrations why it is. **(5 marks)**

(c) Discuss how a mass spectromenter can be used as a mass filter such that it only selects mass m and rejects masses $m - 1$ or less and $m + 1$ or greater. **(10 marks)**

(d) Explain with an appropriate figure and text, how a triple quadrupole mass spectrometry (QqQ) system can be used for multi-reaction monitoring that yield very high selectivity for detection of a specific chemical in a very complex sample matrix. **(6 marks**

QUESTION 4

(a) Briefly describe how an ion pump works. **(9 marks)**

(b) Derive an equation for the particle flux incident on a surface using the Maxwellian velocity distribution. **(8 marks)**

(c) Write the particle flux in terms of pressure. **(3 marks)**

(d) Nitrogen single nitrogen (N_2) molecule has a molecular mass of 28.006148 g per mole and an average diameter of 0.380 nm. The sticking coefficient of the N_2 molecule on a particular surface is $S = 0.800$. Find the monolayer formation time at a pressure on 10^{-3} torr of N_2 gas. **(5 marks)**

QUESTION 5

(a) The Darcy-Weis equation given here is used to determine the pressure loss due to frictional forces in fluid flow in pipes.

$\Delta P = f \frac{L}{D} \frac{\rho v_{ave}^2}{2}$,

where f is the Darcy friction factor, L length of the pipe and D length and diameter of the pipe, ρ the density of the fluid and v_{ave} is the average velocity across the pipe. The equation is applicable for both laminar and turbulent flow provided the Darcy friction factor can be obtained. Derive an expression for the average velocity of the fluid as a function of the pressure gradient along the direction of flow. **(11 marks)**

(b) A badly corroded concrete pipe of diameter 1.50 m has an equivalent roughness of $\varepsilon =$ 15.0 mm. A 10 mm thick lining is proposed to reduce the roughness value to $\varepsilon =$ 0.200 mm. A water discharge rate of 4.00 m^3/s will be adequate for the application. Take the dynamic viscosity of the water to be 10^{-3} $N{\cdot}s{\cdot}m^{-2}$.

i. For each of the cases of the corroded pipe and the lined pipe find the Reynolds number and state the type of flow, and **(6 marks)**
ii. the Darcy friction factor. **(4 marks)**
iii. Calculate the head loss for each case, **(2 marks)**
iv. and the power saved per kilometre of pipe by inserting the lining. **(2 marks)**

DATA SHEET

General data

Air refractive index = 1.00
Avogadro's number $N_A = 6.022 \times 10^{23}$ mol^{-1}
Boltzmann's constant $k_B = 1.38 \times 10^{-23}$ J/K
Coulomb constant $k_e = 8.9875 \times 10^9$ N·m^2/C^2
Density of mercury = 1.36×10^4 kg/m^3
Gas constant $R = 8.314$ J/(mol.K)
Gravitational acceleration $g = 9.80$ m/s^2
Speed of light in vacuum $c = 2.997\,8 \times 10^8$ m/s
Speed of sound in air $v_s = 343$ m/s
Standard atmospheric pressure = 1.013×10^5 Pa

Some equations that may be useful

$$A = P\left(\frac{i}{1-(1+i)^{-n}}\right)$$

$$F = P(1+i)^n$$

$$P = A\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right]$$

$$h_f = f\frac{L}{D}\frac{v^2}{2g}$$

$$f = 0.110\left(\frac{\varepsilon}{D} + \frac{68.0}{Re}\right)^{0250}$$

$$\frac{1}{\sqrt{f}} = -2.0\log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{Re\sqrt{f}}\right)$$

$$\frac{1}{\sqrt{f}} = 1.14 - 2\log\left(\frac{\varepsilon}{D} + \frac{21.25}{Re^{0.9}}\right)$$

$$n = 9.66 \times 10^{18} \times \frac{P}{T}$$

$$f(v) = 4\pi v^2\left(\frac{m}{2\pi k_B T}\right)e^{-mv^2/2k_BT}$$

$$\Gamma = n_V\left(\frac{k_B T}{2\pi m}\right) = \frac{N v_{ave}}{4} = \frac{P}{(2\pi kT)^{1/2}}$$

$$N = \frac{P}{k_B T}$$

$$v_{ave} = \sqrt{\frac{8k_B T}{\pi m}}$$