2020 年　澳門中學物理競賽

Concurso de Física para Alunos do Ensino Secundário de Macau 2020

高级组

Avançada

學生証號碼:

Número do Cartão de Estudante _____

座位編號:

Número do Assento _____

競賽答卷注意事項

1. 使用藍色或黑色圓珠筆答題。若使用鉛筆和其他顏色筆答卷，可被視爲白卷處理。

2. 將答題內容填寫在每一題下方框內。若空間不足，可使用每頁背面的方框繼續填寫。若空間再不足，可使用答卷最後補充頁上（第 17 至 18 頁）的方框繼續填寫，但需要標注填寫內容對應的題號。

3. 保持卷面整潔，適當使用草稿紙。卷面不可使用塗改工具。若必要，可用圓珠筆劃去已填下的不適用內容。

4. 本卷有概念題 5 題及計算題 5 題。概念題每題 10 分、計算題每題 20 分。卷面共 150 分。

Guidelines when answering the exam paper

1. Use blue or black pens to answer. If you use pencils or pens of other colors, those parts might be ignored and considered blank.

2. Fill in your answers within the bounding boxes under the questions. If the space is not enough, you can use the boxed spaces on the back. If that space is still not enough, you can use the boxed spaces on the supplementary pages (pp. 17 and 18) and supply the corresponding question number when you fill in the answers.

3. Keep the pages clean and use the provided scrap papers when needed. Do not use erasing or covering materials on the exam paper. If necessary, strike out the improper filled contents with cross lines.

4. There are 5 concept questions and 5 calculation questions. Each concept question is worth 10 points while each calculation question is worth 20 points. The total number of points counted in the exam is 150.

第一部分：概念题　　PART I: Concept questions

1. 簡述 LCD 顯示屏的工作原理。
   Briefly explain the working principles of a liquid crystal display panel.

2. 當一個橡膠輪胎沿一斜面向下滾動時，運動中有摩擦力存在嗎？滾動過程中，動能與勢能能量守恆嗎？請簡單解釋。
When a rubber tire is rolling down a slope, does friction exist during the motion? During the process of rolling, do the kinetic and potential energies follow the law of conservation of energy? Briefly explain.

3. 什麼是洛倫茲變換？試舉一個例子來說明。
What is Lorentz transformation? Use one example to illustrate briefly.

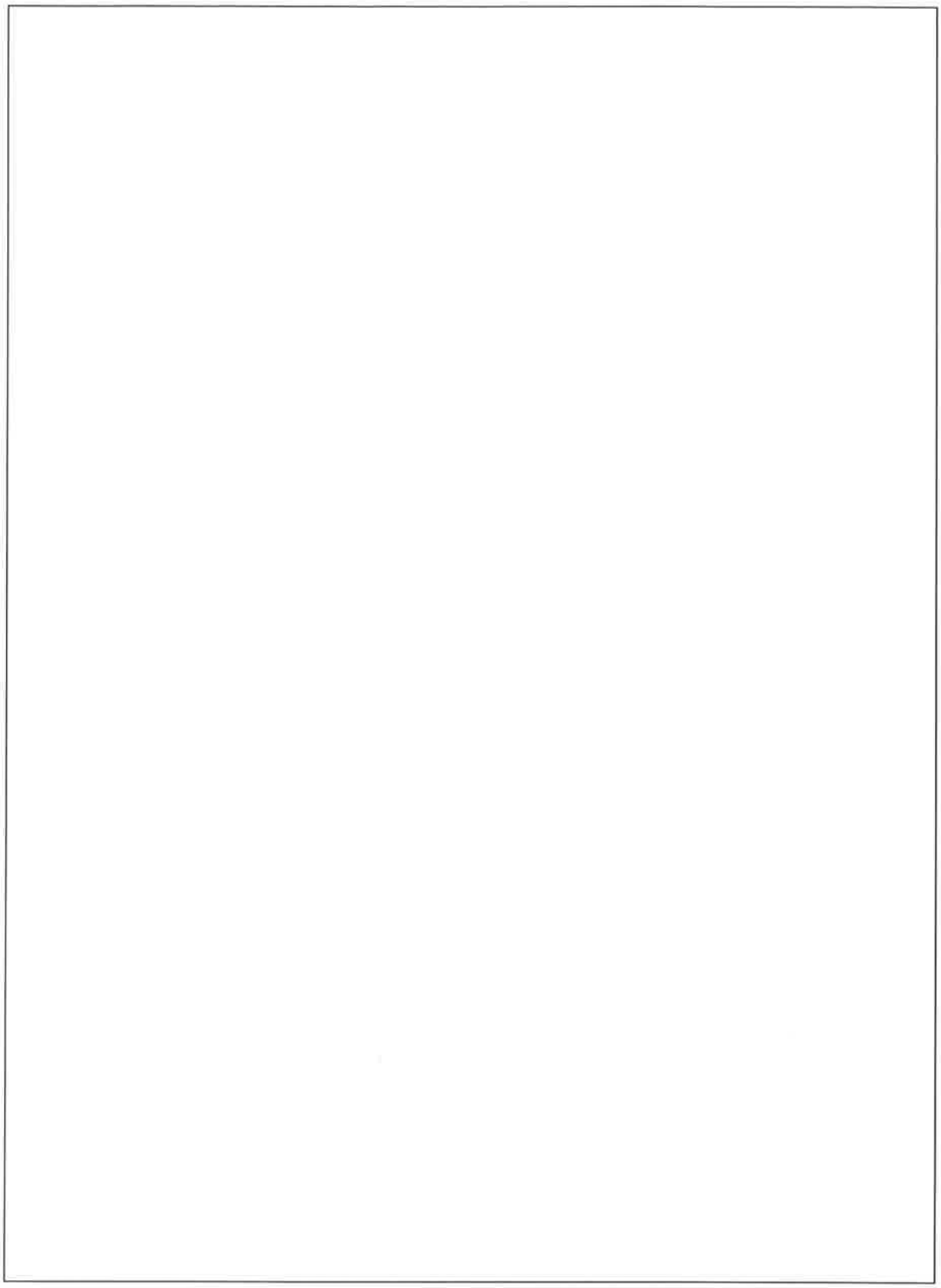
4. 簡述什麼是惠更斯原理。
State the Huygens principle in brief terms.

5. 單擺的週期依賴於引力加速度g和懸掛重量的細繩的長度l。現考慮一情景，假設單擺運動的平面不與地面垂直正交，而是於正交平面形成一θ角，那麼週期的公式是什麼？

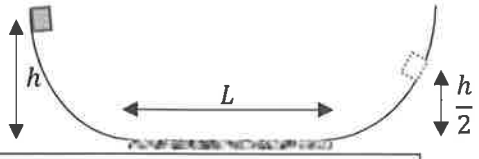
The period of a simple pendulum depends on the gravitational acceleration g and the length l of the string that suspends a weight. Consider the scenario where the plane of the pendulating motion is not perpendicular to the ground, but rather forms an angle θ with the orthogonal plane. What is then the formula of the period?

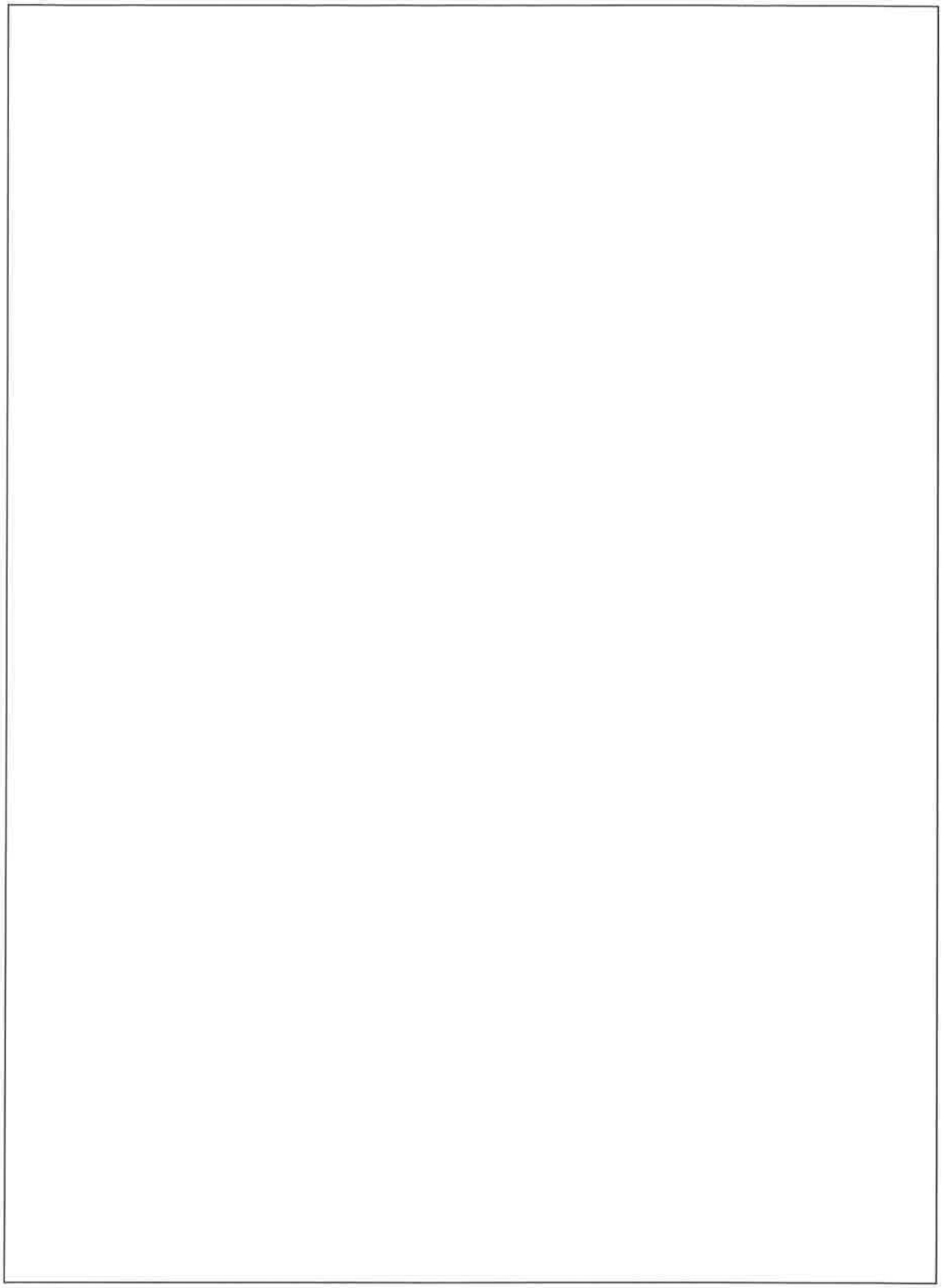
第二部分：計算題　PART II: Calculation questions

1. 設想一個立方體，在其十二個棱的每個棱上裝上一個 10 μF 的電容。那麼立方體對角線上的兩個節點間的等效電容是多少？
   Consider a cube where each of its twelve edges is installed a capacitor of 10μF. What is the equivalent capacitance across the two opposing nodes on the diagonal of the cube?

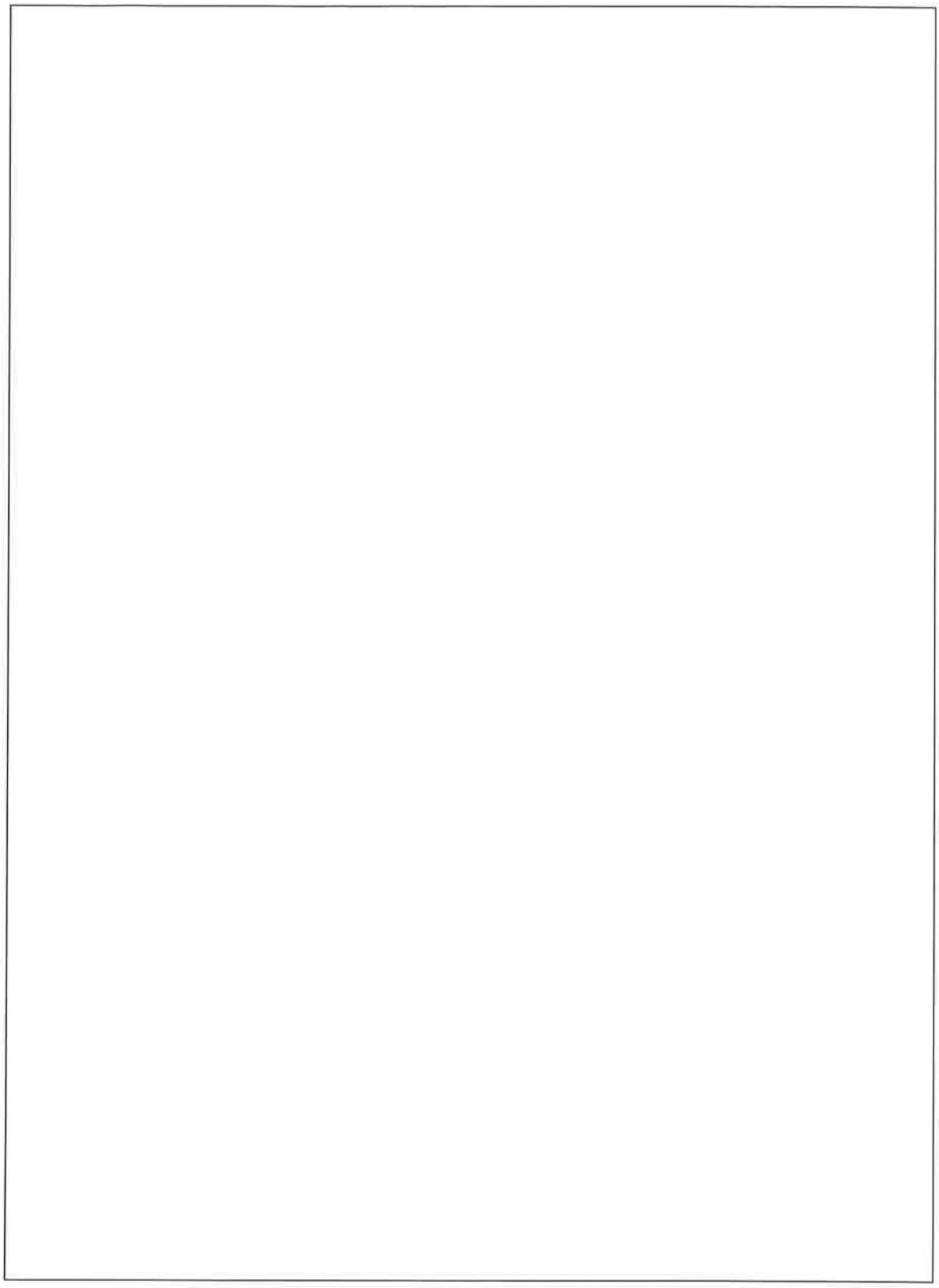


2. 如圖所示，一質量 m 的質塊滑下一高度爲 h 的光滑無摩擦的曲面，經過一段帶摩擦、長度爲 L 的水平面，再沿着另一光滑無摩擦的曲面向上滑動。假如最終質塊能滑到的高度爲 $h/2$，水平面的摩擦係數應爲多少？只考慮靜摩擦力。
As shown in the figure, a block of mass m slides down a smooth frictionless curve surface of height h, enters a frictional horizontal surface of length L, and then slides up another smooth frictionless curve surface. What should the friction coefficient of the horizontal surface be if the block slides up a height of $h/2$? Only static friction needs to be considered.



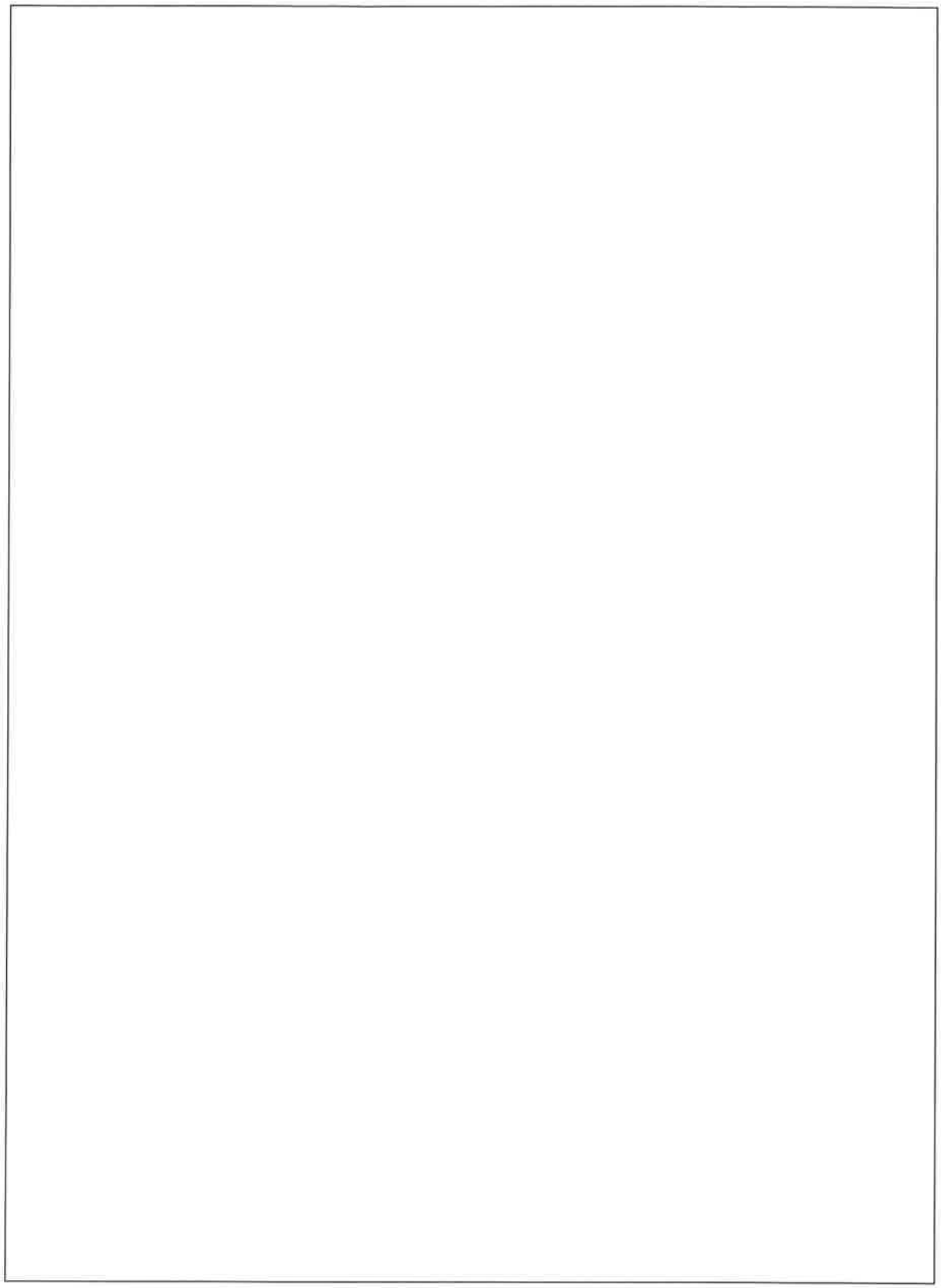


3. 一數碼相機有一正方形 CCD 感光元件，其邊長L爲 24mm，其像素值爲 3 百萬像素。相機鏡頭的光圈數 $F = f/D$定義爲鏡頭焦距 f與光圈直徑 D的比值，可被設爲 2、2.8、4、5.6、8 或 11。對於一波長 $\lambda = 650$nm，穿過焦距 35mm 鏡頭的光束，最佳空間分辨率$\Delta x_{\min}$是多少？若要拍攝出這個分辨率的照片，相機的 CCD 夠好嗎？不是的話，在同樣大小下，至少需要多少像素？[提示：利用瑞利公式]
The square CCD of a digital camera has edge length $L = 24$ mm and total pixel number $N = 3$ Megapixels. The aperture number $F = f/D$ of the camera lens is defined as the ratio of the focal length f of the lens to the aperture diameter D. F can be set to 2, 2.8, 4, 5.6, 8, or 11. For a light beam of wavelength $\lambda = 650$ nm going through a lens of focal length 35mm, what is the best spatial resolution $\Delta x_{\min}$? Is the CCD good enough to capture an image of this resolution? If not, given the same size, what should be the minimal total pixel number [Hint: use Rayleigh's formula.]



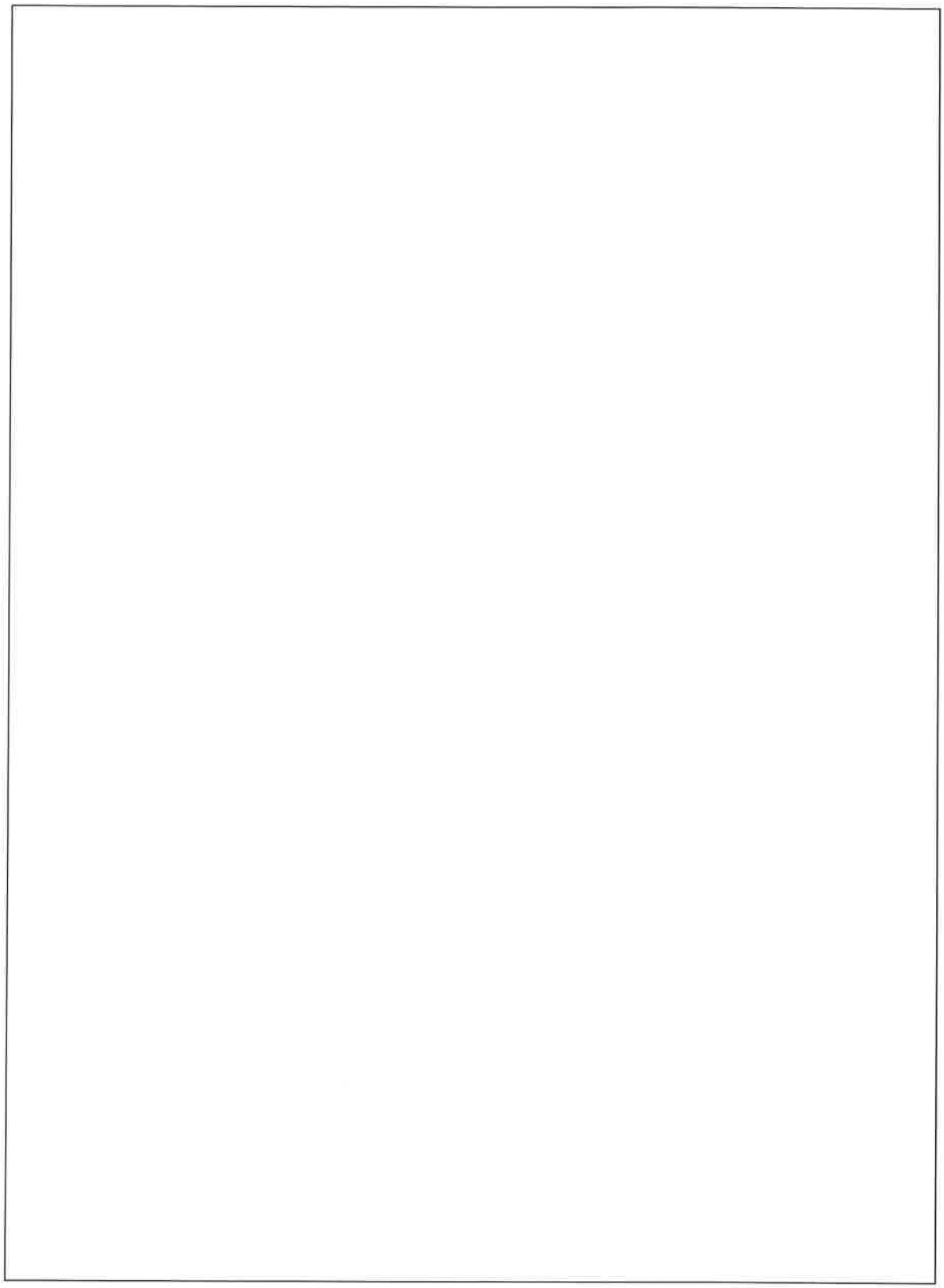
4. 一質量 m 的衛星在地球的同步軌道上圍繞地球轉動。已知地球半徑是 6370 公里以及重力加速度爲 9. 8 ms^{-2}，那麼衛星的軌道半徑是多少？若衛星的質量翻倍，軌道半徑會怎麼改變？

   A satellite of mass m is orbiting about the Earth in a circular geosynchronous orbit. Given the radius of Earth $R_E = 6370$ km and the gravitational acceleration $g = 9.8ms^{-2}$, what is orbit radius r of the satellite? If the satellite mass is doubled, how would the orbit radius change?



5. 數模轉換器（DAC）是一個將由離散電壓表達的比特字串轉換成模擬電壓的電子器件。例如，若由 0V 表達 0 及 1V 表達 1，一個 4 比特字串 0110 可通過連接 DAC 電路的 4 個輸入口轉換成 $6/2^4 = 0.375V$。它等價於將二進制數轉換成十進制數。一個簡單實現 DAC 的方法可由拼組 R 歐姆與 2R 歐姆的電阻而成，其中 R 可以取任意歐姆值。畫出一個 4 比特 DAC 的電路圖，並證明其輸出端口的電壓值確實滿足所要功能。

A digital-analog-converter (DAC) is a device that converts a string of bits in discrete voltage into an analog voltage. For example, using 0V (ground) to represent 0 and 1V to represent 1, a 4-bit string 0110 connecting to 4 input ports of a DAC circuit can be converted into $6/2^4 = 0.375V$. It is equivalent to a base-2 number to base-10 number conversion. One simple implementation of DAC is to interconnect a set of resistors of R ohm and $2R$ ohm, where the value of R is arbitrary. Draw a circuit diagram of such a 4-bit DAC and show that the voltage at the output port indeed satisfies the desired function.



補充頁 1

補充頁 2