Hong Kong Physics Olympiad 2003

2003 香港物理奧林匹克

Education and Manpower Bureau 教育統籌局
Physical Society of Hong Kong 香港物理學會
Hong Kong University of Science and Technology 香港科技大學

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25 May 2003

Multiple-choice Questions 選擇題

Multiple-choice Questions
(2 points for each question, 20 questions in total)
選擇題 (共 20 題，每題 2 分)

The following constants may be useful 可用物理常數：

Specific latent heat of fusion of ice (冰的溶解比潛熱) = 334 KJ/kg
Specific heat capacity of water (水的比熱容量) = 4.2 KJ/kg/K

MC1

Ball A was dropped from the top of a tall building. At the same instant and from the same height ball B was thrown straight downward. Neglecting the effects of air friction, compare their accelerations while they were falling.

A. Their accelerations are equal.
B. Ball A has the greater acceleration.
C. Ball B has the greater acceleration.
D. It is impossible to tell since their accelerations vary greatly.
E. None of the above.

選擇題 1

有一球 A 從一高建築物的頂部落下，與此同時在同一高度另一球 B 被垂直扔下。若不考慮空氣摩擦力的影響，試比較兩物體在下落過程中的加速度？

A. 相等
B. A 球有更大的加速度
C. B 球有更大的加速度
D. 不可能比較兩者的加速度, 因爲兩者的加速度在下落過程中變化很大
E. 以上描述均不正確

MC2

Two objects, A and B, accelerated from rest at the same uniform rate. Object B accelerated for a distance twice as long distance A. Compare to Object A, Object B was moving

A. Twice as fast.
B. 1.414 times as fast
C. Three times as fast.
D. Four times as fast.
E. None of the above.

選擇題 2

兩個物體 A 和 B 由靜止以同樣的加速率開始加速。若 B 加速的距離是 A 的兩倍，那麼與 A 相比，B 的運動速度：

A. 是 A 速率的 2 倍
B. 是 A 速率的 1.414 倍
C. 是 A 速率的 3 倍
D. 是 A 速率的 4 倍
E. 以上描述均不正確

MC3

Five people measured the distance between 2 points by the same ruler with the following results: (1) 5.0cm, (2) 5.2cm, (3) 4.9cm, (4) 5.0cm, (5) 5.5cm. Which of the following is true?

A. We know *for certain* that the distance is between 4.9cm and 5.5cm.
B. We know *for certain* that the distance is 5.12cm.
C. We know *for certain* that the distance is between 4.92 to 5.34cm.
D. The best estimate of the distance is 5.12cm.
E. None of the above.

選擇題 3
五個人以同一把尺量度兩點之間距離的結果是：(1)5.0 公分 (2)5.2 公分 (3)4.9 公分 (4)5.0 公分 (5)5.5 公分。以下哪一項是正確的？

A. 我們確切的知道距離是於 4.9 公分及 5.5 公分之間
B. 我們確切的知道距離是 5.12 公分
C. 我們確切的知道距離是於 4.92 公分至 5.34 公分之間
D. 最佳的估計距離爲 5.12 公分
E. 以上均不正確

MC4
Which of the following statements is correct?

A. When you are not moving there is no force exerting on you.
B. When there is no force exerting on you, you cannot move.
C. When you are not moving there is no *net* force exerting on you.
D. There must always be force acting on you when you move.
E. None of the above.

選擇題 4
下列哪一項是正確的？

A. 當你靜止時，不會有任何力施加在你身上
B. 當沒有力施加於你身上時，你便不能移動
C. 當你靜止時，不會有淨力施加於你身上
D. 當你移動時，一定要有力施加於你身上
E. 以上均不正確

MC5
A desk and a book are resting on the ground. Which of the following changes when the book is put on the desk?

A. The *net* force acting on the desk.
B. The gravitational force acting on the desk.
C. The reaction force from the ground acting on the desk.
D. The kinetic energy of the book.
E. The kinetic energy of the desk.

選擇題 5
地上分別有一張書桌和一本書。如把書放到書桌上，以下哪項會有轉變？

A. 施加到書桌的淨力
B. 施加到書桌的地心吸力
C. 施加到書桌的地面反作用力
D. 書本的動能
E. 書桌的動能

MC6
A large negatively charged object was placed on an insulated table. A neutral metallic ball rolled straight towards the object but stopped before touching it. A second neutral metallic ball rolled along the same path as the first ball, struck the first ball driving it a bit closer to the negatively charged object and stopped. After all balls stopped rolling, the first ball was closer to the negatively charged object than the second ball. At no time did either ball touch the charged object. Which statement is correct concerning the final charge on each ball?

A. The first ball is positive and the second negative.
B. The first ball is negative and the second positive.
C. Both balls remain neutral.
D. Both balls are positive.
E. None of the above.

選擇題 6

一絕緣的桌子上有一帶負電荷的大物體。一不帶電的金屬球沿著直線向這物體滾過來，但在兩者接觸之前停了下來。此時有第二個不帶電的金屬球也以相同的路徑滾過來，並和第一個金屬球發生碰撞，從而把第一個金屬球又往前推進了一點並停下來，而第一個金屬球較第二個金屬球接近帶負電荷的物體。這兩個金屬球從未和帶電物體接觸。以下哪項描述是正確的：

A. 第一個球帶正電，而第二個球帶負電
B. 第一個球帶負電，而第二個球帶正電
C. 兩球都不帶電
D. 兩球都帶正電
E. 以上描述均不正確

MC7

The lamps in a string of Christmas tree lights are connected in parallel. What happens if one lamp burns out? Assume negligible resistance in the wires leading to lamps.

A. The brightness of the other lamps will not change appreciably.
B. The other lamps get brighter equally.
C. The other lamps get brighter, but some get brighter than others.
D. The other lamps get dimmer equally.
E. The other lamps get dimmer, but some get dimmer than others.

選擇題 7

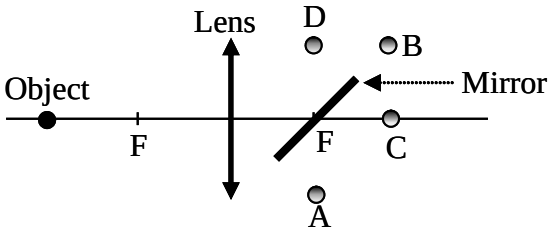
聖誕樹上有一串燈泡被並聯在一起。若其中有一燈泡燒壞了，試問以下哪個描述是正確的：(不考慮電線的電阻)

A. 其他燈泡的亮度不會有明顯變化
B. 其他燈泡都會同等程度地變亮
C. 其他燈泡都會變亮，但變亮的程度不一樣
D. 其他燈泡都會同等程度地變暗
E. 其他燈泡都會變暗，但變暗的程度不一樣

MC8

As shown below, an object is placed on the left side of a lens with its focal points labeled as 'F'. A flat mirror is placed at the right side focal point, with its reflecting surface facing the lens. The image of the object is at

A. Point A
B. Point B
C. Point C
D. Point D
E. Point F on the right side



選擇題 8

如圖示，有一物件放在一透鏡的左邊，F 爲透鏡的焦點。在透鏡的右邊焦點處放了一平面鏡。平面鏡的反射面向著透鏡。物件的影像會落在哪處？

A. A 點
B. B 點
C. C 點
D. D 點
E. 右邊焦點處

MC9

Which of the following setups can make a small conductor coil that is placed horizontally float on top of an object?

A. The object is a magnet that provides a magnetic field pointing straight downward, while the coil carries an electric current flowing clockwise as viewed from top down.
B. The object is a magnet that provides a magnetic field pointing straight downward, while the coil carries an electric current flowing counterclockwise as viewed from top down.
C. The object carries positive electric charge while the coil carries negative charge.
D. The object carries negative electric charge while the coil carries positive charge.
E. None of the above.

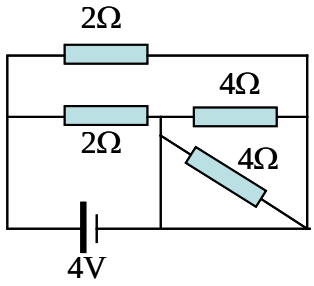
選擇題 9

以下哪一個情況能導致一個水平平放的小導體線圈懸浮於另一物體上？

A. 物體是一塊磁場垂直向下的磁鐵，而線圈帶有順時針方向(從上方觀察)流動的電流
B. 物體是一塊磁場垂直向下的磁鐵，而線圈帶有反時針方向(從上方觀察)流動的電流
C. 物體攜帶正電荷而線圈攜帶負電荷
D. 物體攜帶負電荷而線圈攜帶正電荷
E. 以上均不正確

MC10

In the following circuit, the current through the battery is



A. 4 A
B. 3 A
C. 2 A
D. 1 A
E. None of the above

選擇題 10

在電路圖中，通過電池的電流是

A. 4 安培
B. 3 安培
C. 2 安培
D. 1 安培
E. 以上均不是

MC11

Car A ran the red light and hit Car B which had the right of way at the intersection. Car A was more severely damaged than Car B, but fortunately no one was injured. You are to investigate the accident and decide which of the following statements is correct.

A. Driver of Car A was at fault because Car A collided with Car B before Car B collided with Car A.
B. Driver of Car A was at fault even though both cars collided at the same moment.
C. Both drivers were at fault because both cars collided at the same moment.
D. Driver of Car B was at fault because Car B exerted more force on Car A, and as a result, Car A was damaged more.
E. Driver of Car A was at fault because being the initiator Car A exerted more force on Car B.

選擇題 11

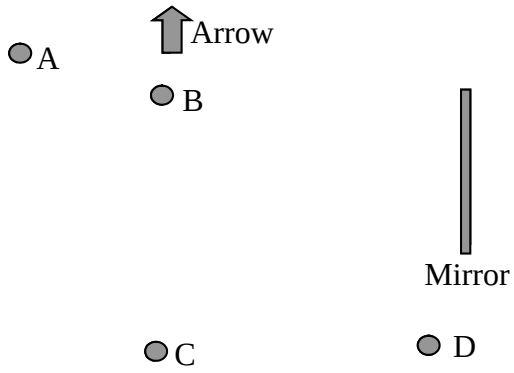
正在十字路口行駛中的車輛乙被衝過紅色交通燈的車輛甲撞到。車輛甲較車輛乙損毀嚴重，但幸虧沒有人受傷。你現在要調查此交通意外及判斷以下哪種是正確的說法：

A. 犯錯的是車輛甲的司機，因爲車輛甲碰撞車輛乙的時間早於車輛乙碰撞車輛甲的時間
B. 儘管兩架車輛於同一時刻相撞，犯錯的還是車輛甲的司機
C. 兩位司機都有犯錯，因爲兩架車輛於同一時刻相撞
D. 犯錯的是司機乙，因爲車輛乙施加較多力在車輛甲上，所以車輛甲的損毀較嚴重
E. 犯錯的是司機甲，因爲引致此意外的是車輛甲，所以車輛甲施加較多力在車輛乙上

MC12

From which point indicated here, if any, should you position your eyesight if you wish to see an image of the arrow in the mirror?

A. Point A
B. Point B
C. Point C
D. Point D
E. None of the above



選擇題 12

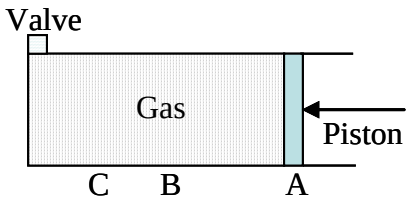
從以下哪一點可以觀看到箭頭在鏡中所成的像？

A. A 點
B. B 點
C. C 點
D. D 點
E. 均看不到

MC13

As shown below, a sealed piston was slowly moving to the left, compressing the (ideal) gas trapped in the chamber. A pressure relieve valve was connected to the chamber. It would let the gas out whenever the gas pressure in the chamber exceeded 3 atm. When the piston was at position A, the chamber volume was V and the gas pressure inside the chamber was 1 atm, same as the air pressure outside the chamber. When the piston reached position B, the chamber volume was reduced to V/2; and at position C, the volume was reduced to V/4. At position B and position C, the gas pressure in the chamber was ___ atm and ____ atm, respectively. The gas temperature remained unchanged throughout the process.

A. 2, 3
B. 2, 4
C. 4, 2
D. 3, 2
E. 2, 0



選擇題 13

如圖示，一個密封室的活塞慢慢向左推進，壓縮著裏面一些理想氣體。有一個"壓力釋放閥門"連接著這個密封室。當室內的壓力高過 3 個大氣壓力時，閥門便會打開及排出氣體。當活塞在位置 A 時，室的體積是 V，室內的氣壓是一個大氣壓力，相等於室外的氣壓。當活塞在位置 B 及 C 時，室的體積分別是 V/2 及 V/4。那麼在位置 B 及 C，室內氣壓分別是 __大氣壓力及 _大氣壓力。氣體的溫度於整個過程中維持不變。

A. 2,3
B. 2,4
C. 4,2
D. 3,2
E. 2,0

MC14

1 kg of ice at 0 °C is mixed with 10 kg of water at 5 °C. After thermal equilibrium the water temperature is

A. -3 °C.
B. 0 °C.
C. -5 °C.
D. 5 °C.
E. -8 °C.

選擇題 14

將一千克 0℃的冰塊與十千克 5℃的清水混和。到達熱平衡後，清水的溫度是 __。

A. –3℃
B. 0℃
C. –5℃
D. 5℃
E. -8 °C

MC15

In Newtonian mechanics the upper limit of speed any object could reach under constant action of a force F is ___. In Relativistic mechanics, however, the mass of an object is no longer a constant, but changes with the speed v of the object in the following way: $m = \frac{m_0}{\sqrt{1 - v^2 / c^2}}$. Here c is the speed of light in vacuum, and m_0 is the mass when the object is at rest. Therefore, the maximum speed the object under constant action of force could reach is ___.

A. ∞, ∞
B. F/m, F/m_0
C. F/ m_0, F/m
D. c, ∞
E. ∞, c

選擇題 15

根據牛頓力學，當物件在受到恆常力(F)作用時，它的速度上限是____。但在相對論力學中，根據以下公式： $m = \frac{m_0}{\sqrt{1 - v^2 / c^2}}$ 物件的質量會隨著它的速度 v 而改變。註：c 是光在真空的速度；m_0 是物件靜止時的質量。因此，當物件在受到恆常力作用時，它的速度上限是 _____。

A. ∞, ∞
B. F/m, F/m_0
C. F/ m_0, F/m
D. c, ∞
E. ∞, c

MC16

Which of the following is *impossible* in electromagnetism?

A. Breaking a magnet in half, with one piece having only north pole and the other having only south pole.
B. Breaking a charged conductor in half with one piece carrying positive charge and the other carrying negative charge.
C. Detecting static electric charges with a compass.
D. Detecting steady electric currents with a compass.
E. Detecting static magnetic field with a voltmeter.

選擇題 16

根據電磁學，以下哪項是<u>不可能</u>做到的？

A. 將一磁鐵分成兩塊，其中一塊只有北極，另一塊則只有南極
B. 將一帶電導體分成兩塊，其中一塊帶正電，另一塊則帶負電
C. 利用指南針探測靜止的電荷
D. 利用指南針探測穩定的電流
E. 利用伏特計探測穩定的磁場

MC17

Which of the following describes what we now believe about our universe?

A. Our universe is expanding.
B. Our universe is contracting.
C. The size of our universe is infinite.
D. Newton predicted the expansion of our universe.
E. Newton predicted the contraction of our universe.

選擇題 17

以下哪一項正確描述我們目前對宇宙的看法？

A. 我們的宇宙正在擴張中
B. 我們的宇宙正在收縮中
C. 宇宙是無限大的
D. 牛頓預言到宇宙的擴張
E. 牛頓預言到宇宙的收縮

MC18

Which of the following describes most closely the color of the sky on the moon?

A. Blue
B. Red
C. White
D. Dark
E. Yellow

選擇題 18

以下哪項最能貼切形容月亮的天空顏色？

A. 藍色
B. 紅色
C. 白色
D. 黑暗
E. 黃色

MC19

Which of the following processes does not involve the transformation of energy from one form to another?

A. You lift up a cup of water.
B. You turn on an air-conditioner.
C. Plants grow under sunlight.
D. You light up a match.
E. A planet moves around a star in a circular orbit.

選擇題 19

以下哪一個過程沒有能量轉換？

A. 提起一杯水
B. 啓動空調
C. 陽光下植物的生長
D. 燃點一根火柴
E. 行星圍繞恆星循圓形軌道運行

MC20

Which of the following describes correctly the difference between microwave and radio wave?

A. One of them is an electromagnetic wave, while the other is a sound wave.
B. Microwave travels faster in vacuum than radio wave.
C. Microwave carries energy but radio wave does not.
D. Water molecules absorb energy from microwave but not from radio wave.
E. Radio waves can travel longer distance than microwave in vacuum.

選擇題 20

以下哪一項正確地形容微波及無線電波的分別？

A. 一個是電磁波，另一個是聲波。
B. 在真空中，微波行走速度比無線電波快。
C. 微波帶有能量而無線電波沒有。
D. 水分子能從微波中吸收能量，卻不能從無線電波中吸取。
E. 在真空中，無線電波能行走的距離比微波遠。

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合辦

25 May 2003

Open-ended Questions 開放題

Open-ended Questions (5 questions in total)
開放題 (共 5 題)

Short Questions 短題目 (10 points each 每題 10 分)

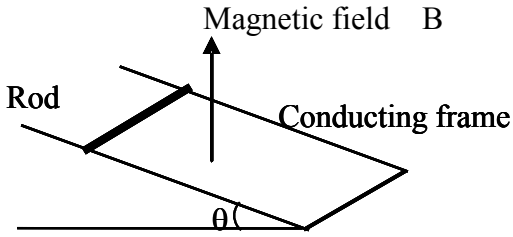
Q.1

As shown in the figure, a conducting slope frame with inclining angle θ is placed in a uniform magnetic field B pointing upwards. A conducting rod of length L, mass M, resistance R, is moving down the frame at steady speed v. (Hint: the e.m.f. of a rod moving in magnetic field is BLv_p, where v_p is the velocity component perpendicular to the field. If the rod carries electric current 'I' which is flowing in a direction perpendicular to the field, then the magnetic force on the rod is BLI.)

(a) Find v in terms of θ, L, M, R, B, and any other physics constants you think appropriate. (5 points)

(b) If the direction of B is reversed, what will be the direction of the steady velocity when the rod is released from rest? (2 points)

(c) If R = ∞, describe the motion of the rod after it is released from rest. (3 points)



題 1

如圖所示，一個導電金屬框架以傾角 θ 放在一個向上的均勻磁場 B 中。一個長短爲 L，質量爲 M，電阻爲 R 的棒形導體以勻速 v 從框架上滑下。(提示：在磁場中運動的棒的電動勢爲 BLv_p，其中 v_p 爲垂直於磁場的速度分量。如果導體棒中的電流是 I 並且垂直於磁場，磁場的力則爲 BLI)

(a) 用 θ，L，M，R，B 和其他適當的物理常數，寫出 v 的表示式 （5 分）

(b) 如果磁場 B 的方向倒轉，求該棒從靜止狀態被釋放後勻速滑動的方向？ （2 分）

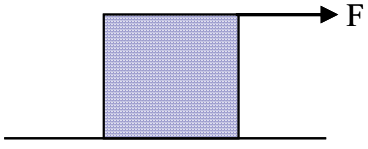
(c) 如果 R = ∞，描述棒形導體從靜止狀態被釋放後的運動 （3 分）

Q.2

Suppose you are to move a piece of heavy furniture at home. Let us approximate it by a cubic block of uniform mass M on a rough floor surface with friction coefficient μ=1. Your strength can only provide a force F = 0.8Mg, where g is the gravity acceleration, so you cannot simply lift the block and move it around.

(a) If you apply the force as shown in the figure, what will happen to the block? (3 points)

(b) You are free to apply the force F in any direction to any point of the block, how to apply the force so the block will have maximum acceleration in sliding motion but without tipping over? (7 points)



[There may be many ways and you are only required to find one. You may also need this: $\sin\theta + \cos\theta = 1.414\sin(\theta + 45^\circ)$]

Hint: The magnitude of the friction is the smaller of the two: F or μN, where N is the reaction force of the floor perpendicular to the surface. The effect of the friction is to keep the block from sliding until it reaches its maximum value μN.

題 2

假定你在家裏移動一件很重的家具。我們可把它近似看成一個質量爲 M 的均勻立方塊，它放在摩擦係數爲 1 的粗糙地面上。而你能提供的最大施力爲 F = 0.8Mg，g 爲重力加速度，因此你不能把該家具提起隨意移動。

(a) 如果你施加一個如圖所示的力，這件家具將如何運動？（3 分）

(b) 你可以在家具的任何位置施加任何方向的力 F。如何施以力 F 才能獲得最大的滑動加速度而不會翻倒？（7 分）

【方法可以很多，但你只需展示其中一種解決方法。你可能會用到下列等式：$\sin\theta + \cos\theta = 1.414\sin(\theta + 45^\circ)$】

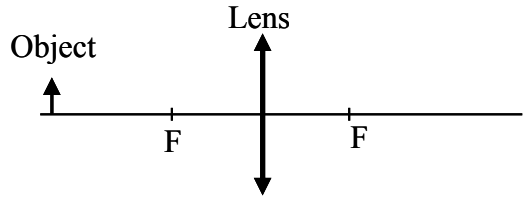
提示：摩擦力的量是力 F 和 μN 兩者中較小者，N 是地面對家具的垂直地面反作用力。摩擦力的作用是阻止家具滑動，直至達到最大值 μN 爲止。

Q.3

(a) Complete the drawing below to show where the image of the object formed by the lens is. (3 points)

(b) Use the drawing you have completed, prove that $\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$. Here *s* is the distance between the object and the lens, *s'* is the distance between the image and the lens, and *f* is the distance between either of the focal points F and the lens. (5 points)

(c) Prove that the image magnification is $M = s'/s$. (2 points)



題 3

(a) 在圖中畫出光線通過透鏡折射後物體所成的影像。 (3 分)

(b) 根據你畫出的影像，證明 $\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$。***s*** 是物體和透鏡之間的距離，***s'*** 是影像和透鏡之間的距離，***f*** 是焦點 F 到透鏡之間的距離。 (5 分)

(c) 證明影像的放大倍數是 $M = s'/s$。 (2 分)

Long Questions 長題目 (15 points each 每題 15 分)

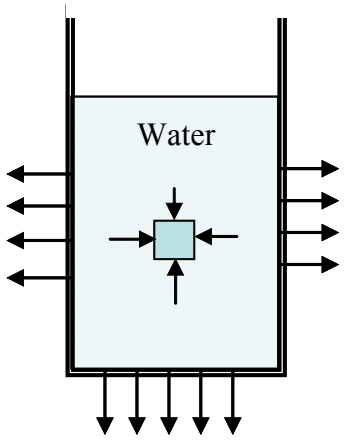
Q.4

Stationary liquid on Earth exerts pressure on any surface in contact, and the resulting net force is always perpendicular to the surface and pointing away from liquid. For example, as shown by the arrows in the figure, the pressure force of water on the sidewalls of the container is horizontal, and the force on the bottom of the container is straight downwards. The same is applicable to any object in liquid. The pressure force of water on the bottom surface of the cubic object shown in the figure is straight upwards; the force on the top surface of the cubic object is straight downwards; and the force on the side surfaces of the cubic object is horizontal and pointing towards the cubic object. (The lengthes of the arrows have no relevance to the strength of the forces.)

(a) Use the above concept, derive an expression for the pressure at any point in water in terms of the depth h of the point (the distance from the point to the water surface in contact with air), mass density of water ρ, and gravity acceleration g on Earth surface. (6 points) (1 point will be deducted in exchange for hint)

(b) Use the results in (a), prove that the net force of water on the cubic object is equal to ρVg and pointing straight upwards, where V is the volume of the cubic object. (5 points)

(c) If the container is placed in a weightless outer space environment, what is the pressure of water on the bottom of the container? (1 point)



(d) We now replace the water and the cubic object with some ideal gas and seal the container. When it is in a weightless outer space environment, is the pressure of the gas on the container the same as it is on Earth? Explain your answer. (3 points)

題 4

地球上靜態液體會向任何接觸面施加壓強，從而產生的合力總是垂直於液面並朝外。例如：圖中箭頭所示，水對容器側壁的壓力是在水平方向，而對底部的壓力則是垂直向下。這原理也適用於液體中的任何物體。水對圖中所示立方體底部的壓力是垂直向上；對頂部的壓力是垂直向下；對立方體側壁的壓力則是水平指向立方體。(箭頭長度與力的大小無關)

(a) 利用以上論述，試求出水中任意一點深度 h 的壓強表示式 (h 是該點與空氣接觸的水面距離)，並以水的密度 ρ，和地球的重力加速度 g 來表示。 (6 分)(換取提示扣 1 分)

(b) 利用(a)所得結果，證明水對立方體的淨力等於 ρVg，並且垂直向上。V 是立方體的體積。(5 分)

(c) 如果容器是放在失重的外太空，那麼水對容器底部的壓強是多少？ (1 分)

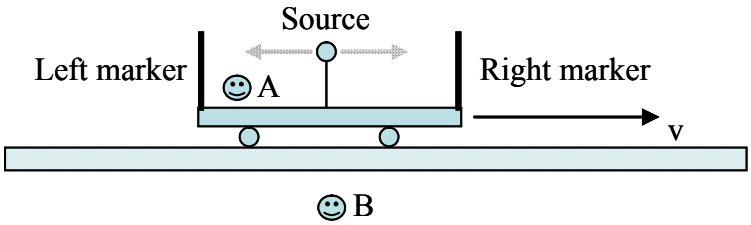
(d) 現在我們用理想氣體代替容器中的水和立方體，並將容器密封。當它處於失重的外太空時，理想氣體對容器的壓強是否和地球上相同？請解釋你的答案。 (3 分)

Q.5

In the following discussions, we assume that all people and objects involved are in vacuum. They can wear oxygen masks when necessary.

One of the principles of Einstein's Relativity is that the speed of light in vacuum is constant c (c = 2.99792458 x 10^8 m/s), regardless of the motion of the light source or the observer. That is to say, once light leaves its source, it 'forgets' all about the motion of the source, and moves at speed c. For example, if the source moves at c/2, the speed of the light emitted by the source in the same motion direction is not c+c/2 = 3c/2, but c. And the speed of the light emitted in the opposite direction is not c–c/2 = c/2, but also c. Furthermore, to someone who is moving with the light source the speed of both light beams is c too. This might sound strange, because common sense tells us that if an air gun moving at speed v relative to you shoots out a bullet at speed u relative to the gun, the speed of the bullet you see is either v+u if it was shot forward, or u–v if it was shot backwards. It turns out, as you may learn later in a university physics course, that the common sense answer is correct only when u and v are much smaller than c, which is the case in ordinary situations such as air gun shooting out bullets. Einstein's principle of speed of light, which has been proven by numerous experiments, has profound implications to the most fundamentals of physics. Here you are asked to study a particular case, as given below.

A cart of length 2L with one marker at each end is moving at constant speed v along a straight rail. On board is Observer A. Right in the middle is a light source. On the ground is Observer B. Both observers are able to measure the time instantly whenever a light pulse (you can treat it as a small ball of light) hits a marker*.



(a) The light source sent out two light pulses simultaneously, one to the left and one to the right. The pulses eventually hit the markers. The time for the right pulse to travel from the source to the right marker is T_r, and the time for the left pulse to travel from the source to the left marker is T_l. Find T_r and T_l in terms of c, L and v if necessary, as recorded by Observer A. According to her, did the two pulses hit their markers simultaneously? (2 points)

(b) Find T_r and T_l as recorded by Observer B. According to him did the two pulses hit their markers simultaneously? (4 points)

(c) Along the same way of thinking as (a) and (b), design an experiment to demonstrate that it is possible for Observer A to see a pulse hits the right marker (let us call it event-1) **before** another pulse hits the left marker (event-2), while according to Observer B the same pulse hits the right marker (event-1) **after** the other pulse hits the left marker (event-2). (5 points)

(d) What has been shown in (c) is that the sequence of two events can be reversed, i.e., according to Observer A **event-1 took place before event-2**, while to Observer B **event-2 took place before event-1**. However, reversing the sequence of two events is not always possible. Use the results in (c), prove that the two events are reversible if the distance between the two events is larger than $|c\Delta t|$, where $\Delta t = T_l - T_r$ is the difference in time between event-1 and event-2. The maximum value of v is c. (4 points)

*Both observers have as many assistants as needed. Any one of them is capable of recording a hit by a pulse on a marker instantly if the marker is right where the assistant is. Observer A can have one assistant at each marker for such purpose. Observer B can have many assistants aligned side by side along the rail so that when a pulse hits a marker, there is always one assistant right at where the marker is to instantly record the event.

題 5

在以下討論中，我們假設所有涉及的人和物均處於真空中。如有必要，他們可以使用氧氣面罩。

愛因斯坦相對論的一個基本原理是：無論光源或觀察者的運動狀態如何，光在真空中的速度是一常數 c ($c = 2.99792458 \times 10^8$ m/s)。也就是說，一旦光離開了光源，它就會失去對光源運動狀態的所有記憶，而以一恆速 c 運動。例如，如果光源以 c/2 運動，朝同一方向由此光源發射的光的速度不是 c+c/2=3c/2，而是 c。同樣朝相反方向發射的光的速度不是 c-c/2=c/2，而同樣是 c。此外，從與光源同步移動的人來看，此兩束光的速度也都是 c。這也許看起來是挺奇怪的，因爲一般經驗告訴我們，如果以速度 v 移動的氣槍，射出一發相對於氣槍以速度 u 運動的子彈，而子彈是向前發射的話，你所看到的子彈的速度應是 v+u；如果它是向後發射的話則應是 u-v。日後通過學習大學物理課程，你就會知道此種憑經驗得出的結果只有在 u 和 v 比 c 小很多的條件下才能成立，例如氣槍發射子彈的情況。經大量實驗證實的愛因斯坦光速原理對物理學的基本法則有著深遠的影響。下面有一特定例子供你研習：

長爲 2L 及兩端各有一標識屏的小車，以恆定速度 v 沿筆直軌道運動。車上有一位觀察者 A。一光源處於車的正中間。地上也有一位觀察者 B。兩位觀察者都能立刻測得光脈衝(可視作是一小光球)打在標識屏的時間*。

(a) 光源同時射出兩個脈衝，一個朝左，一個朝右。光脈衝最終打在標識屏上。右邊的脈衝從光源到右邊標識屏的時間是 T_r，而左邊的脈衝從光源到左邊標識屏的時間是 T_l。以觀察者 A 的角度，用 c，L 和 v(如有需要)表示出 T_r和 T_l。 對她而言，兩個脈衝是否同時打在標識屏上？ (2 分)

(b) 對觀察者 B 而言，T_r和 T_l又是如何呢？兩個脈衝是否同時打在標識屏上？ (4 分)

(c) 以(a)和(b)同樣的思路，設計一個實驗來演示觀察者 A 能在一個脈衝打到左邊的標識屏(事件 2) **之前** 看到另一個脈衝先打在右邊的標識屏上(事件 1)，而觀察者 B 則在同樣一個脈衝打到左邊的標識屏(事件 2) **之後** 才看到另一個脈衝打在右邊的標識屏上(事件 1)。 (5 分)

(d) (c)說明兩件事件的時序是可逆的。對觀察者 A 而言，**事件 1 早於事件 2** 發生，而對觀察者 B 來說，則**事件 2 早於事件 1** 發生。然而，改變兩件事件的時序不是在任何條件下均能做成。由(c)的結果，證明如果兩事件可逆，則兩事件的距離要大於 $|c\Delta t|$，其中 $\Delta t = T_l - T_r$是兩事件相隔時間。v 的最大值是 c。 (4 分)

*兩位觀察者均有足夠助手。當他們處於脈衝撞擊標識屏的位置時，他們都能立刻記錄脈衝對標識屏的撞擊。故此，觀察者 A 在每個標識屏處各有一位助手作出記錄。觀察者 B 亦有許多肩並肩沿著軌道排列的助手，所以每當一個脈衝擊中標識屏時，在標識屏處的助手便可以立即作出記錄。

Take Home Question
家中練習題

The following is an open question that you are encouraged to take home to study. How you answer it will NOT affect in any way your grade and standing in HKPhO.
下列開放題希望你帶回家好好研究。你的答案<u>不會</u>對你的成績有任何影響。

The battle to overcome SARS is still raging, and everyone must maintain high vigilance. Infrared thermometers are used widely in schools now. Due to shortage of disposable lens filters, some schools use plastic wrap sheet instead. But experts warned that wrap sheet will distort the temperature readings.

(a) Design a simple experiment to test whether experts' warning is justified.
(b) If the result of your experiment shows that there is indeed small (~ 1°C) deviation of reading when using wrap sheet, design a way to correct the reading.

對抗 SARS 的戰鬥仍在進行。大家還要保持高度警惕。紅外探熱器在各學校廣泛使用。由於即棄耳套短缺，有時會用保鮮紙來代替。但有專家警告保鮮紙會影響讀數。

(a) 設計一簡單試驗看看專家的警告對不對。
(b) 如果試驗發現確有約 1°C 讀數偏差，設計一糾正方法。

Hong Kong Physics Olympiad 2003
25 May 2003
Answers and Suggested Solutions

Answers to Multiple-choice Questions:

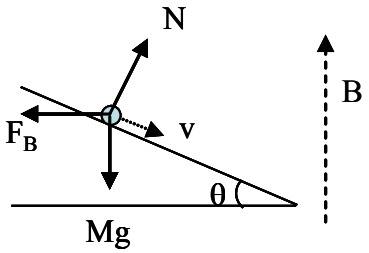
1. A	**2.** B	**3.** D	**4.** C	**5.** C	**6.** A	**7.** A
8. D	**9.** E	**10.** A	**11.** B	**12.** C	**13.** A	**14.** B
15. E	**16.** A	**17.** A	**18.** D	**19.** E	**20.** D	

(Note for MC9: The magnetic field force on the coil is horizontal)

Suggested Solutions to Open-ended Questions:

Q.1

(a) As shown, the forces on the rob are the gravity Mg, the reaction force from the frame N, and the magnetic field force F_B.
The emf is BLvcosθ, so the electric current is
$I = BLv\cos\theta/R$ …….(1)
The magnetic field force on the rod is
$F_b = BLI$……(2)
The balance of force along the slope implies

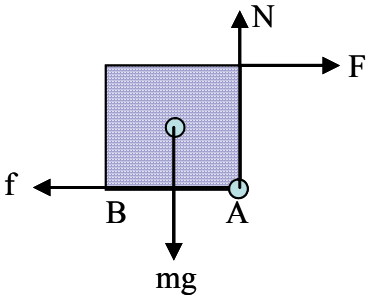


$Mg\sin\theta = F_b\cos\theta = v(BL\cos\theta)^2/R$
So $v = RMg\sin\theta/(BL\cos\theta)^2$

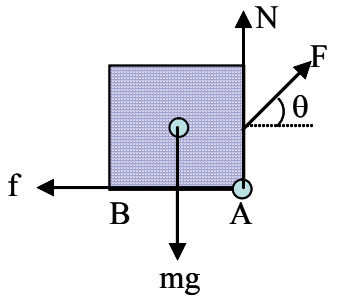
(b) v is the same, but the direction of current is reversed.
(c) Then I = 0 so $F_b = 0$.
The rod will slide down under constant acceleration gsinθ.

Q.2

(a) Taking point-A as the pivot, both the floor reaction force N and the friction force f are acting upon the point because it is where the block touches the floor if it is about to turn. The torque (moment) due to F = 0.8mg is FL and clockwise, where L is the length of the cubic side. The torque due to gravity is mgL/2 and counterclockwise. So the block will tip over around point-A.
On the other hand, the maximum friction force is
$\mu N = \mu mg = mg > F$
So the block will not slide.



(b) With the force applied as shown in the figure, the reaction force of floor N = mg – Fsinθ,
So the maximum f = (mg – Fsinθ).
The sliding acceleration is
$ma = F\cos\theta - (mg - F\sin\theta)$
or
$a/g = 0.8(\cos\theta + \sin\theta) - 1$, and its maximum is 0.13 when θ is 45 degrees.



Now, will the block tip over around point-A or point-B?
The torque due to F is $0.5FL\cos45° < 0.5mgL$ so it will not tip over.

Note that if force F is applied on point-A at 45°, the block will tip over around point-B. To prevent tipping over around either point-A and point-B, force F must be applied near the middle point. Maximum distance x away from the middle point is determined by $(0.5L + x)F\cos45° = 0.5mgL$, which leads to $x = 0.384L$.

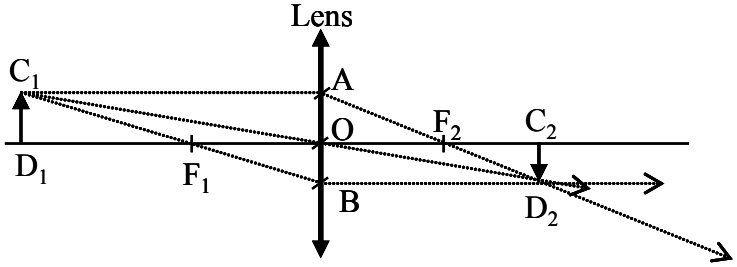
Now let us go back to part (a), and consider F in general term. One type of answer I often encountered during grading is 'The friction and F form a clockwise torque that tips off the block'. This, however, cannot be true because it implies that no matter how small F is, it can always tip off the block, with the help of the friction. The key element missing in the consideration is the illusive reaction force of the floor on the block. Its direction must be upwards and strength equals to mg to balance the gravity force along the vertical direction. The question is, where is the reaction force N (= mg) acting upon? Or more precisely, what is the torque of N? Just for the consideration of torque we can view N as acting upon a point on the bottom of the block, a distance 'X' from the center. The reaction force N is of course acting upon all the places the block is in touch with the floor but the force is NOT uniformly distributed on the bottom surface. The net effect of it is to produce a torque to keep the block in balance.

Choose the center of mass as the pivot point, the torque due to F and f (= F) is FL. This must be balanced off by N so N must acting upon a point at X distance to the right of the center, and $Xmg = FL$, so $X = L(F/mg)$. Note that X cannot exceed L/2 so when $F > 0.5$ mg the block will tip over.

One can also choose point-A as pivot. In that case f produces no torque. The clockwise torque is now $FL + N(L/2-X)$, and the gravity produces a counter-torque 0.5mgL. So we have $FL + mg(L/2-X) = mgL/2$. Again we get $X = L(F/mg)$.

Q.3

(a) Complete the graph

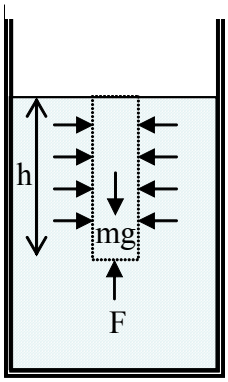


(b) Define:
$\underline{C_1D_1} = h = \underline{AO}$, $\underline{C_2D_2} = h' = \underline{OB}$, $\underline{OD_1} = \underline{AC_1} = s$, $\underline{C_2O} = \underline{BD_2} = s'$, $\underline{OF_1} = \underline{OF_2} = f$,
Angle $\alpha = AC_1B = OF_1B$, Angle $\beta = AF_2O = AD_2B$ (1 point)
Then $\underline{OF_1}/\underline{OB} = h'/f = \tan\alpha = \underline{AB}/\underline{AC_1} = (h + h')/s$ …….. (1)
$\underline{OF_2}/\underline{AO} = h/f = \tan\beta = \underline{AB}/\underline{BD_2} = (h + h')/s'$ ……. (2)
(1) + (2) $(h + h')/f = (h + h')/s + (h + h')/s'$, cancel $(h + h')$.
Note that there are many ways to prove the formula, and any one of them is as good as the others.

(c) Angle C_1OD_1 = Angle C_2OD_2 (1 point), so M = h'/h = s'/s.

Q.4

(a) Consider the column of water of height h and cross area A shown in the figure. The force the rest of the water on the water column must balance the gravity force of the column. Ignore the air pressure on the surface of water, the force on the bottom surface of the column must equal to mg, where m is the mass of the water column.
So
m = ρhA
F = mg, and
pressure P = F/A
Combining the three, one gets P = ρgh



(b) Using the result in (a), the force from water on the top surface of the cubic is $A\rho gh_1$, where h_1 is the depth of the top surface, and is pointing downwards. Likewise, the force on the bottom surface of the cubic is $A\rho gh_2$, where h_2 is the depth of the bottom surface, and is pointing upwards. The net force of water on the side walls of the cubic is zero. So the total net force is
$F = A\rho gh_2 - A\rho gh_1$
$= A\rho g(h_2 - h_1) = \rho gV$

(c) Pressure is zero (not counting the water vapor) because g = 0 in weightless environment.

(d) The same, because pressure of gas is a result of the thermal motion of the gas molecules that keep hitting on the container wall. Acceptable answers also include 'the pressure is smaller because the outer space is cold', or 'the balance of force on the wall is changed because there is no gas pressure outside the container, so it will explode', etc., although the mechanical strength of the container may well sustain such difference in pressure, just as a spaceship can keep normal pressure inside while there is vacuum outside.

Q.5

(a) Observer-A sees the following. The two markers are stationary. The two light pulses are moving at c towards their markers at distance L away. So
$T_r = T_l = L/c$

(b) Observer-B sees the following. The two markers are moving to the right at speed v. The two light pulses are moving at c towards their markers, initially (right after the pulses are emitted) at distance L away.
For the left pulse $L = cT_l + vT_l$, so $T_l = L/(c + v)$
For the right pulse $L = cT_r - vT_r$, so $T_r = L/(c - v) > T_l$
So Observer-B sees that the two pulses hit markers at different times. This means that simultaneity is no longer absolute. It depends on the motion of the observers.

(c) Relocate the light source to the right, so that its distance to the right marker is L_r, and its distance to the left marker is L_l. $2L = L_l + L_r$. Since $L_r < L_l$, $T_r < T_l$, i. e., event-1 takes place ***before*** event-2, according to Observer-A.
According to Observer-B,

$$T_r' = \frac{L_r}{c - v} \qquad \text{and} \qquad T_l' = \frac{L_l}{c + v}$$

If $T_r' > T_l'$, then Observer-B sees event-1 takes place ***after*** event-2.

$$\Delta t' \equiv T_r' - T_l' = \frac{L_r}{c-v} - \frac{L_l}{c+v} = \frac{v(L_r+L_l) - c(L_l - L_r)}{c^2 - v^2} = \frac{2vL - c(L_l - L_r)}{c^2 - v^2}$$

$\Delta t' > 0$ if $2vL > c(L_l - L_r)$. This can be easily achieved since $(L_l - L_r)$ can be as small as we want. For example, let $(L_l - L_r) = 0.1L$, then all we need is $v > 0.05c$.

(d) From the expression of $\Delta t'$ in (c) we see that $2vL$ is maximum if $v = c$ (To save the denominator from being zero we can let v very close to but not equal to c).
The inequality becomes
$2L > (L_l - L_r) = c\Delta t$, where Δt is the time difference of event-1 and event-2 seen by Observer-A. Note also that 2L is the distance between the two events.
So the general criteria is (distance) > (speed of light) x (time difference).
To put it into words, suppose Observer-A sees that event-1 takes place at time Δt before event-2 at a distance S away from event-1, then it is possible for Observer-B, who is moving relative to Observer-A, to see event-2 takes place before event-1 if $S > c\Delta t$. But if $S < c\Delta t$ then it is not possible given the restriction that he cannot move faster than light.

Take-Home Question

Answer to (a)

Take two measurements on the same person, one with the filter and the other with the wrap, and compare the readings.

Answer to (b)

I would like to ask a more general question: Is the reading of infrared thermometer reliable? There are several aspects to be considered.

First, what is the random error of the reading? This is the spread of the readings when you use the thermometer to measure a person (perhaps yourself) many (say 20 +) times within a short period of time, and do statistics of the 20+ data to find out the Mean (say 36 ˚C) and the Standard Deviation (say 0.2 ˚C), which is the random error of the thermometer you operate. The Mean may not necessarily be the same as your true body temperature. This brings out the second point: the systematic error of the thermometer.

The body temperature can be most reliably measured by the old fashioned mercury/glass thermometer. In the following, when I say 'temperature' I mean that measured by a mercury/glass thermometer. When I say 'reading' I mean the temperature reading displayed by the infrared thermometer. Obviously, to find out the systematic error, you need to compare your body temperature with the reading. Now, what if the reading is different from the temperature but the difference is smaller than the random error? Then your thermometer is fine. But what if the difference is larger than the random error? In that case you need to do a 'calibration' of your infrared thermometer using the 'standard' mercury/glass thermometer. First, you need to find an object that you can change its temperature with relative ease. Second, such object must give out the same reading as your body when its temperature is the same as your body. This ensures that the emissivity (I will explain what it really means later) of the object is the same as your body. Third, change and record the temperature of the object within the normal range of human being (say 34 to 42 ˚C) and record the reading at each temperature. The data you obtain (temperature versus reading) then give you the correction you need. You can even fit the data by a function with temperature as the Y value and reading as the X value. Suppose you find that the temperature (Y) versus reading (X) data can be best described by Y =

1.2 + 0.9*X, then when you get a reading of X = 39, you know the true temperature is 36.3 ˚C.

Some general information

The working principle of an infrared thermometer is that it measures the amount of infrared light emitted from a particular part of a human body, say inside an ear, the forehead, etc, and from the amount determines the temperature. Every object at non-zero degree Kelvin emits light, or electromagnetic waves. This is the so called blackbody radiation. The total amount of emitted energy is proportional to $(\text{Temperature})^4$. So a little bit of change in temperature brings a much larger change in emission power. An ideal blackbody (totally black object) does not reflect any light, and in return it emits the highest amount of light among all other non-black objects held at the same temperature. Hence comes the term emissivity e. Blackbody's e is 1. Other objects have $e < 1$, and their e's vary from object to object. But some objects may happen to have almost the same e's. In general, objects that look shinny (high reflection) tend to have low e's. A piece of charcoal for barbeque has $e \sim 0.95$, while a piece of gold has $e < 0.05$. Therefore, at the same temperature, a piece of charcoal emits 19 times the amount of energy of a piece of gold. An infrared thermometer should have been calibrated for emissivity of human skin. But skin covered by other substances such as sun cream or water may have its emissivity modified. All these variations, however, can be tested by yourself. Different parts of the human body have different temperatures. How do you deal with that?