2022 年　澳門中學物理競賽

Concurso de Física para Alunos do Ensino Secundário de Macau 2022

初级组

Elementar

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.

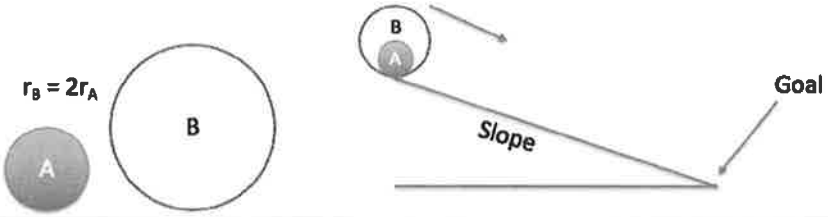
3. Keep the pages clean and use the provided scrap papers when needed. Do not use erasing or covering materials on the exam paper. If necessary, strike out the improper filled contents with cross lines.

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：概念題　　PART I: Concept questions

1. 兩個圓盤 A 和 B 具有相同的質量。 B 的半徑是 A 半徑的兩倍。假設它們被放置在斜坡的頂部，並且同時從靜止狀態向下坡移動。 在沒有摩擦力下，哪一個能先到達斜坡盡頭？為什麼？（提示：圓盤的轉速取決於轉動慣量。轉動慣量越大→相同扭矩下轉動速度越慢）

   Two discs, A and B, have the same mass. Radius of B is two times the radius of A. Suppose that they are placed at the top of a slope and are allowed to move down from rest at the same time. Assuming that there is no friction, which one can reach the goal first? Why? (Hint: the rotation speed of a disc depends on the moment of inertia. Larger moment of inertia → slower rotational speed under the same torque)



2. 玻璃、銀和鑽石中，哪一種的導熱能力最高？ 哪個導熱能力最低？ 解釋你的選擇。
Among glass, silver and diamond, which one has the highest heat conductivity? Which one has the lowest heat conductivity? Explain your choice.

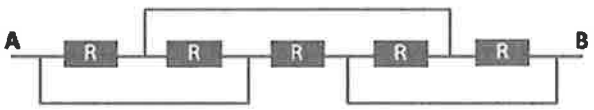
3. 在室溫下（例如 24 °C），冰會自發融化成水，但水不會自動凍結成冰。 為什麼？ 冰箱如何將水冷凍成冰？
   At room temperature (e.g. 24 °C), ice spontaneously melts into water but water does not automatically freeze into ice. Why? How does a fridge freeze water into ice?

4. 天空的顏色在一天中的不同時間會發生變化。解釋此現象。
The color of the sky changes at different times of the day. Explain the phenomenon.

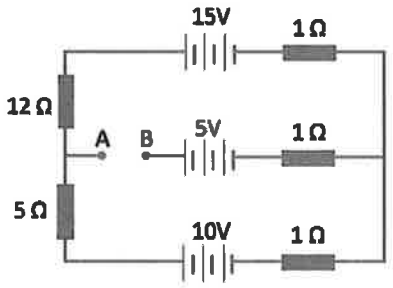
5. 在地球上，乒乓球會在水面上漂浮，但在無重力的外太空中乒乓球不會自動浮上水面，試解釋箇中原因。
Table tennis ball floats in water on the Earth but not in outer space where gravity is negligible. Explain the phenomenon.

第二部分：計算題　　PART II: Calculation questions

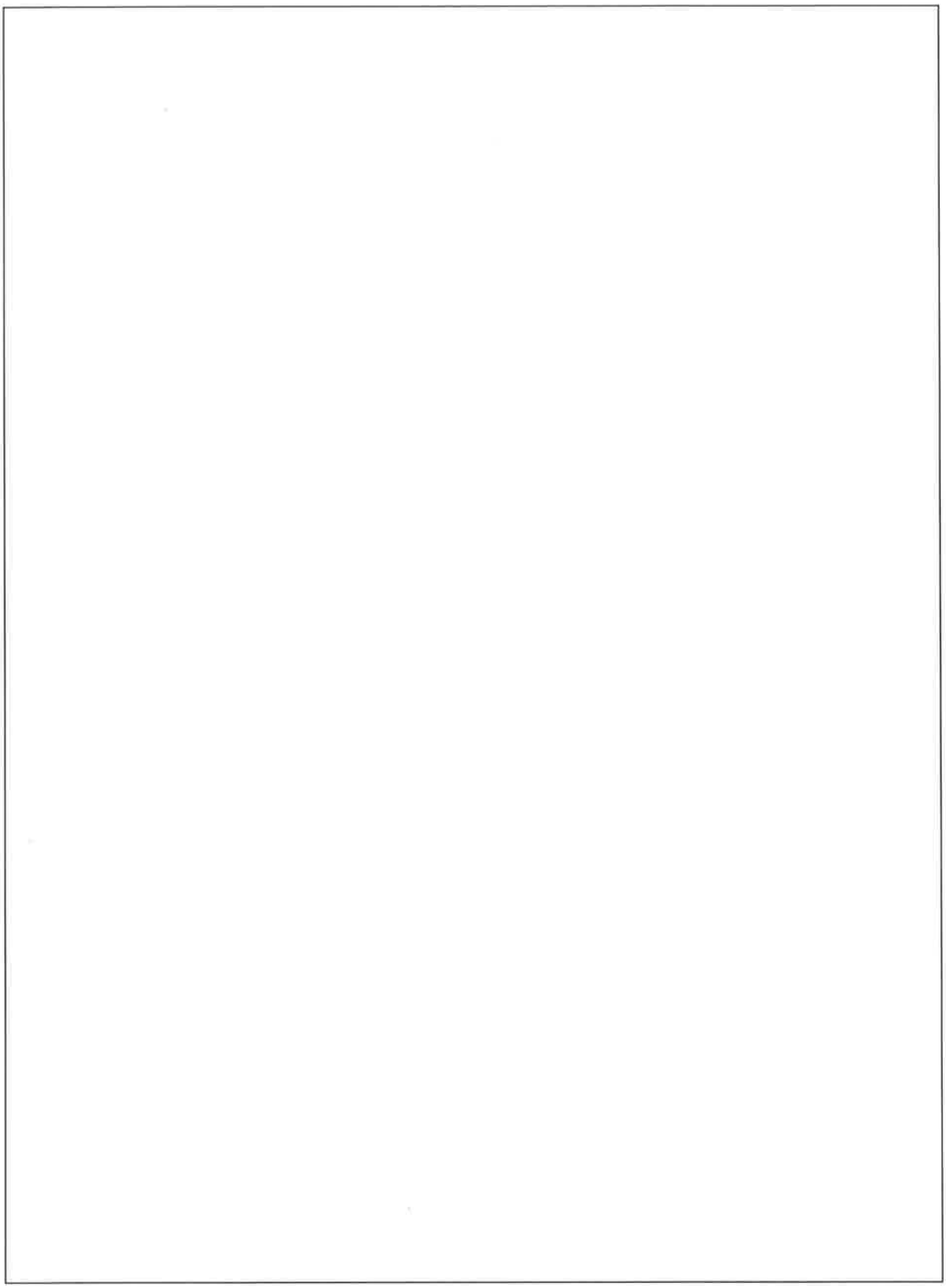
1. (i) 在電路 (I) 中，找出 A 和 B 之間的等效電阻。
   In Circuit (I), find the equivalent resistance across A and B.
   (ii) 在電路 (II) 中，找出 A 和 B 之間的電位差。
   In Circuit (II), find the potential difference between A and B.



(I)

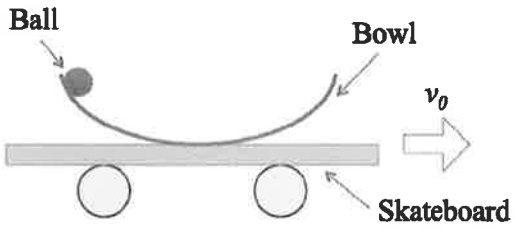


(II)

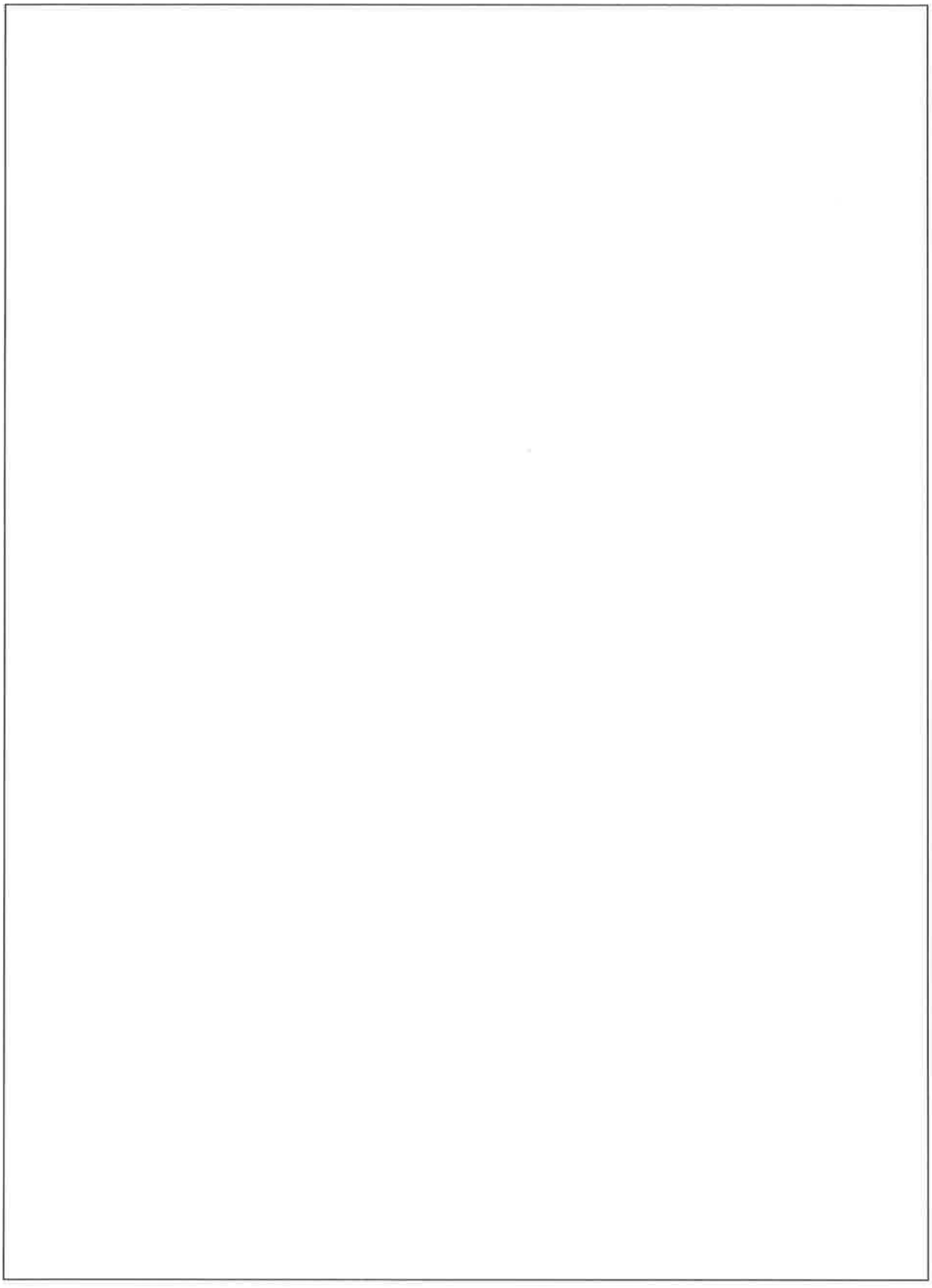


2.

右圖顯示了一個質量為 m 的球，從一個碗的邊緣滑下，而該碗粘附在一架滑板之上。 碗和滑板總質量為 M，並一起移動。在時間 t = 0 時，滑板相對於地面以 v_o 的速度向右移動，而球相對於碗則處於靜止狀態。 在 $t = t_1$ 時，球滑下至碗底，相對於滑板的速度為 v_b 。在這一刻，滑板相對於地面的速度是多少？



The figure shows a ball of mass m rolling down a bowl glued onto a skateboard. The bowl and the skateboard move together and have a total mass of M. At time t = 0, the skateboard moves to the right with a speed of v_o with respect to the ground, while the ball is at rest relative to the bowl. The ball slides down and reaches the bottom of the bowl at $t = t_1$, with a speed of v_b relative to the skateboard. At this instant, what is the speed of the skateboard with respect to the ground?



3. (a) 電荷 Q 在 P 點處的電勢可以算式 $V = \frac{1}{4\pi\epsilon_o}\frac{Q}{r}$ 計算，當中 r 是 P 與 Q 的距離，ϵ_o 是介電常數。考慮相距 d 的兩個 +q 電荷。證明兩電荷中間點的電勢為

$$V_a = \frac{q}{\pi\epsilon_o r}$$

(提示：電勢是一個標量，總電勢是每個電荷引起的電勢的總和)

(b) 考慮一個實心立方體，邊長為 a, 並具有均勻電荷密度 ρ。已知立方體中心的電位為

$$V_{cube} \approx \frac{0.1894\rho a^2}{\epsilon_o}$$

使用此結果回答以下問題。用 ρ、a 和 ϵ_o 表達你的答案，數字常數應保留小數後四位。

(i) 在同一個立方體中，一個角上的電勢 V_{corner} 是多少?

(ii) 考慮一個邊長為 a、高為 a/2 且均勻電荷密度為 ρ 的正方形底邊的金字塔。金字塔頂端的電位 V_{tip} 是多少?

(iii) 考慮一個邊長為 a 且面積電荷密度為 σ 的正方形板，證明在其中心上方 a/2 高度處的電勢為

$$V_{plate} \approx \frac{0.126\sigma a}{\epsilon_o}$$

(a) The electric potential at a point P due to a charge Q can be calculated by $V = \frac{1}{4\pi\epsilon_o}\frac{Q}{r}$, where r is the distance of P from Q and ϵ_o is the permittivity constant. Consider two $+q$ charges separated by a distance of d. Show that the electric potential at the mid-point between the two charges is

$$V_a = \frac{q}{\pi\epsilon_o r}$$

(Hint: Electric potential is a **scalar** quantity – the resultant electric potential is simply the algebraic sum of the electric potential caused by each charge)

(b) Now consider a solid cube with a uniform charge density ρ and side length a. It is known that the electric potential at the center of the cube is

$$V_{cube} \approx \frac{0.1894\rho a^2}{\epsilon_o}$$

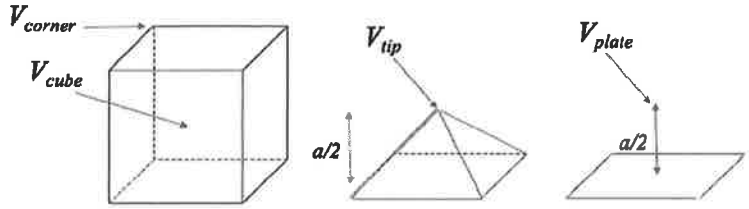
Use this result to answer the following questions. Express your answers in terms of ρ, a and ϵ_o. Keep four decimal places for any numerical constant.

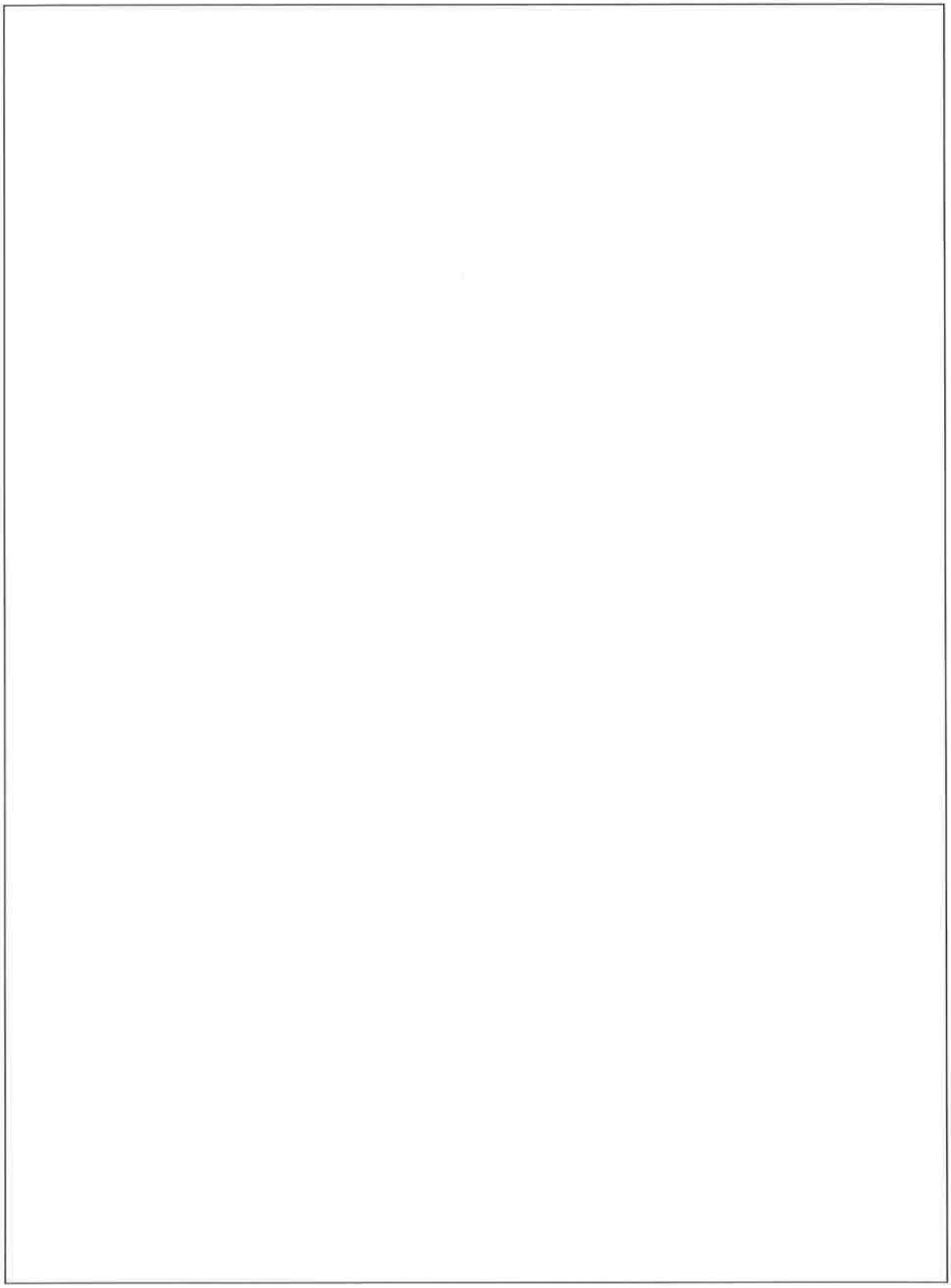
(i) What is the electric potential V_{corner} at a corner of the same cube?

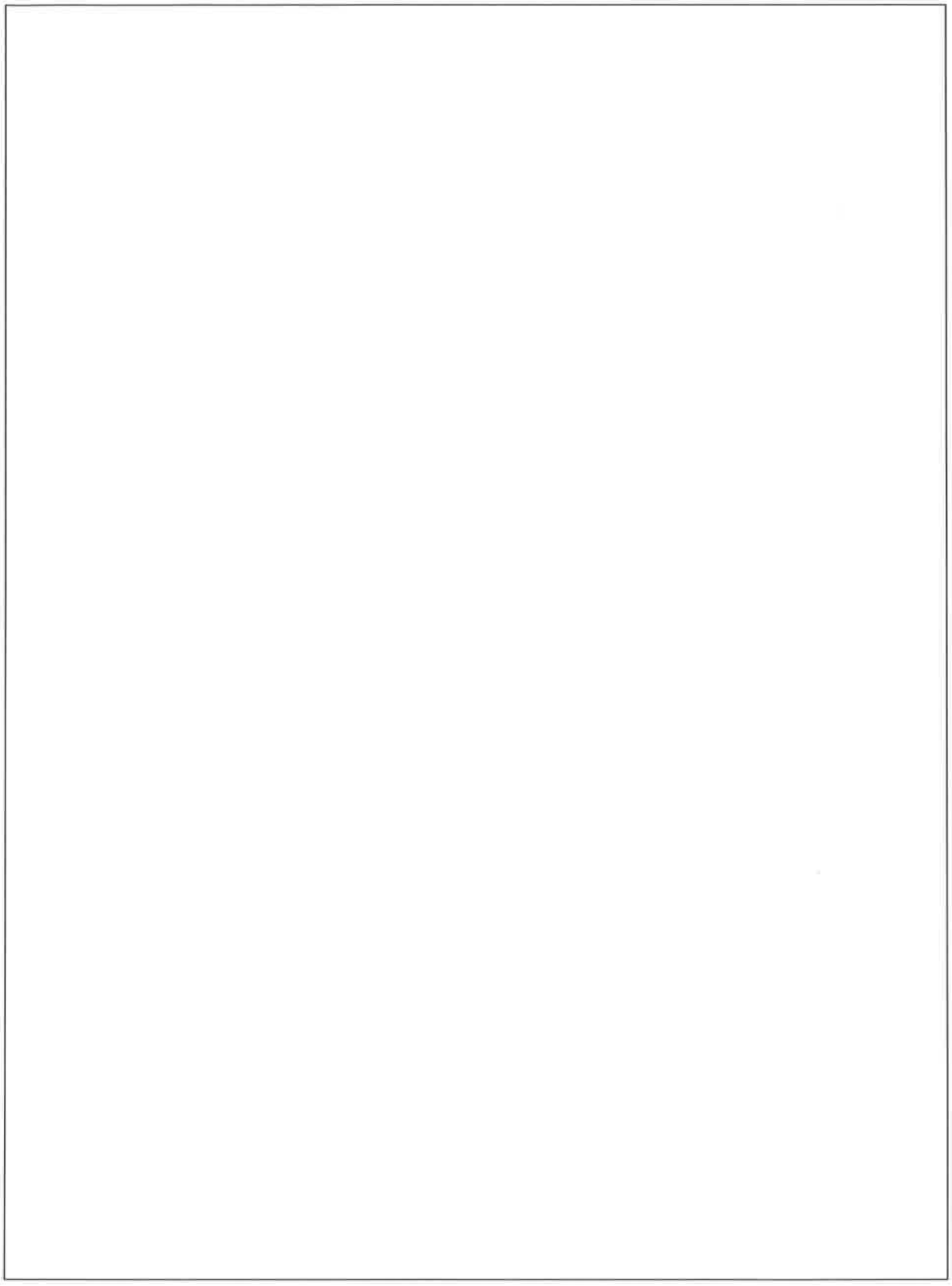
(ii) Consider a pyramid with a square base of side length a, height $a/2$ and uniform charge density of ρ. What is the electric potential V_{tip} at the tip of the pyramid?

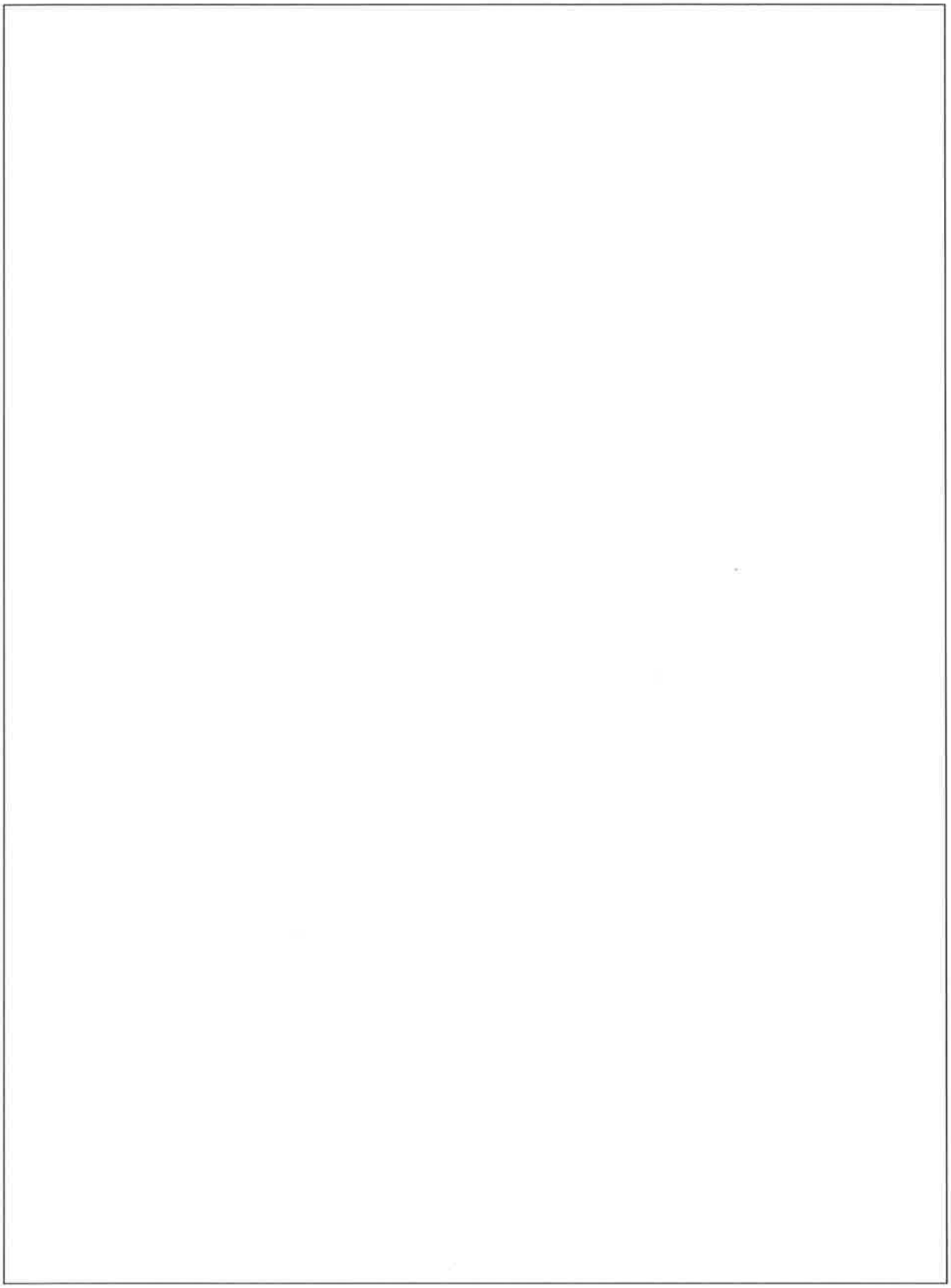
(iii) Prove that the electric potential due to a square plate with side length a of uniform area charge density σ at a height $a/2$ above its center is

$$V_{plate} \approx \frac{0.126\sigma a}{\epsilon_o}$$









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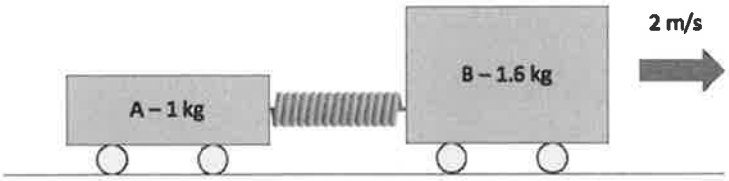


小車 A 和 B 由質量可忽略不計的彈簧連接在一起。 彈簧被壓縮和夾緊，而推車和彈簧作為一個整體移動。 最初，小車們以 2 m/s 的速度向右移動。 在 $t = t_1$ 時，夾具突然鬆開，小車分開，小車 B 以 2.5 m/s 的速度向右移動。

Carts A and B are linked together by a spring with negligible mass. The spring is compressed and clamped so that the carts and the springs are moving as a single unit. Initially, the carts move towards the right with a speed of 2 m/s. At time $t = t_1$, the clamp is suddenly released and the carts separate, with cart B moving to the right at 2.5 m/s.

(a) 在彈簧解壓後，小車 A 的速度是多少？

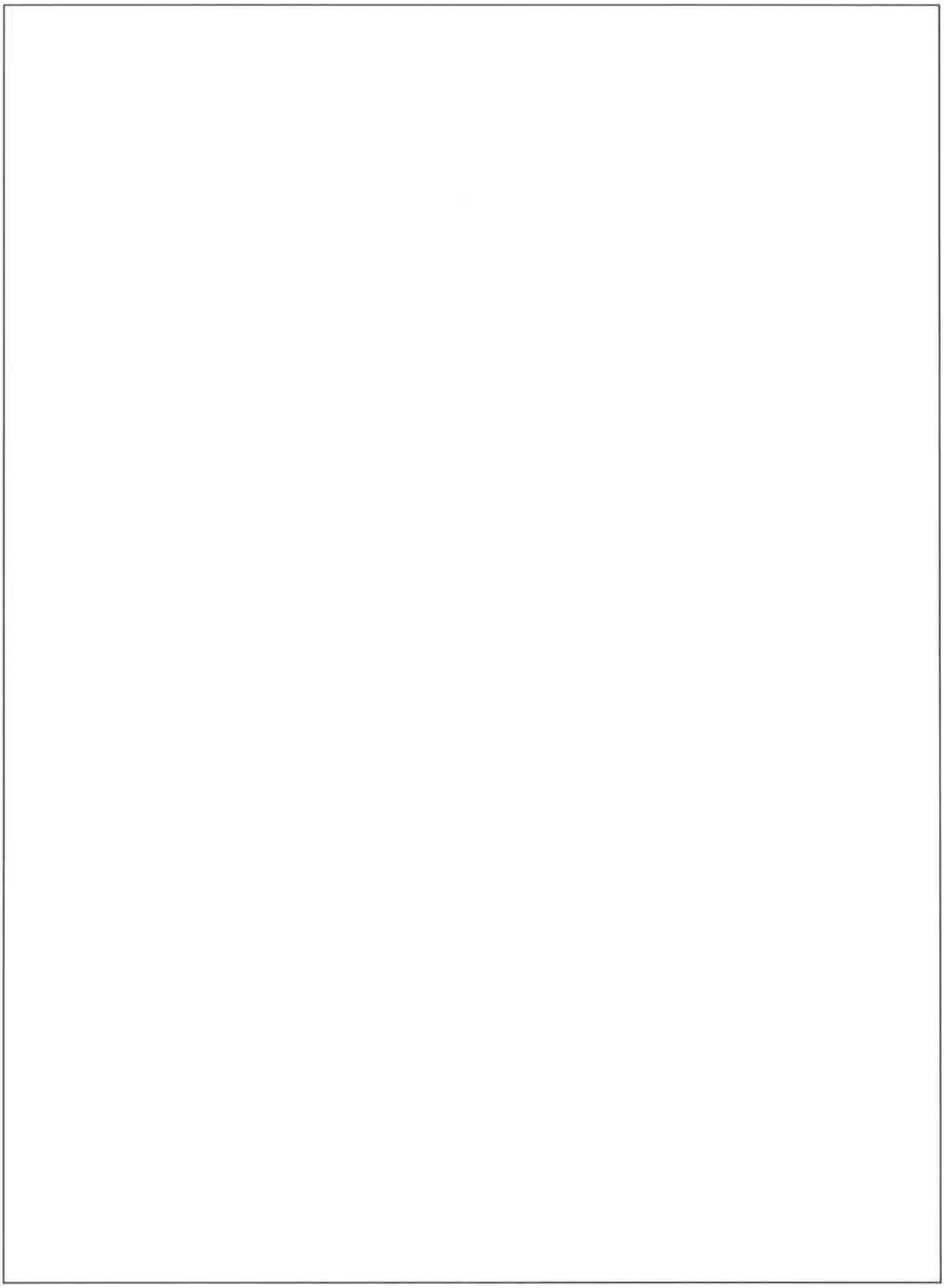
What is the velocity of cart A immediately after the spring decompresses?

(b) 兩車分開後，系統的總動能是否保持不變、增加或減少？ 解釋。

Does the total kinetic energy of the system remain the same, increase or decrease after the separation of the two carts? Explain.

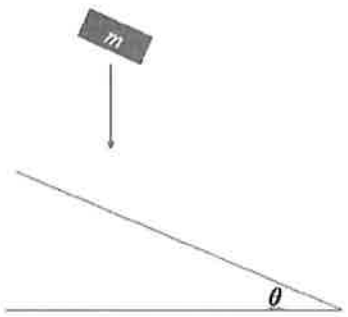
(c) 如果彈簧一開始被壓縮 5 cm，它的彈簧常數是多少？

If the spring is compressed by 5 cm at the beginning, what is its spring constant?



5.

一個質量為 m 的方塊垂直掉落到一個仰角為 θ 的斜坡上，並以速度 v 撞擊斜坡。假設方塊在與斜坡碰撞後不會發生旋轉，而且在整個運動過程中靜止和動態摩擦系數均為 μ。



(a) 如果方塊在撞擊後立即滑下斜坡，速度會是多少？ 以 v、θ 和 μ 表達你的答案。

(b) 如果要讓碰撞後方塊的速度為 0，最小的 μ 值是多少？

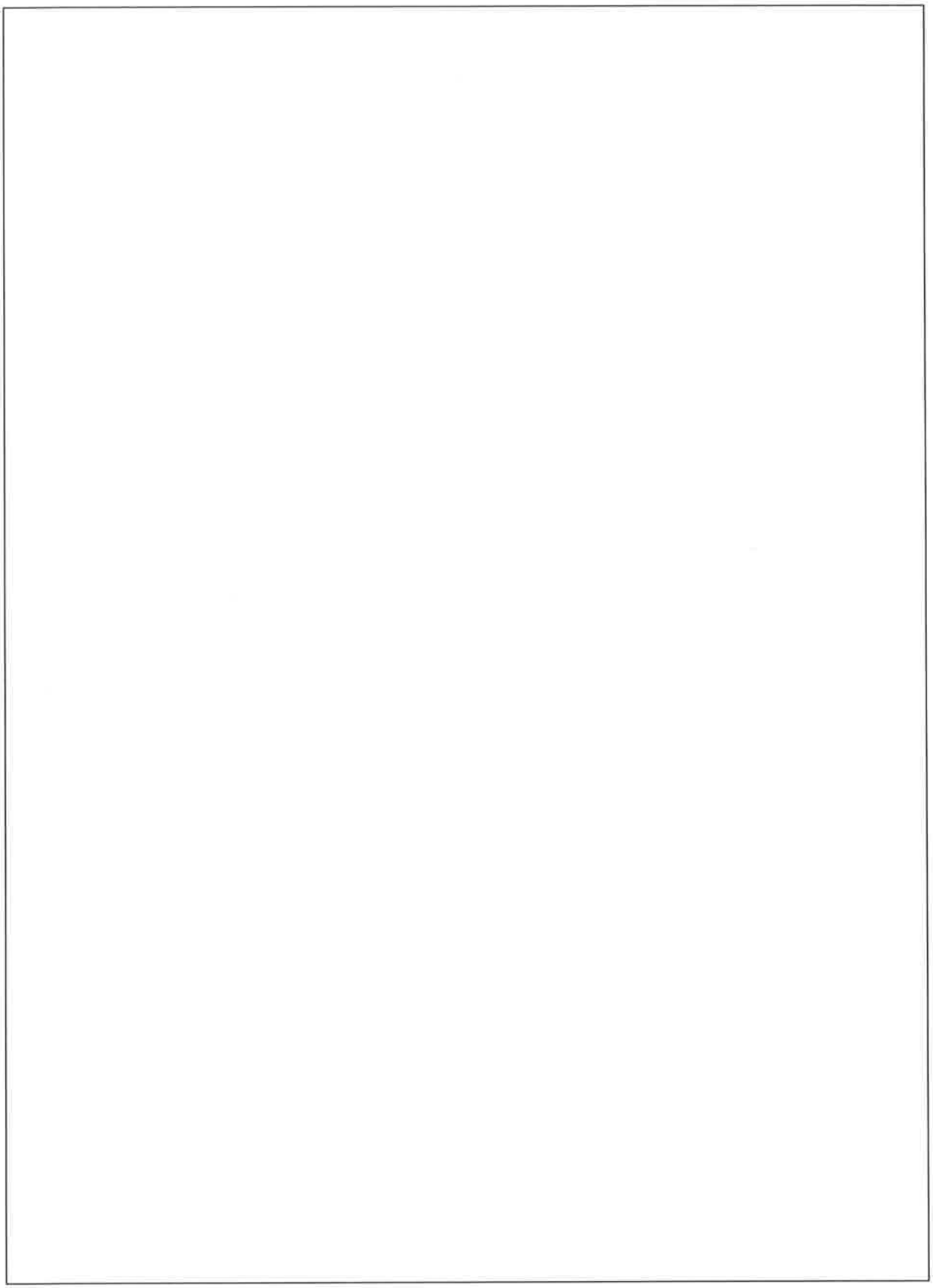
(c) 假設方塊是一塊磁鐵，而斜坡由非磁性金屬製成。 當方塊向下滑動時，一個會阻礙方塊運動的電磁力 F_e 將會產生。假設 $F_e = bv_s$，其中 b 是一個常數，v_s 是滑動速度。 運動的最終速度是多少？ （提示：識別所有作用在方塊上的力，當中包括摩擦力）

A block of mass m is allowed to fall vertically onto a fixed ramp with an elevation angle θ and hits the ramp at a speed v. The block is dropped in such a way that it does not rotate after colliding with the ramp. Assume the static and dynamic frictional coefficients are μ throughout the motion.

(a) If the block slides down the ramp immediately after the impact, what is the speed of the block right after the collision? Express your answer in terms of v, θ *and* μ.

(b) What is the minimum μ such that the speed of the block right after the collision is 0?

(c) Suppose that the block is a magnet and the ramp is made of non-magnetic metal. As the block slides down, an electromagnetic force F_e would be induced and hinder the motion. Assume that $F_e = bv_s$, where b is a constant and v_s is the sliding speed. What is the terminal speed of the motion? (Hint: Identify all forces, including friction, acting on the block when it slides down)



補充頁 1

補充頁 2