UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF PHYSICS

MAIN EXAMINATION 2020/2021

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 EIGHT 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) You are in charge of a research and development laboratory in a company and you are sent to attend a conference. At the conference you are attracted to a piece of equipment that you believe can add value to a product manufactured by the company. You want to make a proposal to higher management to purchase such equipment, which costs E500,000.00. The company requires that the equipment be paid back in 24 months, and will release money invested where it earns 17% per annum compounded monthly to pay for it. You decide that the breakeven method is suitable to determine the financial viability of the equipment. You do further research and find the information given in the tabel below.

Item	Amount (E)
Laboratory overheads per month	5,000.00
Marketing costs	15,000
Labour per unit	35.00
Materials per unit	25.00
Value added per unit	95.00

i. Calculate the amount lost by the company by taking money out of the investment and using it to purchase the equipment. Also convert this amount to its present value. **(5 marks)**

ii. Convert the laboratory overheads over the two-year period to present value, taking the interest rate to be 8%. **(3 marks)**

iii. Determine the breakeven point in units and monetary investment. **(4 marks)**

iv. Sketch a fully labeled graph that can be used to determine the breakeven point. **(7 marks)**

v. Explain why higher management may want to see the graph even after you have provided the breakeven units and investment amount in figures. **(2 marks)**

vi. Give two strengths of the breakeven analysis method and also outline two of its limitations. . **(4 marks)**

QUESTION 2

(a) State what optical spectroscopy is in one sentence? **(2 marks)**

(b) Briefly discuss four things that astronomers use optical spectroscopy for. **(8 marks)**

(c) Make a diagram that illustrates two closely spaced wavelengths appearing after being dispersed by a grating at say orders $m = 0$ to 2 or 3 and explain it. **(4 marks)**

(d) Explain how a grating can make light in the UV region to be detected in the spectrum observed in the visible region, for example light at $\lambda = 230$ nm. Also state how this can be addressed. **(3 marks)**

(e) What grating resolving power will be needed to resolve the spectral lines of the following wavelength pairs:

i. First pair being 489.0 and 489.6 nm, and second one being 689.0 and 689.6. **(2 marks)**

ii. Comment on the results obtained from i. above. **(1 mark)**

(f) When a molecular species is excited, discuss the mechanisms by which it can return to the ground state. **(5 marks)**

QUESTION 3

(a) Discuss the overall operation of a quadrupole mass spectrometer. **(6 marks)**

(b) Discuss how a quadrupole mass spectrometer can be used as a low mass filter. **(6 marks)**

(c) Discuss how a quadrupole mass spectrometer can be used as a high mass filter. **(6 marks)**

(d) A mass spectrometer has a resolution of 1 000. Find out whether or not it can resolve species with m/q = 1060.2 and m/q = 1061.2. **(3 marks)**

(e) Why is the Full Width at Half Maximum (FWHM) an important consideration in mass spectroscopy? **(4 marks)**

QUESTION 4

(a) Would you consider the 'empty space' between galaxies a perfect vacuum? Explain your answer. **(2 marks)**

(b) Derive an expression for the efflux of particles incident on a surface in terms of the concentration of particles per unit volume n and the average particle velocity $\bar{v}$. **(9 marks)**

(c) Find the mean free path for the following pressures assuming an average molecular diameter of 3.00×10^{-1} m at room temperature: **(3marks)**

i. Atmospheric pressure at 1 atmosphere,
Roughing pump pressure at 10^{-3} torr, and
High vacuum at 10^{-8} torr. **(2 marks)**

(d) With the information from (c) above, within what range of pressures would you operate a mass spectrometer (give an explanation). **(2 marks)**

(e) Vacuum system gas load is a problem in a vacuum chamber.

i. What is a gas load and why is it a problem? **(3 marks)**

ii. Discuss four (4) mechanisms by which it arises. **(4 marks)**

QUESTION 5

(a) Distinguish between dynamic and kinetic viscosity. **(4 marks)**

(b) Define Reynolds number and explain its usefulness. **(5 marks)**

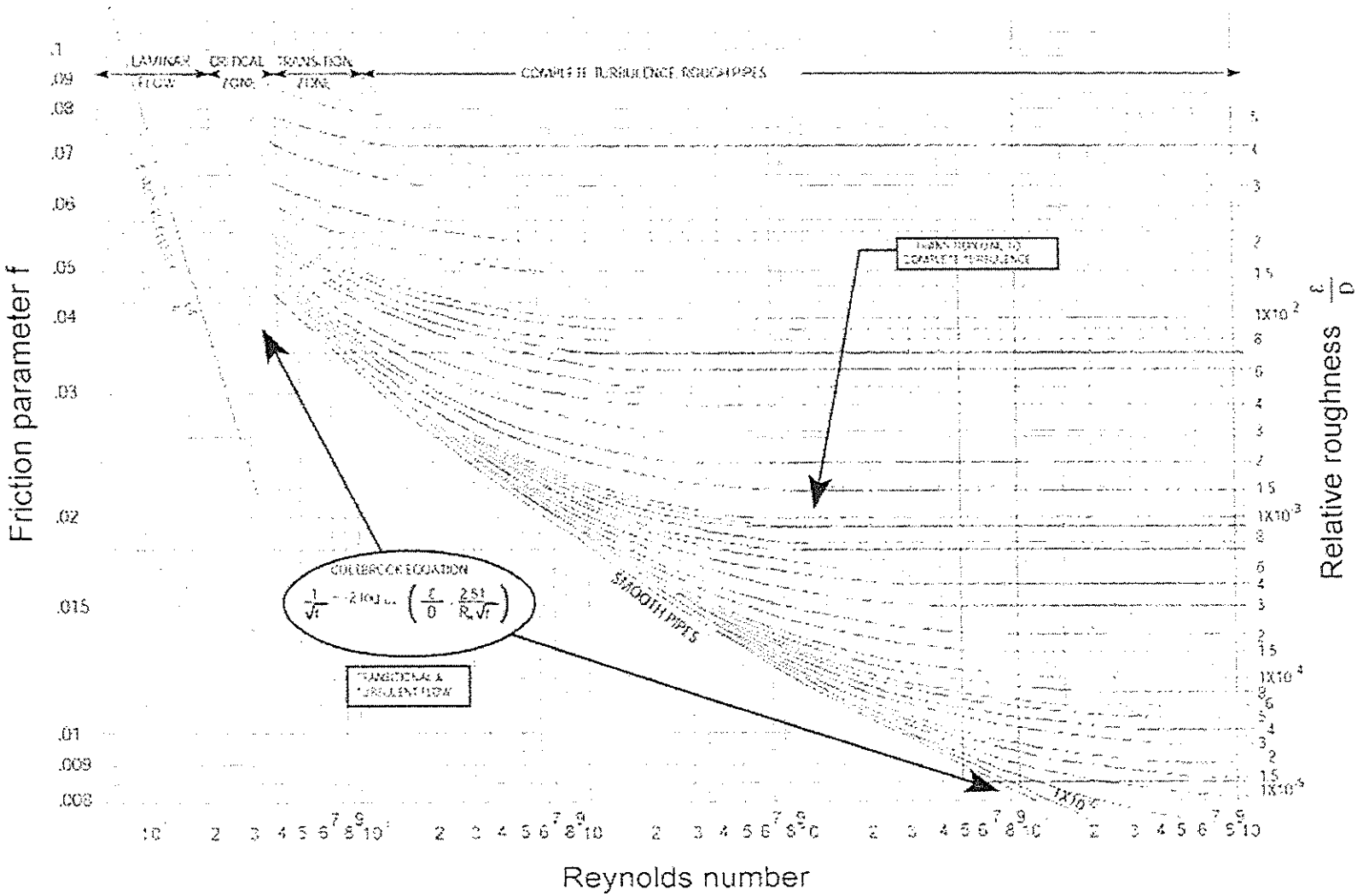
(c) A pipe carries 200 l/s of petrol ($\rho = 680$ kg/m^3 and $\mu = 2.92 \times 10^{-4}$ N·s/m^2) through a 30.0 cm pipe. The pipe is 500 m long and has an equivalent roughness magnitude of 0.200 mm.

i. Determine the head loss using calculation. **(9 marks)**

ii. Find the cost of pumping the petrol for 12 hours if electricity costs E1.75 per kWh. **(3 marks)**

iii. Find friction factor f using the Moody chart. (Also submit the chart showing how it was used to obtain the friction factor). **(4 marks)**

Moody Chart


Friction parameter f
Reynolds number
Relative roughness ε/D
LAMINAR FLOW
CRITICAL ZONE
TRANSITION ZONE
COMPLETE TURBULENCE ROUGH PIPES
SMOOTH PIPES
COLEBROOK EQUATION

INFORMATION THAT MAY BE USEFUL IN SOME QUESTIONS

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 $= 1.36 \times 10^4$ 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 $= 1.013 \times 10^5$ Pa

Other Information

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

$$P_n = \frac{PV}{N} + \left(PV - \frac{PV}{N}n\right)i$$

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

$$FV = PMT\frac{[(1+i)^n - 1]}{i}$$

$$PV = PMT \cdot \left[\frac{1-\frac{1}{(1+i)^n}}{i}\right]$$

$$PV = PMT \cdot \left[\frac{1-\frac{1}{(1+i)^n}}{i}\right] \cdot (1+i)$$

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

$$\frac{1}{\sqrt{f}} = 1.14 - 2\log\left(\frac{\varepsilon}{D} + \frac{21.6}{Re^{0.9}}\right).$$