

壹. 機構學 (50%)

1. Please state the basic assumptions of the kinematics (or mechanisms). [5]
2. Please determine the degrees of freedom of the planetary gear train shown in Fig. 1. Before that please indicate the number of links, types and number of joints. [5]
3. Please determine graphically the angular velocity and acceleration of shaped component shown in Fig. 2, if the crank OP rotates with a constant clockwise angular velocity of 10 rad/s. [10]
4. Please design a disk cam to produce the following motion of a translating flat-faced follower: a rise through distance h with simple harmonic motion during 180° of rotation, followed by a return, also with simple harmonic motion, during the remaining 180° of cam rotation; please also determine the lower bound of the width of the follower face. [10]
5. Two meshing standard 20° , full-depth spur gears, with a module of 4 mm, have 14 teeth and 45 teeth. What must be the actual operating pressure angle and the center distance, in order to avoid interference? [10]
6. Please design a drag-link quick-return mechanism, as shown in Fig. 3, with a 70 mm stroke, and the time ratio is 3. [10]

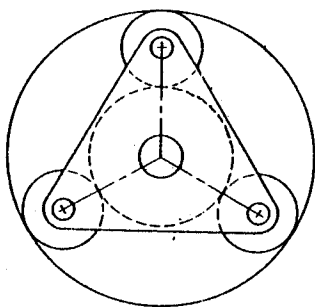


Fig. 1

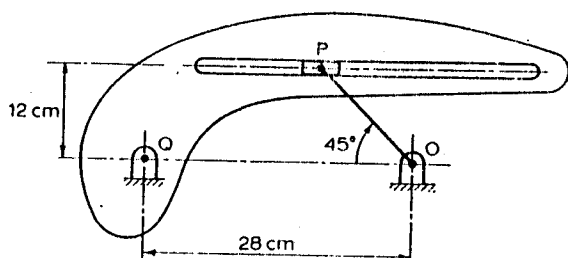


Fig. 2

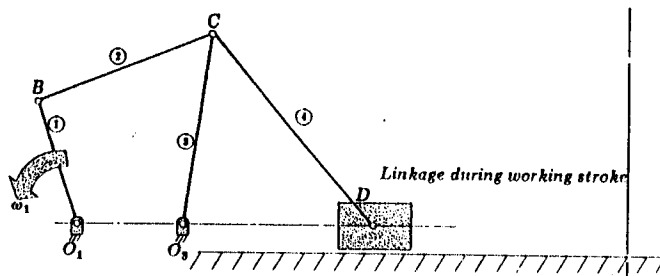
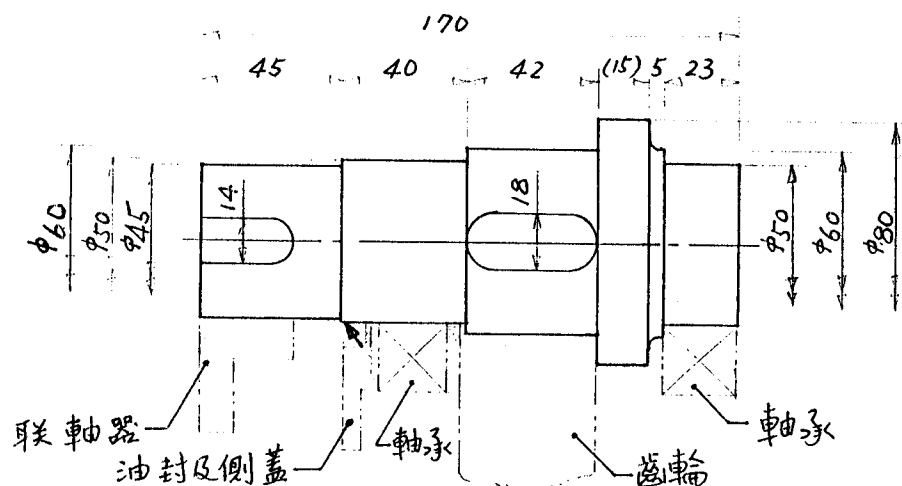


Fig. 3

(背面仍有題目,請繼續作答)

7. (a) 請描述你認為合理之機械設計過程(Mechanical Design Process)及其特性，試以圖示(可舉例)說明有那些步驟？ (b) 各步驟之先決條件(Inputs)及結果(Outputs)。 (c) 設計之優劣可依那些辨別條件(Criteria)來判斷？(可舉例說明)。 (15%)
8. 滾動軸承(Rolling Contact Bearings)規格之選擇，及滑動軸承(Journal Bearings)之設計， (a) 有那些條件必需事先知道？ 其中有那些項目可由設計者自行決定？ (b) 若轉速 2,500rpm 之傳動軸，軸承位置直徑設計為 50mm，你會選用滑動軸承或滾動軸承？請說明理由。 (10%)
9. (a) 轉動軸在傳動系統中，如何協助組裝在軸上之元件扮演預期之功能？以簡圖舉例說明。 (b) 下圖中之傳動軸(黑色實線部份)，有那些資料得再補充，才稱得上是設計完整之零件圖？請分項列舉說明(定性即可，不必定量)。 (10%)

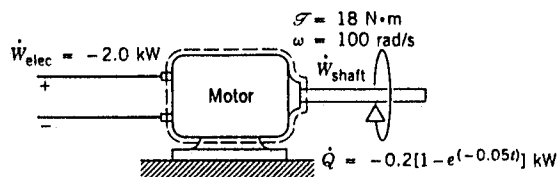


10. (a) 齒輪破壞的現象有那幾種？引起破壞的原因有那些？ (b) 設計齒輪時，常以負荷下之應力與可選用之材料強度互相比較；請依你熟悉之經驗公式，說明估算各應力與強度時之影響因數，及其代表意義；應力及可用強度又如何比較。 (c) 請舉簡例說明設計過程中，設計者可自行決定那些項目。 (15%)

1. (18%) The rate of heat transfer between a certain electric motor and its surroundings varies with time as

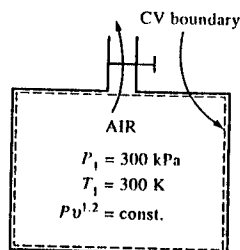
$$\dot{Q} = -0.2[1 - e^{(-0.05t)}]$$

where t is in seconds and $\dot{Q}$ is in kilowatts. The shaft of the motor rotates at a constant speed of $\omega = 100 \text{ rad/s}$, and applies a constant torque of $\tau = 18 \text{ N}\cdot\text{m}$ to an external load. The motor draws a constant electric power input equal to 2.0 kW as shown. Obtain an expression for the time rate of change of energy of the motor.



2. (12%) A household freezer operates in a room at 20°C . Heat must be transferred from the cold space at a rate of 2 kW to maintain its temperature at -30°C . What is the theoretically smallest (power) motor required to operate this freezer?

3. (20%) A 1 m^3 rigid tank contains air initially at 300 kPa and 300 K . A valve is opened and air is allowed to escape slowly until the pressure in the tank drops to the atmospheric pressure of 100 kPa . The air in the tank is observed to have undergone a polytropic process ($Pv^n = \text{constant}$) with $n = 1.2$. Determine the heat transfer for this process. $R = 0.287 \text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K}$



Ideal-gas properties of air

T K	h kJ/kg	P_r	u kJ/kg	v_r	s° kJ/(kg · K)
200	199.97	0.3363	142.56	1707.0	1.295 59
210	209.97	0.3987	149.69	1512.0	1.344 44
220	219.97	0.4690	156.82	1346.0	1.391 05
230	230.02	0.5477	164.00	1205.0	1.435 57
240	240.02	0.6355	171.13	1084.0	1.478 24
250	250.05	0.7329	178.28	979.0	1.519 17
260	260.09	0.8405	185.45	887.8	1.558 48
270	270.11	0.9590	192.60	808.0	1.596 34
280	280.13	1.0889	199.75	738.0	1.632 79
285	285.14	1.1584	203.33	706.1	1.650 55
290	290.16	1.2311	206.91	676.1	1.668 02
295	295.17	1.3068	210.49	647.9	1.685 15
300	300.19	1.3860	214.07	621.2	1.702 03
305	305.22	1.4686	217.67	596.0	1.718 65
310	310.24	1.5546	221.25	572.3	1.734 98
315	315.27	1.6442	224.85	549.8	1.751 06
320	320.29	1.7375	228.42	528.6	1.766 90
325	325.31	1.8345	232.02	508.4	1.782 49
330	330.34	1.9352	235.61	489.4	1.797 83
340	340.42	2.149	242.82	454.1	1.827 90

(背面仍有題目,請繼續作答)

4. (15 %) Consider a Carnot-cycle heat pump having 1 kg of nitrogen gas in a cylinder/piston arrangement. This heat pump operates between reservoirs at 300 K and 400 K. At the beginning of the low-temperature heat addition, the pressure is 1 MPa. During this process the volume triples. Analyze each of the four processes in the cycle and determine
($C_{p_0} = 1.0416 \text{ kJ/kg-K}$, $C_{v_0} = 0.7448 \text{ kJ/kg-K}$, $k = 1.4$)
(a) The pressure, volume, and temperature at each point
(b) The work and heat transfer for each process
5. (15%) In an air-standard Otto cycle, all the heat transfer q_H occurs at constant volume. It would be more realistic to assume that part of the q_H occurs after the piston has started to move downward in the expansion stroke. Therefore, consider a cycle identical to the Otto cycle except that the first two-thirds of the total q_H occurs at constant volume and the final one-third occurs at constant pressure. Assume that the total q_H in this cycle is 2400 kJ/kg, the pressure and temperature at the beginning of the compression process are 100 kPa, 25°C, and the compression ratio is 10. Calculate the maximum pressure and temperature and the thermal efficiency of this cycle, and compare the results with a conventional Otto cycle having the same given variables.
($C_{p_0} = 1.0035 \text{ kJ/kg-K}$, $C_{v_0} = 0.7165 \text{ kJ/kg-K}$, $k = 1.4$)

6. (20%) Determine the low-pressure Joule-Thomson inversion temperature

$$\lim_{P \rightarrow 0} \mu_J = 0$$

as predicted by an equation of state, using the van der Waals equation

$$P = \frac{RT}{v-b} - \frac{a}{v^2} \text{ in which } a = \frac{27}{64} \frac{R^2 T_c^2}{P_c}, \quad b = \frac{RT_c}{8P_c}$$

一、解釋名詞：（每小題五分）

1. 聖維南原理 (Saint-Venant's Principle)
2. 軸向剛性 (Axial Rigidity)
3. 重疊法 (Superposition Method)
4. 剪力中心 (Shear Center)

二、問答題：（每小題十分）

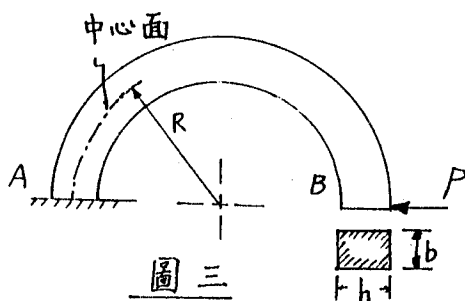
1. 解決旋轉軸承受扭力矩之問題 (Torsional Problem) 時，嚴格的說，應屬三維彈性力學問題，亦即其應力狀態包含所有應力分量 σ_{ij} ($i, j = x, y, z$)。但是以材料力學的觀點而言，該結構之應力狀態可簡化為單純之剪應力狀態，即 σ_{zy} 與 σ_{zx} (z 為旋轉軸)。請說明簡化過程中所作之假設。

2. 彈性體受力後，物體內每一點將產生位移 u, v 及 w ，請論述該位移是由那幾個動作形成的。

三、計算題（二十分）

半圓環結構，如圖三所示，左側 A 為固定端，右側 B 則受到水平力 P 的作用。已知圓環中心面的曲率半徑及矩形剖面的深度及厚度分別為 R 、 h 及 b ，且 E 、 G 為常數，試求：

1. 儲存於圓環內的總應變能。
2. B 點水平位移 δ_H 。
3. 若 h 及 $b \ll R$ ，討論各應變能分量對 δ_H 的影響。

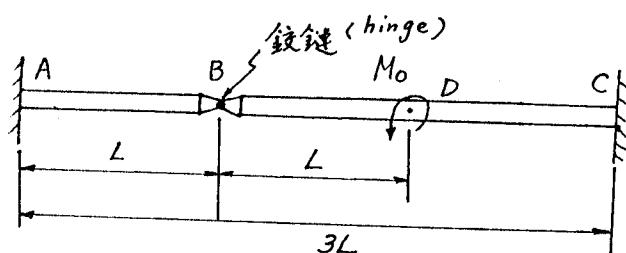


(背面仍有題目,請繼續作答)

四、計算題 (二十分)

兩桿件AB與BC，如圖四所示，以銷連接於B點，另一端A與C則皆為固定端。若有一已知集中力矩 M_0 作用於BC桿的D點，且EI為常數，試求：

1. 兩桿件在固定端A與C的反作用力。
2. B點的垂直位移 δ_v 。



圖四

五、熱力學部份 (二十分)

1. (a) Distinguish between open and closed system. (5%)
(b) What is a coefficient of performance (c.o.p.) of a refrigeration process? (5%)
2. An inventor claims to have developed a power cycle capable of delivering a net work output of 500 KJ for an energy input by heat transfer of 1000 KJ. The system undergoing the cycle receives the heat transfer from hot gases at a temperature of 500 K and discharge energy by heat transfer to the atmosphere at 300 K. Evaluate this claim. (10%)

(1) (10%)

Please give a state-space representation, (A,B,C,D), of the transfer function (5%)

$$G(s) = \frac{s+4}{s^3 + 6s^2 + 11s + 6}$$

Find the eigenvalues of A and the value of CAB. (5%)

(2) (10%)

Consider a unity feedback system where

$$G(s) = \frac{200}{s(s+15)}$$

is the controlled plant and

$$K(s) = \alpha \frac{s+z}{s+p}$$

is the compensator to be designed. Find the parameters of $K(s)$ such that the closed-loop system has the natural frequency $\omega_n = 20$ and the damping ratio $\zeta = 0.7$.

(3) (10%)

Find the transfer function, $\frac{V_2(s)}{V_1(s)} = k \frac{\tau_1 s + 1}{\tau_2 s + 1}$, of the network circuit shown in Fig.1. (5%)

Draw the Bode diagram (only approximate curve, but having the information of k , τ_1 and τ_2) of the system while $R_1 = 9$, $R_2 = 1$ and $C = \frac{1}{9}$. (5%)

(4) (20%)

Design a feedback control system of Fig.2 that satisfies the following specifications:

- settling time (i.e., within 2% of the final value) of the system ≤ 3 sec;
- damping ratio of dominant poles ≥ 0.707 ;
- Steady-state error for a ramp input = 12.5% of input magnitude.

Compute the desired parameter K_1 . (5%)

Determine the region of the closed-loop poles in the complex plane for this design. (5%)

Draw a root locus plot as K varies, and then show the range which will satisfy the specifications. (10%)

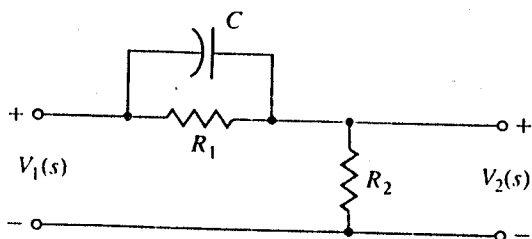


Fig. 1

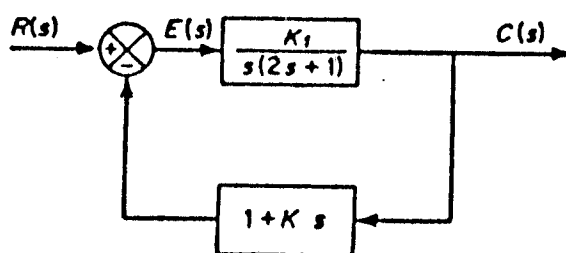


Fig. 2

(背面仍有題目,請繼續作答)

- (15%) 5. A machine element is modeled for control purposes as two masses, a dashpot, and a spring sliding on a frictionless surface, as shown below. The compliance comes from such elements as lead screws, gears, belts, etc.

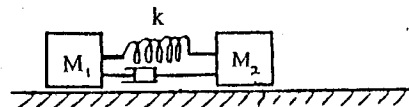


Figure 3 Machine Element Model

The goal is to control the position of M_2 . The system is driven by a DC motor directly connected to M_1 .

- For modest sized motors, the motor can be considered as a torque source. Derive the transfer function between motor input and position of M_2 for the case in which there is no damping (these systems are normally very lightly damped). (5%)
- Can the system be made asymptotically stable with pure derivative control (i.e., feedback of $\dot{v}_2$)? (Take $k=M_1=M_2=1$ for this part.) (5%)
- If a very large motor is used, the motor appears as a velocity source to the driven system. Discuss what the model would be like in this circumstance and whether control would be easier or more difficult. (5%)

- (35%) 6. A second order linear time invariant plant is under proportional feedback control.

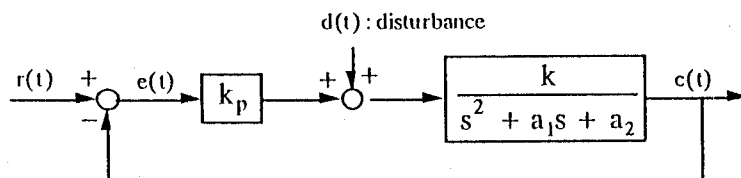


Figure 4

The unit step reference input response for this system, when the control gain k_p was set to 8, is shown in the figure below. (Assume that the disturbance was constant during the test.)

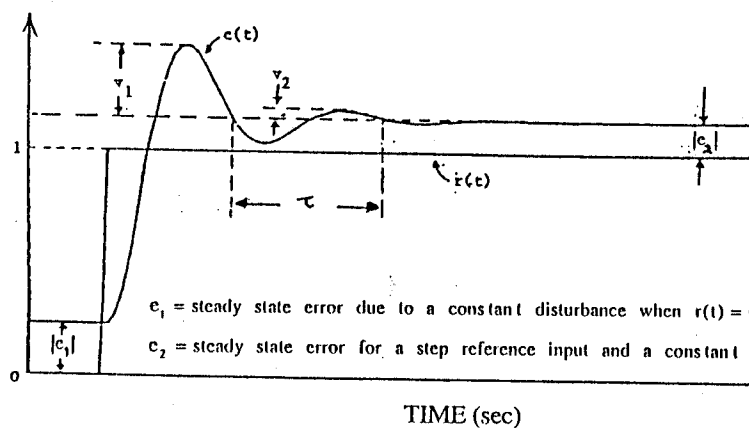


Figure 5

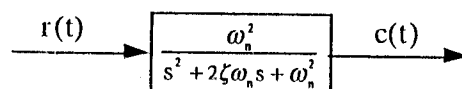
where $e_1 = -0.23$, $e_2 = -0.15$

$$\tau = \frac{2}{3} \pi \text{ sec}, \quad \frac{v_2}{v_1} = e^{\frac{-2\pi}{3}}$$

e_1 = steady state error due to a constant disturbance when $r(t) = 0$

e_2 = steady state error for a step reference input and a constant disturbance

- Find the plant open loop poles. (20%)
- You are requested to design a new feedback control system for this plant with the following specifications: (15%)
 - The steady state error for a step reference input and a constant disturbance must be zero.
 - The unit step reference input response pattern of the closed loop system should be similar (but not necessarily equal) to the response pattern of the following second order system when $c(0) = 0$, $d(t) = 0$.



$$\zeta = 0.7, \quad \omega_n = 4 \text{ sec}^{-1}$$

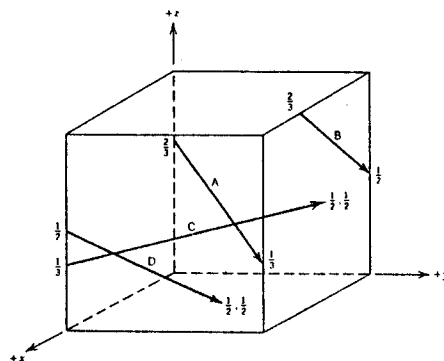
Figure 6

Hints: The similar response pattern referred to in this problem means that both systems should have the same closed loop zeros and that the dominant poles should be equal. You may consider ideal proportional, derivative and integral action in cascade (series) or in minor loop configurations, whichever satisfies the control specifications given above.

(1). Cite the relative Burgers vector-dislocation line orientations for edge, screw and mixed dislocations. (5%)

(2). The metal rhodium has a FCC crystal structure. If the angle of diffraction for the (311) set of planes occurs at 36.12° (first-order reflection) when monochromatic x-radiation having a wavelength of 0.0711 nm is used, compute (a) the interplanar spacing for this set of planes, and (b) the atomic radius for a rhodium atom. (8%)

(3). Determine the indices for the directions shown in the following cubic unit cell: (8%)



(4). An FCC iron-carbon alloy initially containing 0.10 wt% C is carburized at an elevated temperature and in an atmosphere wherein the surface carbon concentration is maintained at 1.10 wt%. If after 48 h the concentration of carbon is 0.30 wt% at a position 3.5 mm below the surface, determine the temperature at which the treatment was carried out. (7%)

(5). (a) Cite the primary differences between elastic, anelastic, and plastic deformation behaviors. (b) Cite five factors that lead to scatter in measured material properties. (8%)

(6) (a) what is slip system? (b) Determine the slip system for the FCC structure. (8%)

(7). If a hypereutectoid steel is slowly cooled from the austenite region, the primary cementite crystals form a continuous layer in the austenite grain boundaries. This brittle network seriously reduces the ductility of the steel at room temperature. What heat treatment would be most effective in removing this cementite network? (6%)

(背面仍有題目,請繼續作答)

1. 如圖所示乃是車床欲車斷半徑為 R 的圓形工件。車床主軸為 n rpm, 主切刀長 l mm, 進給 v_f mm/rev. 轉速

a. 主軸的角速度 $\omega = ?$ rad/sec (2%)

b. 工件相對於刀具的總速度 $\vec{v}_{res} = ?$ (以 x, y, z 表示在座標系 (x, y, z)) (3%)

c. 主切刀的向量 $\vec{l} = ?$ (表示在 (x, y, z)) (3%)

d. 若此為正切削, 則 $\phi = \phi_{orth} = ?$ (3%)

e. 在 $\phi = \phi_{orth}$ 下, 切屑的面積 $A_c = ?$ (3%)

f. 在 $\phi = \phi_{orth}$ 下, 體積切削率 $Z_w = ?$ mm³/sec (表示成 r 的函數) (3%)

2. 解釋名詞 (5%)

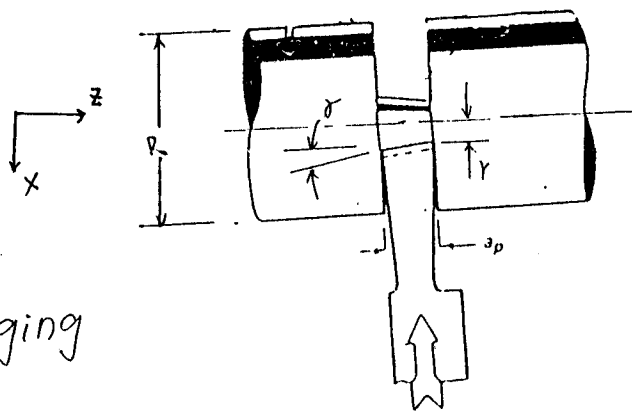
a. riser (冒口)

b. chill (冷塊)

c. core (砂心)

d. 「cold shut」in forging

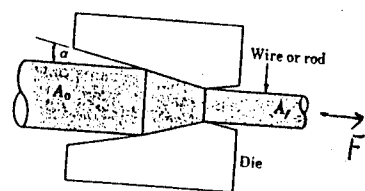
e. 2-piece can



3. 在 Die casting 中有 hot-chamber die-casting process 及 cold-chamber process。試就 (a) 其澆注系統外形上的差異 (b) 所能澆鑄金屬之溶點高低 (c) 生產速度快慢 (d) 鑄件品質 (e) 澆注系統壽命 作詳細說明。 (10%)

(背面仍有題目, 請繼續作答)

4. 如图是 wire drawing, 素材面積為 A_0 ,
長度 L_0 。成品面積為 A_f



(1) 其真應變 (true strain) = ? (2%)

(2) 若材料是 perfectly plastic material
且不考慮 friction 之影響, 則單位體積
所須的功 u = ? (2%)

(3) 完成此過程須總功 (total work) W = ? (2%)

(4) 拉力 F = ? (2%)

5. 鑽床其鑽頭為 2 刃鑽頭, 鑽床主軸轉速為 n rpm, 進給為
 V_f mm/sec, 孔深為 l mm, 孔徑為 d mm, 鑽頂角為 2θ .

(1) 切削時間 t_m = ? (2%)

(2) 切屑厚度 a_c = ? (2%)

(3) 切屑寬度 a_e = ? (2%)

(4) 切屑面積 A_c = ? (2%)

(5) 作積切除率 Z_w = ? (2%)

(1)
(15%)

A block having a mass of 2 kg is given an initial velocity of $v_0 = 1$ m/s when it is at the top surface of the smooth cylinder shown in Fig. 1. If the block travels along a path of 0.5-m radius, determine the angle $\theta = \theta_{\max}$ at which it begins to leave the cylinder's surface.

(2)
(15%)

The sphere of mass m falls and strikes the triangular block with a vertical velocity v . If the block rests on a smooth surface and has a mass $3m$, determine its velocity just after the collision. The coefficient of restitution is e .

(3)
(20%)

The block B of the quick-return mechanism is confined to move within the slot in member CD . If AB is rotating at a constant rate of $\omega_{AB} = 3$ rad/s, determine the angular velocity and angular acceleration of member CD at the instant shown.

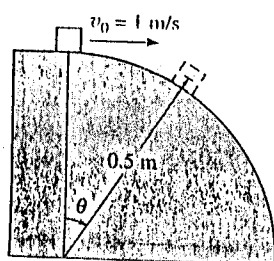


Figure 1

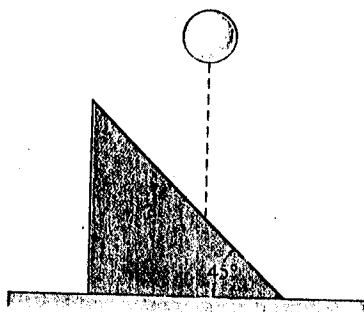


Figure 2

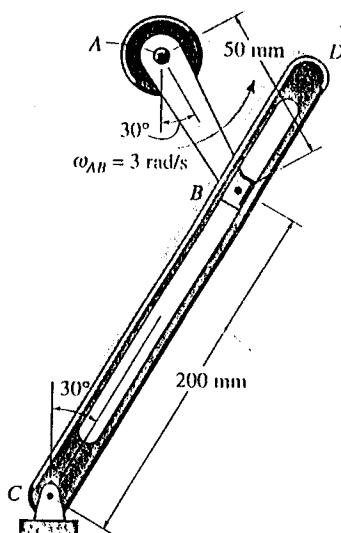
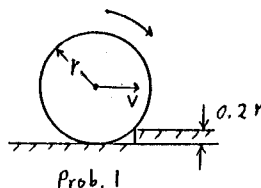


Figure 3

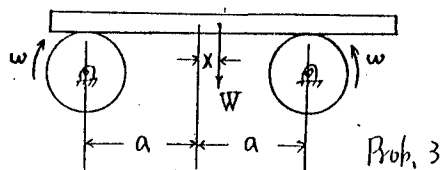
(背面仍有題目,請繼續作答)

1. The disk has a mass m , radius r and rolls without slipping. If it strikes a rough step having a height $0.2r$ as shown, determine the smallest velocity v the disk can have and not rebound off the step when it strikes it. (15%)



Prob. 1

2. State and prove the Euler's theorem regarding the rotation of a rigid-body about a fixed point. (15%)
3. A uniform board of length L and weight W as shown is supported on two wheels which rotate in opposite directions at a constant angular speed ω . If the coefficient of kinetic friction between the board and the wheels is μ , determine the frequency of vibration of the board if its center of mass is displaced slightly, a distance x from the midpoint between the wheels, and released. (20%)



Prob. 3

1(a) The fluid velocity along the x axis shown in Fig. 1(a) changes from the 12 m/s at point A to 36 m/s at point B. It is also known that the velocity is a linear function of distance along the streamline. Determine the acceleration at points A, B, and C. Assume steady flow. (5%)

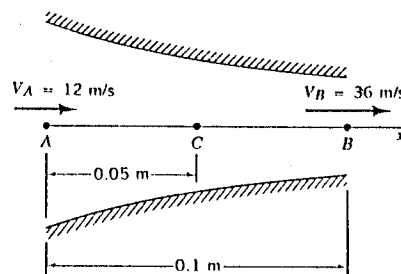


Fig. 1(a)

1(b) A fluid flows steadily along the stream-line as shown in Fig. 1(b). Determine the acceleration at point A. At point A what is the angle between the acceleration and the x axis? At point A what is the angle between the acceleration and the streamline? (5%)

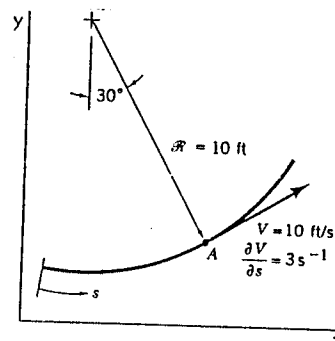


Fig. 1(b)

2. A long porous pipe runs parallel to a horizontal plane surface as shown in Fig. 2. The longitudinal axis of the pipe is perpendicular to the plane of the paper. Water flows radially from the pipe at a rate of $0.5\pi \text{ ft}^3/\text{s}$ per foot of pipe. (1) Determine the difference in pressure (in lb/ft^2) between point B and point A. The flow from the pipe may be approximated by a two-dimensional source. (2) Determine the pressure force acting on the length AB. (20%)

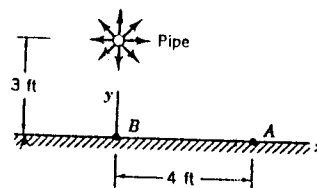


Fig. 2

3. A liquid flows with a velocity V through a hole in the side of a large tank. Assume that

$$V = f(h, g, \rho, \sigma)$$

where h is the depth of fluid above the hole, g is the acceleration of gravity, ρ is the fluid density, and σ is the surface tension. The following data were obtained by changing h and measuring V , with a fluid having a density $= 10^3 \text{ kg}/\text{m}^3$ and surface tension $= 0.074 \text{ N}/\text{m}$. Plot these data by using appropriate dimensionless variables. Could any of the original variables have been omitted? (20%)

$V \text{ (m/s)}$	3.13	4.43	5.42	6.25	7.00
$h \text{ (m)}$	0.50	1.00	1.50	2.00	2.50

(背面仍有題目,請繼續作答)

4. (a) What is the drag coefficient C_D ? Give a brief discussion of the fluid flow mechanisms contributing to the magnitude of C_D . (10%)
- (b) At the separation point of a two-dimensional viscous boundary layer around a blunt body, the vorticity is equal to zero. True or False. Explain. (5%).
5. For ordinary Newtonian fluids, the universal turbulent velocity profile in a pipe of diameter D can be approximated by the relationship of

$$\frac{\bar{u}}{u^*} = 8.7 \left(\frac{yu^*}{\nu} \right)^{1/7}$$

where $u^* = (\tau_w / \rho)^{1/2}$ is the frictional velocity and y is the distance from the pipe wall. A fluid containing a small amount of certain additives behaves somewhat differently and its universal velocity profile can be expressed as

$$\frac{\bar{u}}{u^*} = 8.7 \left(\frac{yu^*}{\nu} \right)^{1/7} + A$$

where A is a constant. For such a fluid derive an equation involving Re and A that can be used to determine the pipe friction factor f , where $Re = VD / \nu$ and V is the mean flow velocity in the pipe. (15%)

6. Starting with the momentum boundary layer equation for a uniform flow stream over a flat plate and using the free stream velocity U_∞ and the boundary layer thickness δ as the reference velocity and the characteristic length, respectively, derive by means of the order-of-magnitude analysis the following relationship between the local skin friction coefficient, $C_f (= \tau_w / (\rho U_\infty^2 / 2))$ and the Reynolds number based on the downstream distance x , $Re = (U_\infty x / \nu)$

$$C_f \sim Re_x^{-1/2}$$

(20%)

1. Find the general solution of $xy' - y = \frac{y}{\ln(y) - \ln(x)}$ (12%)

2. Evaluate $\oint_{\Gamma} e^{1/z} dz$

if Γ is a closed path enclosing the origin. (13%)

3. Find the equation of the tangent plane and normal line to the surface $2x = 3 + \cos(xyz)$ at the point $(1, \pi, 1)$. (12%)

4. Find the flux of $\vec{F} = xz\vec{i} - y\vec{k}$ across the part of the sphere $x^2 + y^2 + z^2 = 4$ lying above the plane $z = 1$. (13%)

5. (a) Consider the differential equation

$$(1 - x^2)y'' - 2xy' + \lambda y = 0,$$

in which λ is a constant and $-1 \leq x \leq 1$. Does the above equation constitute a Sturm-Liouville problem?

(b) We can use the convolution theorem to show that the Laplace transform of $\int_0^t f(\tau) d\tau$ is equal to $(1/s)F(s)$. Here, $F(s)$ is the Laplace transform of $f(t)$. What assumptions are needed about $f(t)$? (10%)

6. Determine all possible 2×2 orthogonal matrices. (10%)

7. Let $f(x) = e^{-kx}$ for $x \geq 0$, with k a positive constant. Answer the following.

(a) Is the Fourier cosine integral representation of $f(x)$ equal to $f(x)$ for all $x \geq 0$? Why?

(b) Is the Fourier sine integral representation of $f(x)$ equal to $f(x)$ for all $x \geq 0$? Why?

(c) Is the coefficient $A(\omega)$ in the Fourier cosine integral of $f(x)$ equal to the product of a constant and the Laplace transform of $\cos(\omega x)$? Why? (15%)

8. Solve the problem:

$$\frac{\partial h}{\partial t} = a^2 \left(\frac{\partial^2 h}{\partial x^2} - \frac{\eta}{L} \frac{\partial h}{\partial x} \right) \quad (0 < x < L, t > 0),$$

$$h(0, t) = h(L, t) = 0 \quad (t > 0),$$

$$h(x, 0) = \frac{KL}{a^2 \eta} [1 - e^{-\eta(1-x/L)}] \quad (0 \leq x \leq L). \quad (15\%)$$