Hong Kong Physics Olympiad 2012
2012 年香港物理奧林匹克競賽

(Senior Level 高級組)

Jointly Organized by

The Hong Kong Academy for Gifted Education
香港資優教育學院
The Education Bureau of HKSAR
香港特區政府教育局
The Hong Kong Physical Society
香港物理學會
The Hong Kong University of Science and Technology
香港科技大學

共同舉辦

March 17, 2012
2012 年 3 月 17 日

Rules and Regulations 競賽規則

1. All questions are in bilingual versions. You can answer in either Chinese or English.

   所有題目均爲中英對照。你可選擇以中文或英文作答。

2. The multiple-choice answer sheet will be collected 1.5 hours after the start of the contest. You can start answering the open-ended questions any time after you have completed the multiple-choice questions without waiting for announcements.

   選擇題的答題紙將於比賽開始後一小時三十分收回。若你在這之前已完成了選擇題，你亦可開始作答開放式題目，而無須等候任何宣佈。

3. Please follow the instructions on the multiple-choice answer sheet, and use a HB pencil to write your 8-dight Participant ID Number in the field of "I. D. No.", and fill out the appropriate circles **fully**. After that, write your English name in the space provided and your Hong Kong ID number in the field of "Course & Section No."

   請依照選擇題答題紙的指示，用 HB 鉛筆在選擇題答題紙的 "I. D. No." 欄上首先寫上你的 8 位數字參賽號碼，並把相應寫有數字的圓圈**完全塗黑**，然後在適當的空格填上你的英文姓名，最後於 "Course & Section No. " 欄內填上你的身分證號碼。

4. After you have made the choice in answering a multiple choice question, fill the corresponding circle on the multiple-choice answer sheet **fully** using a HB pencil.

   選定選擇題的答案後，請將選擇題答題紙上相應的圓圈用 HB 鉛筆**完全塗黑**。

5. On the cover of the answer book, please write your Hong Kong ID number in the field of "Course Title", and write your English name in the field of "Student Name" and your 8-dight Participant I. D. Number in the field of "Student Number". You can write your answers on both sides of the sheets in the answer book.

   在答題簿封面上，請於 Course Title 欄中填上你的身分證號碼；請於 Student Name 欄中填上你的英文姓名；請於 Student Number 欄中填上你的 8 位數字參賽號碼。 答題簿可雙面使用。

6. The information provided in the text and in the figure of a question should be put to use together.

   解題時要將文字和簡圖提供的條件一起考慮。

7. Some open problems are quite long. Read the entire problem before attempting to solve them. If you cannot solve the whole problem, try to solve some parts of it. You can even use the answers in some unsolved parts as inputs to solve the others parts of a problem.

   開放題較長，最好將整題閱讀完後才著手解題。若某些部分不會做，也可把它們的答案當作已知來做其它部分。

The following symbols and constants are used throughout the examination paper unless otherwise specified:

g – gravitational acceleration on Earth surface, 9.8 (m/s^2)
G – gravitational constant, 6.67×10^{-11} (N m^2/kg^2)
e – charge of an electron, -1.6×10^{-19} (A s)
ε_0 – electrostatic constant, 8.85×10^{-12} (A s)/(V m)
m_e – electron mass = 9.11×10^{-31} kg
c – speed of light in vacuum, 3.0×10^8 m/s
Mass of Earth = 5.97×10^{24} kg
Radius of Earth = 6,371 km
Mass of Moon = 7.4×10^{22} kg
Radius of Moon = 1,737 km
Density of water = 1.0×10^3 kg/m^3
Air Density at 20 °C and 1 atm = 1.2 kg/m^3

除非特別注明，否則本卷將使用下列符號和常數：

g – 地球表面重力加速度, 9.8 (m/s^2)
G – 萬有引力常數, 6.67×10^{-11} (N m^2/kg^2)
e – 電子電荷, -1.6×10^{-19} (A s)
ε_0 – 靜電常數, 8.85×10^{-12} (A s)/(V m)
m_e – 電子質量, 9.11×10^{-31} kg
c – 真空光速, 3.0×10^8 m/s
地球質量 = 5.97×10^{24} kg
地球半徑 = 6,371 km
月球質量 = 7.4×10^{22} kg
月球半徑 = 1,737 km
水的密度 = 1.0×10^3 kg/m^3
20 °C、一個大氣壓的空氣密度 = 1.2 kg/m^3

The following conditions will be applied to all questions unless otherwise specified:

1) All objects are near Earth surface and the gravity is pointing downwards.
2) Neglect air resistance.
3) All speeds are much smaller than the speed of light in vacuum.

除非特別注明，否則下列條件將適用於本卷所有問題：

1) 所有物體都處於地球表面，重力向下；
2) 忽略空氣阻力；
3) 所有速度均遠小於真空中的光速。

Multiple Choice Questions

(2 points each. Total 10 MC's. Select one answer in each question.)

選擇題（每題 2 分，共 10 題，每題選擇一個答案。）

The questions with the '*' sign may require information on page-3.

帶 * 的題可能需要用到第三頁上的資料。

MC1 選擇題 1

Two small blocks A and B with mass ratio $M_A / M_B = 3$ are connected by a light spring and on a smooth horizontal floor. The blocks are pressed towards each other a little and then released. The ratio of the maximum displacements from their initial positions of the two blocks A_A / A_B is _____.

二個物塊 A、B，其質量比爲 $M_A / M_B = 3$ ，以一輕彈簧相連，並放在水平的光滑平面上。現將两物塊壓縮一點後放開，則物塊最大位移之比 A_A / A_B 爲_____。

(a) 1/9 (b) 1/3 (c) 1 (d) 3 (e) 9

MC2 選擇題 2

Following MC1, the ratio of maximum momenta of the two blocks P_A / P_B is _____.

接上題。物塊最大動量之比 P_A / P_B 爲_____。

(a) 9 (b) 3 (c) 1 (d) 1/3 (e) 1/9

MC3 選擇題 3

Following MC1, the ratio of maximum kinetic energy E_A / E_B is _____.

接上題。物塊最大動能之比 E_A / E_B 爲_____ 。

(a) 9 (b) 3 (c) 1 (d) 1/3 (e) 1/9

MC4* 選擇題 4

The period of a simple pendulum on the ground is 1 s. If it is placed on the surface of the moon, the period of the pendulum will approximately be _____.

一個單擺，在地面的週期爲 1 秒。若將它放在月球表面，則它的週期約爲_____。

(a) 11.2 s (b) 1 s (c) 2.45 s (d) 0 (e) ∞

MC5 選擇題 5

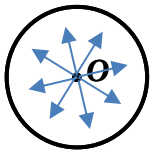
If the pendulum in MC4 is placed on a satellite on a circular orbit around Earth at 100 km above the ground, its period will approximately be _____.

若將 MC4 裡的單擺放在離地面 100 公里在圓形軌道上運行的衛星上，則它的週期約爲_____ 。

(a) 11.2 s (b) 1 s (c) 2.45 s (d) 0 (e) ∞

MC6 選擇題 6

Electric current I is flowing out from point-O and spread out radially on a conducting plane. Find the magnetic field amplitude on the axis through point-O and perpendicular to the plane, at distance H from the plane.



電流 I 從 O-點均勻地在一導電面上沿徑向向外流出。中心軸經過 O-點與平面垂直。求在軸上距離平面 H 处的磁場強度。

(a) 0 (b) $\frac{\mu_0 I}{2\pi H}$ (c) $\frac{\mu_0 I}{\pi H}$ (d) $\frac{2\mu_0 I}{\pi H}$ (e) $\frac{\mu_0 I}{4\pi H}$

MC7 選擇題 7

Two chambers of the same volume are filled with air and connected by a pathway. The temperatures in the two chambers are maintained at different values. Which chamber contains more air?

(a) the chamber with lower temperature
(b) the chamber with higher temperature
(c) the chamber with higher pressure
(d) neither, because both have the same pressure
(e) neither, because both have the same volume

二個相同體積的腔室充滿空氣，並由通道相連，如果兩個腔室的溫度不同，那麼哪個腔室含有較多的空氣？

(a) 溫度較低的腔室　(b) 溫度較高的腔室　(c) 氣壓較高的腔室
(d) 都不是，因爲它們具有相同的氣壓　(e)都不是，因爲它們具有相同的體積。

MC8 選擇題 8

Which of the following correctly describes the difference between microwaves and radio waves?

(a) Microwaves are used for communication but not radio waves.
(b) Microwaves are electromagnetic waves, while radio waves are sound waves.
(c) Microwaves travel faster in vacuum than radio waves.
(d) Microwaves carry energy but radio waves do not.
(e) Radio waves can go around a building but microwaves cannot.

以下哪一項正確地形容微波及無線電波的分別？

(a) 微波可用來通訊但無線電波不能。
(b) 微波是電磁波，無線電波是聲波。
(c) 在真空中，微波的傳播速度比無線電波快。
(d) 微波帶有能量而無線電波沒有。
(e) 無線電波能繞過大廈但微波不能。

MC9 選擇題 9

Which of the following statements about a magnetic mono-pole is correct?

(a) It must have a south pole.
(b) It must have a north pole.
(c) It has a south pole or a north pole, but not both.
(d) It must have a north pole and a south pole.
(e) It must have more than one pairs of north poles and south poles.

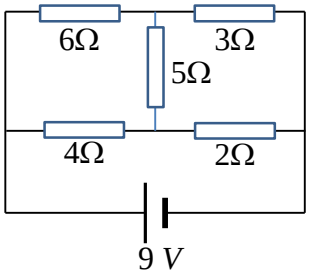
以下哪一項關於磁單極子的說明是正確的？

(a) 它只含有南極。
(b) 它只含有北極。
(c) 它有一個南極或一個北極，但不能同時含有兩極。
(d) 它必須有一個北極和一個南極。
(e) 它必須有一對以上的南、北極。

MC10 選擇題 10

As shown, the electric currenet through the 3Ω resistor is _____ Amperes.
如圖所示，流經 3Ω電阻的電流爲_____安培。

(a) 0 (b) 1.0 (c) 1.75 (d) 2 (e) 2.25



《End of MC's 選擇題完》

Open Problems 開放題
Total 6 problems 共 6 題

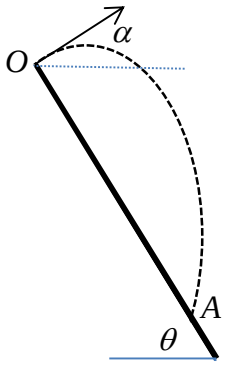
Q1* (10 points)　　題 1（10 分）

Estimate the force of heavy rain on an umbrella, and compared it with that of wind with a modest wind speed of 36 km/hour. Please provide the details on how you reach the answer.

估計下大雨時雨傘受到的衝擊力，并與中度風（風速 36 公里/小時）對傘的力作比較。請給出導出答案所需的細節。

Q2 (10 points)　　題 2（10 分）

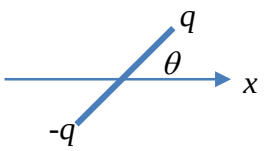
In a ski jumping competition on a slope with inclination angle $\theta = 60^0$, an althlet jumps at point-O with initial speed $v_0 = 25$ m/s and lands at point-A. Find the optimum jumping angle α so that the distance OA is maximum, and the maximum distance. (You may need to use $\sin x \cos y = \frac{\sin(x+y)+\sin(x-y)}{2}$.)



在傾角$\theta = 60^0$的雪坡上舉行跳臺滑雪比賽。運動員在起跳點 O 以速率 $v_0 = 25$ m/s、仰角α 起跳，最後落在斜坡上 A 點。取 O、A 兩點的距離 L 爲比賽成績。求運動員可以跳得最遠距離的仰角α和這個最遠距離 L。(你或許會用到：$\sin x \cos y = \frac{\sin(x+y)+\sin(x-y)}{2}$.)

Q3 (15 points)　　題 3（15 分）

A rigid uniform stick of length L is restricted to move on the horizontal X-Y plane. A point charge q is fixed on one end of the stick and a point charge $-q$ is fixed on the other end. At a particular moment the velocity of the stick center is $\vec{v} = v_x\hat{x} + v_y\hat{y}$, the stick is at an angle θ to the X-axis, and is spinning around its center at angular velocity ω. A uniform magnetic field B is applied along the Z-axis. Find the net force on the stick and the net torque relative to the center of the stick.



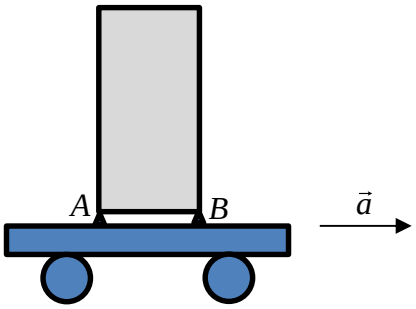
一長度爲 L 的均勻杆，只能在平面 X-Y 上運動。杆的一端帶有點電荷 q，另一端帶有點電荷$-q$。在某一時刻，杆中心的速度爲$\vec{v} = v_x\hat{x} + v_y\hat{y}$，杆與 X-軸成角度$\theta$，杆繞其中心旋轉的角速率爲$\omega$。外加磁場 B 沿 Z-軸方向。求杆受到的合力，以及相對於其中心的力矩。

Q4 (15 points)　　題 4（15 分）

A 50 kg refrigerator, which can be regarded as a uniform block, is resting on two feet A and B on a cart. The static friction coefficient between the feet and the cart floor is 0.4. The height of the refrigerator is 3 times of its width.

(a) Find the maximum horizontal acceleration below which the refrigerator can still rest on the cart. (5 points)

(b) For acceleration $a = 0.1g$, where g is the gravity acceleration, find the total force acting on each foot by the cart. (10 points)



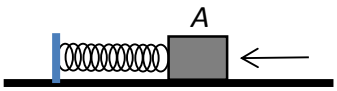
一個質量爲 50 kg 的雪櫃，可當作一個均勻的長方體，其高度是寬度的 3 倍，放在貨車上，雪櫃的前、後腳 A、B 與貨車地板之間的摩擦係數爲 0.4。

(a) 若貨車加速時，雪櫃仍不會相對貨車而動，求最大加速度。（5 分）

(b) 若貨車加速度爲 $a = 0.1g$，g 爲重力加速度，求貨車對雪櫃每個腳的作用力。（10 分）

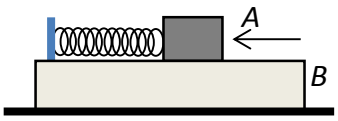
Q5 (10 points)　　題 5（10 分）

(a) A block of mass M is connected to a weight-less spring with force constant k and on a horizontal plane. The friction coefficient between the block and the floor is μ. Initially the spring is at its natural length. Now give the block an initial velocity v to the left. If the block stops oscillating completely before it moves to the right, find the displacement of the block and the initial velovity in tems of M, k, μ, and gravity acceleration g. (4 points)



一質量爲 M 的方塊，連在一力常數爲 k 的輕彈簧上。物塊與水平面之間的摩擦係數爲μ。初始時彈簧沒有被拉開或壓縮。現給物塊一個向左的初始速度 v。若物塊在向右運動前已不再振動，求它的位移和初始速度。答案需以 M、k、μ、重力加速度 g 表達。（4 分）

(b) The block-spring assembly in (a) is now fixed on a plateform B with the same mass M as the block, which is on a smooth floor, as shown in the figure. The friction coefficient between the block and the platform is μ. Initially the spring is at its natural length. Now give the block an initial velocity v to the left. If the block stops oscillating completely before it moves to the right relative to the platform, find the displacement of the block relative to the platform and the initial velovity in tems of M, k, μ, and gravity acceleration g. (6 points)



將物塊和彈簧放在質量同樣爲 M 的底座 B 上，物塊 A 與底座 B 之間的摩擦係數爲μ。底座放在平滑的平面上。初始時彈簧沒有被拉開或壓縮。現給物塊一個向左的初始速度 v。若物塊相對於底座向右運動前已不再振動，求它相對於底座的位移和初始速度。答案需以 M、k、μ、重力加速度 g 表達。（6 分）

Q6 (20 points)　　題 6（20 分）

A number of gas cylinders, each containing n moles of ideal gas with pressure P_0 and volume V_0, are used to fill up an empty tank with volume $V = 10V_0$, until the gas pressure in it reaches $P = P_0 / 2$. The temperature remains the same throughout the process.

(a) If a gas pump is used to pump all the gas inside a cylinder to the tank, how many cylinders of gas is needed? (5 points)

(b) If the pump is not used, then the gas transfer can only be done by natural flow of gas. Suppose a number of cylinders can be connected together and to the tank. A valve on the inlet of the tank is then opened to let gas flow until no gas is flowing in or out of the tank. How many cylinders of gas is needed? (5 points)

(c) Suppose each time only one cylinder can be connected to the inlet of the tank and no pump is used. After the gas stops flowing, the valve is closed, the cylinder is removed, and another cylinder full of gas is connected to the inlet,…., find the number of cylinders needed. (10 points)

若干容積爲 V_0 的氣瓶，每瓶裝有氣壓爲 P_0 的 n 摩爾理想氣體，被用來給一個空的氣室充氣，直到氣室的氣壓達到 $P = P_0 / 2$。氣室的容積爲 $V = 10V_0$。在整個充氣過程中氣體的溫度不變。

(a) 若使用氣泵，把每個氣瓶裡的氣體全部抽進氣室，需要用幾瓶氣？ (5 分)

(b) 若不用氣泵，則充氣只能靠氣體的自然流動來實現。如果可以一次把幾個氣瓶和氣室連接在一起，打開氣室入口的閥門讓氣體流入，氣體停止流動後將閥門關上，需要用幾瓶氣? (5 分)

(c) 若不用氣泵，並且每次只能把一個氣瓶連接到氣室的入口，气体停止流動後將閥門關上，将气瓶移走，换上另一瓶满的气瓶，….，需要用幾瓶氣? (10 分)

《END 完》