

國立中正大學九十學年度碩士班招生考試試題  
系所別：機電光整合工程研究所 科目：物理

本科目分為四大領域，分別為工程力學、電學、光學與熱流，每一領域之分數分別都為 100 分，考生可以任意選擇一領域作答，但不得選擇跨領域作答。

壹、工程力學

1. (25%) Each member of the truss in Fig.1 will safely support a tensile force of 10 kN and a compressive force of 2 kN. What is the largest downward load  $F$  that the truss will safely support?

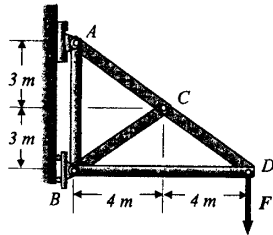


Fig. 1

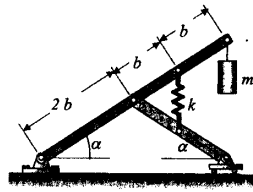


Fig. 2

2. (15%) (a) For the system shown in Fig.2, the spring is unstretched when  $\alpha = 90^\circ$ . If  $mg = bk/2$ , determine the value of  $\alpha$  in the range  $0 < \alpha < 90^\circ$  for which the system is in equilibrium.  
(10%)(b) Determine whether the equilibrium position is stable or unstable.
3. (25%) A disk lying in the horizontal plane rotates about a fixed shaft at the origin with constant angular velocity  $\omega$  as shown in Fig. 3. The slider  $A$  of mass  $m$  moves in a smooth slot in the disk. The spring is unstretched when  $x=0$ . If the slide is given an initial velocity  $\frac{dx}{dt} = v_0$  at  $x=0$ , determine its velocity as a function of  $x$ .

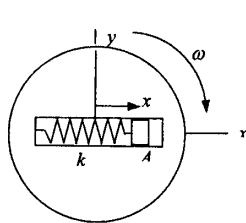


Fig.3

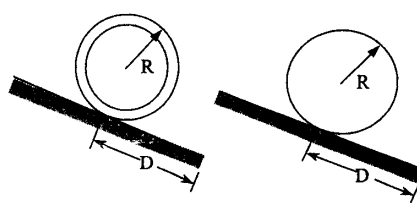


Fig. 4

4. (25%) A thin ring and a circular disk as shown in Fig.4, each of mass  $m$  and radius  $R$ , are released from rest on an inclined surface and allowed to roll a distance  $D$ . Determine the ratio of the times required.

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貳、電學

(一)(25%)圖一中之平行板之面積為 2000 平方厘米或  $2 \times 10^{-1}$  平方米，其間距離為 1 厘米或  $10^{-2}$  米。其間原先之電位差  $V_0$  為 3000 伏特，而當介質層插入板間時，則降低成 1000 伏特。計算(a)原先之電容  $C_0$ ，(b)各板上之電荷  $Q$ ，(c)插入介質後之電容  $C$ ，(d)介質之介質常數  $K$ ，(e)介質之介電係數  $\epsilon$ ，(f)介質各面之感應電荷  $Q_i$ ，(g)板間之原先電場  $E_0$ ，及(h)介質插入後之電場  $E$ 。(空氣之介電係數  $\epsilon = 8.85 \times 10^{-12}$  庫侖<sup>2</sup>牛頓<sup>-1</sup>米<sup>-2</sup>)

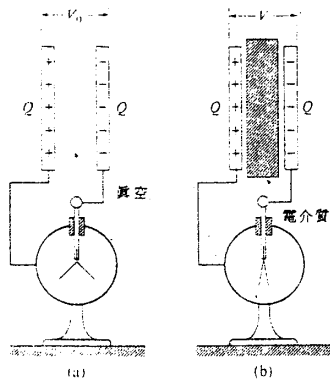


圖 1 電介質置於平行板電容器間之影響。

- (a) 予以已知電荷, 電位差是  $V_0$   
(b) 仍是相同電荷, 電位差  $V$  小於  $V_0$ 。

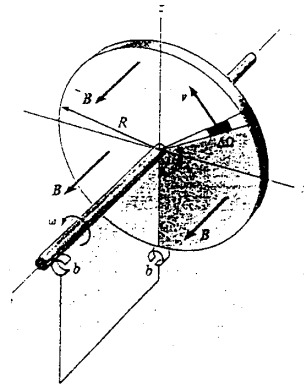


圖 2

(二)(10%)如圖 2 所示，一半徑為  $R$  之圓盤置於  $xz$  平面中，而以均勻之角速度  $\omega$  繞  $y$  軸轉動。該盤是在一平行於  $y$  軸之均勻且恒定之磁場  $B$  中，試計算中心與盤緣間之電動勢。

(三)(15%)試決定下列各線路，何者為低通濾波器？何者為高通濾波器？何者為帶通濾波器？何者為帶拒濾波器？(其中  $\omega = 2\pi f$ )

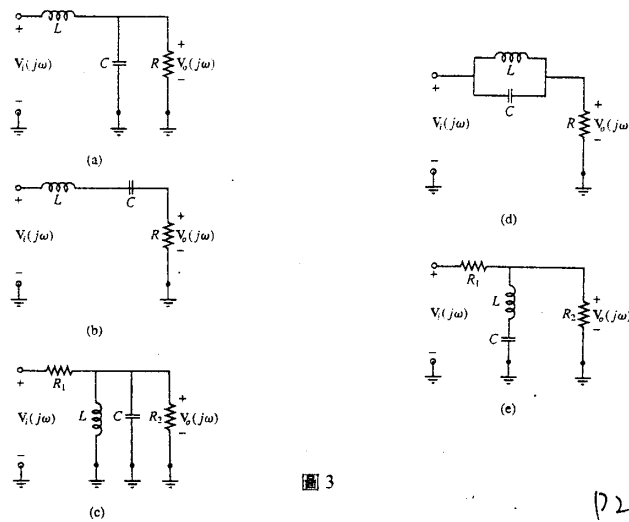


圖 3

D2

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(四)、(10%)在圖 4 的串聯電路中，令  $R=300\Omega$ ， $L=0.9H$ ， $C=2.0\text{Mf}$ ， $\omega=1000$  弧度·秒<sup>-1</sup>。請問跨接感應器，電容器，及電阻的電壓為何？

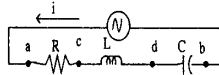


圖 4

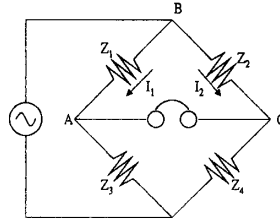


圖 5 惠斯頓電橋

(五)、(10%)有一質點帶電荷  $q=3 \times 10^{-9}$  庫侖，從 a 到 b 沿一直線運行一總距離  $d=0.5$  公尺。沿這線是均勻電場，方向是自 a 到 b，大小是  $E=200$  牛頓·庫侖<sup>-1</sup>。求作用於 q 的力，電場作用於這點 q 的功，與電位差  $V_a-V_b$ 。

(六)(10%)試分析如圖 5 惠斯頓型電橋(Wheatstone type Bridge)的平衡條件(以  $Z_i$  的關係表示)。

(七)(10%)設長導線載電流  $I$ ，另一方線圈其邊長為  $b$ ，寬為  $a$ ，自導線邊緣以  $v$  速度平行離開導線，如圖 6 所示，試計算方線圈之磁通量及電動勢。

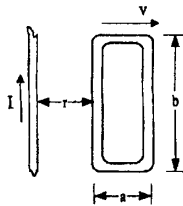


圖 6 直線電流所建立的磁場

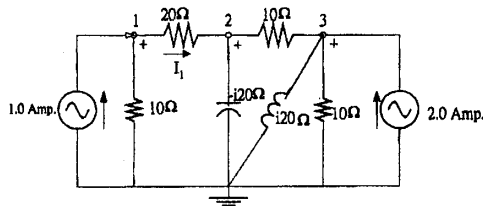


圖 7 電位差法的運用

(八)(10%)電路如圖 7，試求  $I_1$ 。

**參、光學**

1. A natural light is incident into a cup of milk. Please draw the scattered light polarization states for different scattering directions. (10%)
2. A horizontally linear polarized light is needed in one experiment, but unfortunately, we only have a vertically linear polarized light source, how can we obtain a horizontally linear polarized light. (5%)
3. Suppose you have a piece of very thin metal foil for which you want to measure the thickness accurately. You place two microscope slides together so they are touching at one end, but they are held apart at the other end by the piece of foil. Using light from a sodium lamp ( $\lambda_0=589 \text{ nm}$ ) that is normally incident on the air "film" formed between two slides, you observe 40 bright fringes from the edges in contact to the edges held apart by the foil. What is the thickness of the foil? (15%)

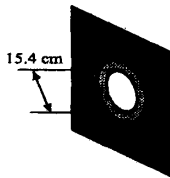
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4. An Yb:YAG laser defense weapon is mounted on a military tank (Yb stands for the rare-earth element Ytterbium pronounced "yuh-ter-be-um" and YAG is an acronym for Yttrium Aluminum Garnet, a kind of crystal). The laser has wavelength of 1030 nm and is aimed at an incoming missile 0.3 miles away. At the output of the laser, the beam has a diameter of 1mm and it propagates to the missile it "diffracts" (expands) so that its diameter at the missile is 0.5 m. If the laser has output power of 1 MW (mega-Watt), what is the time average intensity  $\langle I \rangle$  of the light at the output of the laser and at the missile? If there was a 10 cm diameter detector on the missile (that is a smart missile, and it wants to know when it is being targeted!), what would be the power measured? (10%)

5. Suppose you are handed a pinhole (essentially a small piece of metal with a very tiny circular hole in it) and a HeNe laser ( $\lambda = 633 \text{ nm}$ ), and told to determine the diameter of the pinhole. You shine the laser through the pinhole and onto a screen 10 m away. You observe the resulting diffraction pattern and measure a diameter of 15.4 cm across the first-zero "ring". (a) What is the diameter of the pinhole? (b) If the pinhole was smaller, would the diameter of the first-zero "ring" be larger or smaller? Why? (10%)



6. Given the wave equation  $\frac{\partial^2 \psi}{\partial x^2} - \frac{1}{v^2} \frac{\partial^2 \psi}{\partial t^2} = 0$ , determine which of the following describes traveling waves:

(a)  $\psi(x, t) = \exp[-(a^2 x^2 + b^2 t^2 - 2abtx)]$ ,

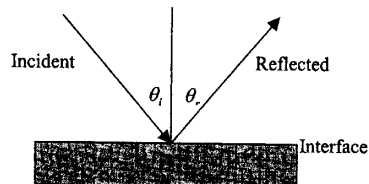
(b)  $\psi(x, t) = A \sin(ax^2 - bt^2)$ ,

(c)  $\psi(x, t) = A \sin 2\pi \left( \frac{x}{a} + \frac{t}{b} \right)^2$ ,

(d)  $\psi(x, t) = A \cos^2 2\pi(t - x)$ ,

(e)  $\psi(x, t) = A \exp(-\alpha x) \cdot \cos(ax - bt)$ . (10%)

7. Derive the Law of Reflection,  $\theta_i = \theta_r$ , (as depicted in the figure below), by using the calculus to minimize the transit time, as required by Fermat's principle. (10%)



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8. A biconcave lens ( $n_l = 1.5$ ) has radii of 20 cm and 10 cm and an axial thickness of 5 cm. Describe the image of an object 1-inch tall placed 8 cm from the first vertex. Use the thin-lens equation to see how far off it is in determining the final-image location. (10%)

9. Determine the state of polarization of the following waves:

- (a)  $\vec{E}(z,t) = \hat{x}E_0 \cos(kz - \omega t) - \hat{y}E_0 \cos(kz - \omega t)$ ,
- (b)  $\vec{E}(z,t) = \hat{x}E_0 \sin(kz - \omega t) - \hat{y}E_0 \sin(kz - \omega t)$ ,
- (c)  $\vec{E}(z,t) = \hat{x}E_0 \sin(\omega t - kz) + \hat{y}E_0 \sin(\omega t - kz - \pi/4)$ ,
- (d)  $\vec{E}(z,t) = \hat{x}E_0 \cos(\omega t - kz) + \hat{y}E_0 \cos(\omega t - kz + \pi/2)$ . (10%)

10. Image that we chop a continuous laser beam (assumed to be monochromatic at  $\lambda_0 = 632.8 \text{ nm}$ ) into 0.1-ns pulses, using some sort of shutter. Compute the resultant linewidth  $\Delta\lambda$ , bandwidth, and coherence length. Find the bandwidth and linewidth that would result if we could chop at  $10^{15} \text{ Hz}$ . (10%)

### 肆、熱力與流力

1. One kilogram of air, initially at 5 bar, 350 K, and 3 kilograms of carbon dioxide ( $\text{CO}_2$ ), initially at 2 bar, 450K, are confined to opposite sides of a rigid, well-insulated container, as illustrated in Figure 1. The partition is free to move and allows conduction from one gas to the other without energy storage in the partition itself. The air and carbon dioxide each behaves as ideal gases. Determine the final equilibrium temperature (in K) and pressure (in bar). Assume air and carbon dioxide each behaves as ideal gases and with constant specific heats. For air  $c_p = 1.013 \text{ kJ/kgK}$ ,  $c_v = 0.726 \text{ kJ/kgK}$ ; for  $\text{CO}_2$   $c_p = 0.939 \text{ kJ/kgK}$ ,  $c_v = 0.750 \text{ kJ/kgK}$ . (20%)



Figure 1

2. As shown in Figure 2, electronic components mounted on a flat plate are cooled by convection to the surroundings and by liquid water circulating through a U-tube bonded to the plate. At steady state, water enters the tube at 20°C and a velocity of 0.4 m/s and exits at 24°C with a negligible change in pressure. The electrical components receive 0.5kW of electrical power. The rate of energy transfer by convection from the plate-mounted electronics is estimated to be 0.08 kW. If kinetic and potential energy effects of water can be ignored. Determine the tube diameter, in cm. (If the water is assumed with constant specific volume,  $v = 1.0018 \times 10^{-3} \text{ m}^3/\text{kg}$ , and the specific enthalpies at 20°C and 24°C are  $h(20^\circ\text{C}) = 83.96 \text{ kJ/kg}$  and  $h(24^\circ\text{C}) = 100.7 \text{ kJ/kg}$ , respectively.) (15%)

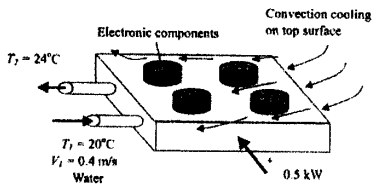


Figure 2

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3. An isolated system, see Figure 3, of total mass  $m$  is formed by mixing two equal masses of the same liquid initial at temperature  $T_1$  and  $T_2$ . Eventually, the system attains an equilibrium state. Each mass is incompressible with constant specific heat  $c$ .

(a) show that the amount of entropy produced,  $\sigma$ , is

$$\sigma = mc \ln \left[ \frac{T_1 + T_2}{2\sqrt{T_1 T_2}} \right]. \quad (10\%)$$

(b) demonstrate that  $\sigma$  must be positive. (5%)

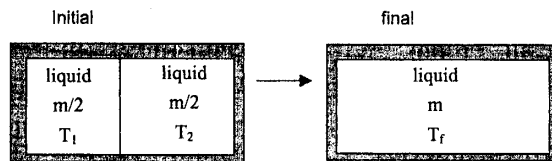


Figure 3

4. A drop of water in a zero-g environment (as in the Space Shuttle) will assume a spherical shape as shown in the left portion of Figure 4. The shape of a raindrop in earth is more nearly like that shown in the right portion of Figure 4. Please explain why these shapes are as indicated. (10%)



Figure 4

5. The fluid velocity along the  $x$  axis shown in Figure 5 changes from 6 m/s at point A to 18 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 B and C. Assume steady state. (10%)

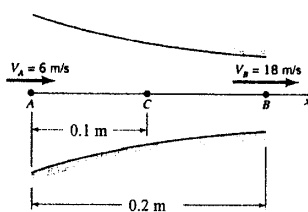


Figure 5

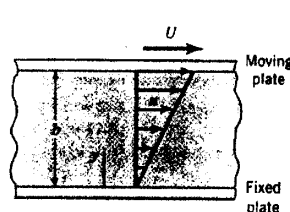


Figure 6

6. An incompressible viscous fluid is placed between two parallel plates as shown in Figure 6. The bottom plate is fixed and the upper plate moves with a constant velocity,  $U$ . For these conditions the velocity distribution between the plates is linear and can be expressed as  $u = Uy/b$ . Please determine (a) the rate of work done by the upper plate on the fluid per unit area (10%), (b) the volumetric dilatation rate (5%), and (c) the vorticity (5%)

7. Please explain the physical meanings of (a) "streamline" and (b) "potential flow". (10%)