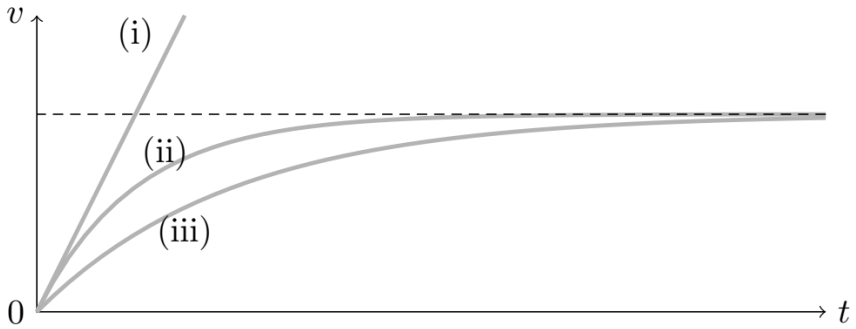
2022 第三十七屆成大數理比賽 - 物理
37th NCKU Science and Mathematics Competition 2022 - Physics

1. 一具繞地球運動的衛星，名為阿爾法，其質量為m_α。若該軌道為半徑r的圓形，週期T_α，下列敘述何者正確？
A satellite of mass m_α, named Alpha, is orbiting around the earth. The orbit is approximately a circle with radius r and period T_α. Which of the following is correct?

   (A) 由克普勒第三定律可知，$T_\alpha \propto r^3$。
   $T_\alpha \propto r^3$, consistent with Kepler's third law.
   (B) 由克普勒第三定律可知，$T_\alpha \propto r^{2/3}$。
   $T_\alpha \propto r^{2/3}$, consistent with Kepler's third law.
   (C) 若有另一具衛星，質量為$m = 2m_\alpha$，以相同的軌道運動，則其週期與T_α一樣。
   If another satellite with mass $m = 2m_\alpha$ has the same orbit, its period will remain unchanged.
   (D) 若阿爾法衛星以一模一樣的軌道繞月球運動，則其週期與T_α一樣。
   If Alpha is now orbiting around the moon with exactly the same orbit, its period will remain unchanged.
   (E) 若阿爾法衛星的軌道為橢圓，則其繞軌速率會隨位置改變，總機械能也是。
   If the orbit of Alpha is an ellipse, its orbiting speed will vary with position, and so does its total mechanical energy.

2. 以下曲線(i)–(iii)描述速度一自由落體（離地表沒有太遠）之速度v隨時間t的變化情形：
直線(i)之斜率等於$g = 9.8\,\mathrm{m/s^2}$。下列何者正確？
The following curves (i)–(iii) describe the speed v of a falling body (not too far from the surface of the earth) as a function of time t:
The slope of the straight line (i) is equal to $g = 9.8\,\mathrm{m/s^2}$. Which of the following is correct?



   (A) 曲線(i)–(iii)皆可能描述有空氣阻力之自由落體。
   All of the curves (i)–(iii) may describe a free-fall in the presence of air resistance.
   (B) 只有曲線(ii)和(iii)可能描述有空氣阻力之自由落體。
   Only curves (ii) and (iii) may describe a free-fall in the presence of air resistance.
   (C) 只有曲線(ii)可能描述有空氣阻力之自由落體。
   Only curve (ii) may describe a free-fall in the presence of air resistance.
   (D) 只有曲線(iii)可能描述有空氣阻力之自由落體。
   Only curve (iii) may describe a free-fall in the presence of air resistance.
   (E) 曲線(i)–(iii)皆不可能描述有空氣阻力之自由落體。
   None of the curves (i)–(iii) may describe a free-fall in the presence of air resistance.

3. 關於機械能與功，下列何者正確？
About mechanical energy (ME) and work, which of the following is correct?

(A) 力作用於一物體，必對該物體作功。
A force acting on an object must do work to the object.

(B) 自由落體由於重力的作用而加速。所以，重力對該物體作功，其機械能也隨著增加。
A falling body is speeding up due to gravity. Thus gravity is doing work on the body, and its total ME is increasing.

(C) 摩擦力總是作負功。
Frictional forces always do negative work.

(D) 摩擦力也可能作正功。
Frictional forces can also do positive work.

(E) 一質量繫於彈簧而隨時間震盪。該彈簧對質量所作的功都是正的。
A mass block attached to a spring is oscillating with time. The spring is doing positive work to the mass block all the time.

4. 有關機械能守恆，下列敘述何者正確？
About conservation of mechanical energy (ME), which of the following is correct?

(A) 一系統之機械能無論如何都會是守恆的。
The ME of a system is always conserved, no matter what.

(B) 一系統之機械能只有當所受淨力為零時才會守恆。
The ME of a system is conserved, only if there is no net force acting on the system.

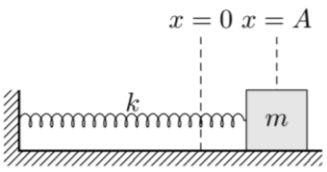
(C) 只要系統裡涉及了摩擦力，機械能就不會守恆。
Whenever there are frictional forces involved in a system, the mechanical energy of the system would not be conserved.

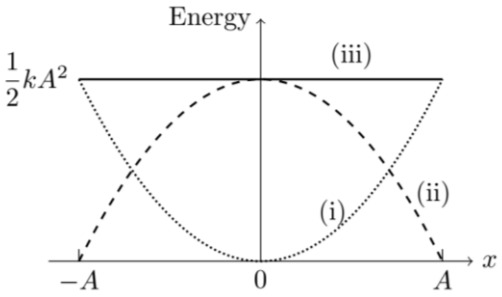
(D) 一自由落體（無空氣阻力）之位置為$y(t) = h - \frac{1}{2}gt^2$，速度為$v(t) = -gt$。其機械能則為$mgy(t) + \frac{1}{2}mv^2(t) = mgh$，是個與時間無關而守恆的量。
A free-fall (without air resistance) is described by position $y(t) = h - \frac{1}{2}gt^2$ and velocity $v(t) = -gt$. Its ME given by $mgy(t) + \frac{1}{2}mv^2(t) = mgh$ is conserved, independent of time.

(E) 人在地球表面的機械能也是守恆的，因為地球的重力是保守力。
The ME of a human on the earth surface is also conserved, because the gravitational field of the earth is conservative.

5. 一質量繫於一彈簧在無摩擦之表面上運動，且於位置$x = A$由靜止釋放。當彈簧處於自然長度時，該質量的位置在$x = 0$，如左下圖所示：

A block attached to a spring on a frictionless ground is released from rest at position x = A. When the spring is at its natural length, the block is at position x = 0, as shown by the diagram on the left below.





關於右上圖所示之能量曲線，下列何者正確？

About the energy curves on the right above, which of the following is correct?

(A) 曲線(i)描述的是動能。
The dotted line of curve (i) describes the kinetic energy.

(B) 曲線(ii)描述的是位能。
The dashed line of curve (ii) describes the potential energy.

(C) 直線(iii)描述的是機械能。
The solid straight line (iii) describes the mechanical energy.

(D) 以下兩種情形皆可能：(i)是位能、(ii)是動能；(i)是動能、(ii)是位能。
Both of the following situations are possible: (i) describing the potential energy while (ii) the kinetic energy; (i) describing the kinetic energy while (ii) the potential energy.

(E) (iii)為水平直線所代表意義的是線性動量的守恆。
The fact that (iii) is horizontally flat indicates the conservation of linear momentum.

6. 續5：該質量進行簡諧運動，其位置隨時間t變化的函數為：

Continued with 5: The mass undergoes a simple harmonic oscillation with its position as a function of time t given by

$$x(t) = A\cos\left(\sqrt{\frac{k}{m}}t\right)$$

其中，A是震幅。下列敘述何者正確？

with A being the amplitude of the oscillation. Which of the following is correct?

(A) 週期可由$x(t)$的表示式看出，也就是$2\pi\sqrt{m/k}$。
The period can be obtained from the expression of $x(t)$, and is given by $2\pi\sqrt{m/k}$.

(B) 週期無法由$x(t)$的表示式看出。
The period cannot be obtained from the expression of $x(t)$.

(C) A越大，週期越長。
The larger the amplitude A, the longer the period.

(D) A越大，週期越短。
The larger the amplitude A, the shorter the period.

(E) 質量運動的速度與A無關。
The velocity is independent of A.

7. 有關線性動量的守恆，下列敘述何者正確？
About conservation of linear momentum (LM), which of the following is correct?

(A) 兩個物體在無外力的情況下相互碰撞。無論碰撞是彈性或非彈性，兩物體之總線性動量總是守恆的。
Two objects collide with each other in the absence of external forces. No matter the collision is elastic or inelastic, the total LM of the two objects is always conserved.

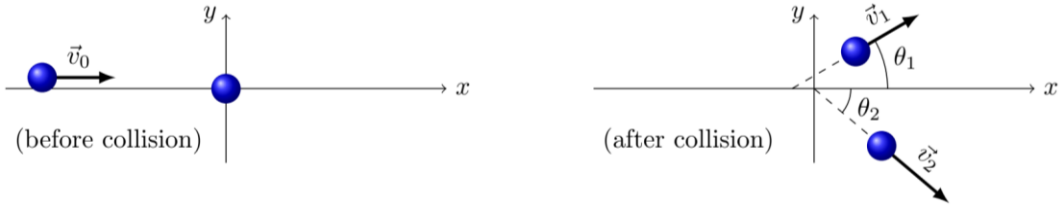
(B) 兩個物體在無外力的情況下相互碰撞。唯有非彈性碰撞，兩物體之總線性動量才會守恆。
Two objects collide with each other in the absence of external forces. The total LM of the two objects is conserved only when the collision is inelastic.

(C) 兩個物體在無外力的情況下相互碰撞。唯有彈性碰撞，兩物體之總線性動量才會守恆。
Two objects collide with each other in the absence of external forces. The total LM of the two objects is conserved only when the collision is elastic.

(D) 兩個以上的物體，其總線性動量守恆與否，與內力有關。
Whether the total LM of a system of more than two objects is conserved or not depends on the internal forces between the objects.

(E) 兩個以上的物體，其總線性動量不可能守恆。
The total LM of a system of more than two objects is never conserved.

8. 兩個一模一樣的球，質量為m，進行二維的彈性碰撞，一個原處於靜止，另一個以速度$\vec{v}_0$接近：
下列敘述何者正確？
Two identical balls of mass m undergo a two-dimensional elastic collision, one ball being initially at rest and the other approaching with velocity $\vec{v}_0$:
Which of the following is correct?



(A) 由於線性動量的守恆，所以$\vec{v}_0 = \vec{v}_1 + \vec{v}_2$。
Due to conservation of linear momentum, $\vec{v}_0 = \vec{v}_1 + \vec{v}_2$.

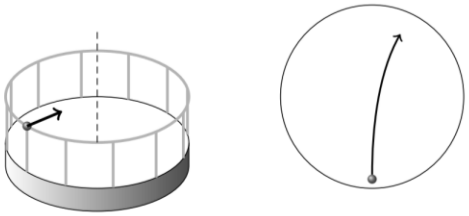
(B) 由於線性動量的守恆，所以$v_0 = v_1 + v_2$。
Due to conservation of linear momentum, $v_0 = v_1 + v_2$.

(C) 由於線性動量的守恆，所以$v_0^2 = v_1^2 + v_2^2$。
Due to conservation of linear momentum, $v_0^2 = v_1^2 + v_2^2$.

(D) 即使碰撞是非彈性，$\theta_1 + \theta_2 = 90°$也必然為真。
$\theta_1 + \theta_2 = 90°$ is always true, even if the collision is not elastic.

(E) 對於這樣的彈性碰撞，$\theta_1 + \theta_2 \neq 90°$也可能發生。
$\theta_1 + \theta_2 \neq 90°$ can happen for such elastic collisions.

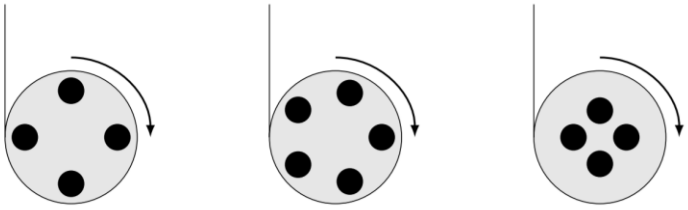
9. 一個小孩站在旋轉木馬的邊緣，朝向對面丟球，如左下圖所示：
A kid stands at the edge of a merry-go-round and throws a ball aiming at the opposite side, as shown by the diagram on the left below.



在旋轉木馬的座標系統裡，球的軌跡如右上圖所示。下列何者正確？
In the frame of the merry-go-round, the trajectory of the ball shown by the diagram on the right above. Which of the following is correct?

(A) 旋轉木馬必定是相對於地面作順時鐘旋轉。
The merry-go-round must be rotating clockwise relative to the ground.
(B) 旋轉木馬必定是相對於地面作逆時鐘旋轉。
The merry-go-round must be rotating counterclockwise relative to the ground.
(C) 旋轉木馬一定有相對於地面在旋轉，而旋轉方向可能是順時鐘也可能是逆時鐘。
The merry-go-round must be rotating, and the direction can be clockwise or counterclockwise.
(D) 旋轉木馬相對於地面不一定有在旋轉。
The merry-go-round is not necessarily rotating.
(E) 旋轉木馬的旋轉速度必然隨時間改變。
The merry-go-round must be rotating at a varying angular velocity.

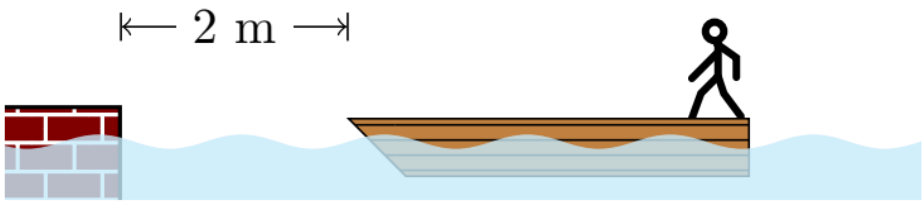
10. 三個溜溜球設計如下：
Three yoyos are designed as below.



黑點代表相同的質量圓盤。若三個溜溜球從一樣的高度釋放，下列敘述何者正確？
The black dots represent identical disks of equal masses. If the yoyos are released from rest at the same height, which of the following is correct?

(A) 左邊的溜溜球會下降最快。
The left yoyo will descend the fastest.
(B) 中間的溜溜球會下降最快。
The middle yoyo will descend the fastest.
(C) 右邊的溜溜球會下降最快。
The right yoyo will descend the fastest.
(D) 所有溜溜球會以相同的速度下降。
All yoyos will descend at the same rate.
(E) 左邊和右邊的溜溜球會以相同的速度下降。
The left and right yoyos will descend at the same rate.

11. 一個六十公斤重的人從船的一端試圖走向另一端，如下圖所示：
若船重四十公斤、長三公尺，船可在水面上無摩擦滑動，且開始走之前，船頭距離碼頭兩公尺遠，試問此人走到船頭時，距離碼頭有多遠？
A 60-kg man is at the rear of a stationary boat of mass 40kg and length 3m, which can move freely on the water. The front of the boat is 2 m from the dock initially. When the man reaches the front end, how far is the man from the dock?

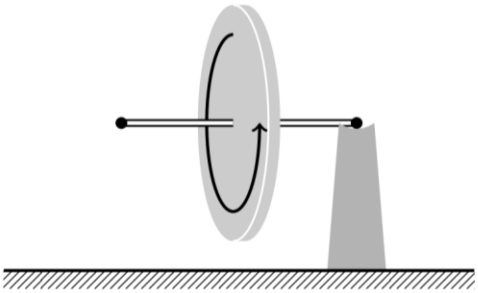


(A) 3 m.
(B) 3.2 m.
(C) 3.5 m.
(D) 3.8 m.
(E) 2 m.

12. 克普勒的第二行星運動定律表示，所有繞軌的天體，其「面積速率」保持不變。下列何者為此定律背後的物理機制？
Kepler's second law of planetary motion states that the "areal velocity" of an orbiting planet is always constant. Which of the following physical principles leads to the above stated Kepler's second law?

(A) 機械能守恆。
Conservation of mechanical energy.
(B) 疊加原則。
Principle of superposition.
(C) 狹義相對論。
Special relativity.
(D) 角動量守恆。
Angular momentum conservation.
(E) 克普勒第一定律。
Kepler's first law.

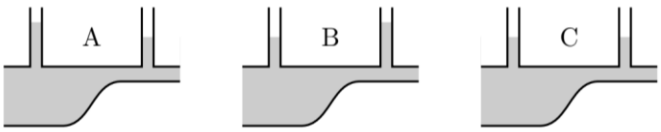
13. 考慮下面所繪陀螺儀，其轉盤正以相當的速度在轉動，轉動方向如箭頭所示：
Consider the following gyroscope with its disk spinning at a rather high angular velocity in the direction indicated by the arrow:



下面何者正確？
Which of the following is correct?

(A) 角動量是守恆的。
The angular momentum is conserved.
(B) 重力拉扯的關係，陀螺儀會立刻倒下來。
The spinning wheel will immediately fall down because of the gravity.
(C) 陀螺儀進動的方向（從上面看）是順時針。
The precession direction of the gyroscope is clockwise when looking from above.
(D) 陀螺儀進動的方向（從上面看）是逆時針。
The precession direction of the gyroscope is counterclockwise when looking from above.
(E) 陀螺儀不一定會進動。
The gyroscope does not necessarily precess.

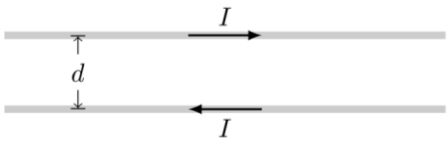
14. 考慮下面所繪文氏管（喉形管），內有流動中的液體：
Consider a Venturi tube filled with a **flowing** liquid:



下列何者正確？
Which of the following is correct?

(A) 只有A圖是合理的。
Only sketch A is reasonable.
(B) 只有B圖是合理的。
Only sketch B is reasonable.
(C) 只有C圖是合理的。
Only sketch C is reasonable.
(D) A圖和B圖都有可能發生，但C不可能。
Both of sketches A and B can happen, but not C.
(E) 三個圖都有可能發生。
All of A, B, and C can happen.

15. 兩條長直導線帶有反平行電流如下圖所示：
Two straight parallel wires carry currents in opposite directions as shown in the diagram below.



下列敘述何者正確？
Which of the following is correct?

(A) 兩導線相互吸引，且吸力正比於$1/d^2$。
The two wires attract each others with a force proportional to $1/d^2$.

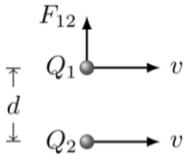
(B) 兩導線相互排斥，且排斥力正比於$1/d^2$。
The two wires repel each other with a force proportional to $1/d^2$.

(C) 兩導線相互吸引，且吸力正比於$1/d$。
The two wires attract each others with a force proportional to $1/d$.

(D) 兩導線相互排斥，且排斥力正比於$1/d$。
The two wires repel each other with a force proportional to $1/d$.

(E) 由於電流方向相反，故兩導線之間無作用力。
There is no force between the wires as the currents are in opposite directions.

16. 考慮兩電荷以速率v平行移動：
Consider two charges moving side by side at speed v:



若$F_0 = Q_1Q_2/(4\pi\epsilon_0 d^2)$為庫倫靜電力，$c$是光速，則下列$F_{12}$的表示式何者正確？
If $F_0 = Q_1Q_2/(4\pi\epsilon_0 d^2)$ is the force following from the Coulomb's law, and c is the speed of light, which of the following expressions for F_{12} is correct?

(A) $F_{12} = F_0$，無關乎v。
$F_{12} = F_0$ independent of v.

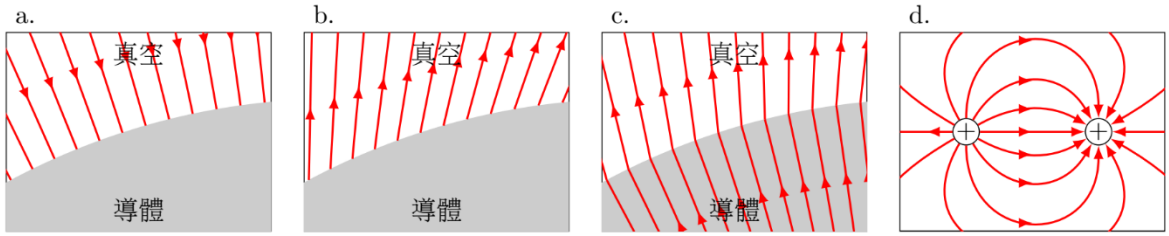
(B) $F_{12} = (1 - v^2/c^2)F_0$.

(C) $F_{12} = (1 + v^2/c^2)F_0$.

(D) $F_{12} = (1 - v/c)F_0$.

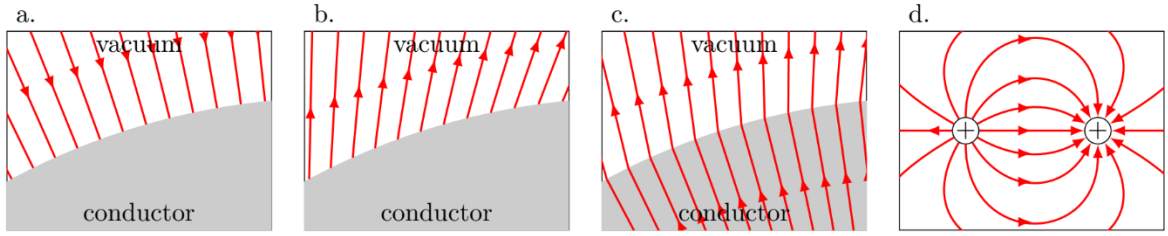
(E) $F_{12} = (1 + v/c)F_0$.

17. 考慮下列靜電平衡下的電場線：



哪個圖是合理的？

Consider the following electric field lines in electrostatic equilibrium:



Which sketch is reasonable?

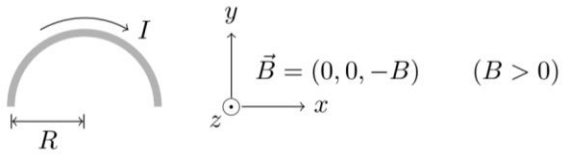
(A) a.
(B) b.
(C) c.
(D) d.
(E) 以上皆非。None of them.

18. 一電容器由兩塊導體組成，其電容為C。下列敘述何者正確？
A capacitor of capacitance C is made of two conducting plates. Which of the following is correct?

(A) 若施加電壓增倍，則電容值加倍。
The capacitance doubles when the applied voltage is doubled.
(B) 若電容器儲存之電荷加倍，電容值亦加倍。
The capacitance doubles when the amount of charge stored is doubled.
(C) 兩個這樣的電容器串聯後，其等效電容為$2C$。
Two such capacitors connected in series have an equivalent capacitance $2C$.
(D) 兩個這樣的電容器並聯後，其等效電容為$C/2$。
Two such capacitors connected in parallel have an equivalent capacitance $C/2$.
(E) 電容值並不取決於施加電壓及儲存電荷。
The capacitance depends neither on the applied voltage nor on the stored charge.

19. 一半圓型導線攜帶電流I置放於均勻磁場$\vec{B}$如下圖所示：

A semicircular wire carrying current I placed in a uniform magnetic field $\vec{B}$ as shown in the diagram below.



下列敘述何者正確？

Which of the following is correct?

(A) 導線將受淨力，強度 IRB ，方向朝 +y。
The wire experiences a net force of magnitude IRB pointing to +y.

(B) 導線將受淨力，強度 IRB ，方向朝 −y。
The wire experiences a net force of magnitude IRB pointing to −y.

(C) 導線將受淨力，強度 $2IRB$ ，方向朝 +y。
The wire experiences a net force of magnitude $2IRB$ pointing to +y.

(D) 導線將受淨力，強度 $2IRB$ ，方向朝 −y。
The wire experiences a net force of magnitude $2IRB$ pointing to −y.

(E) 由於圓環對稱，導線並不受淨力。
The wire does not experience any net force due to the circular symmetry.

20. 有關光學，下列敘述何者正確？

About optics, which of the following is correct?

(A) 折射與繞射（衍射）屬於幾何光學的範疇。
Refraction and diffraction are phenomena in the scope of geometric optics.

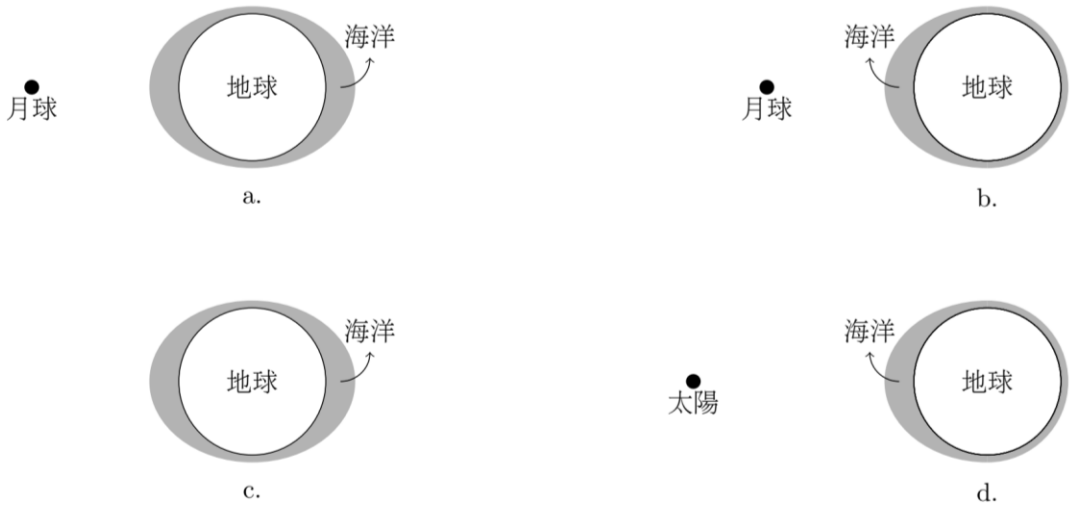
(B) 反射與折射屬於波動光學的範疇。
Reflection and refraction are phenomena in the scope of wave optics.

(C) 繞射（衍射）與干涉屬於波動光學的範疇。
Diffraction and interference are phenomena in the scope of wave optics.

(D) 彩虹的形成是光波干涉所致。
The formation of rainbow is a consequence of wave interference.

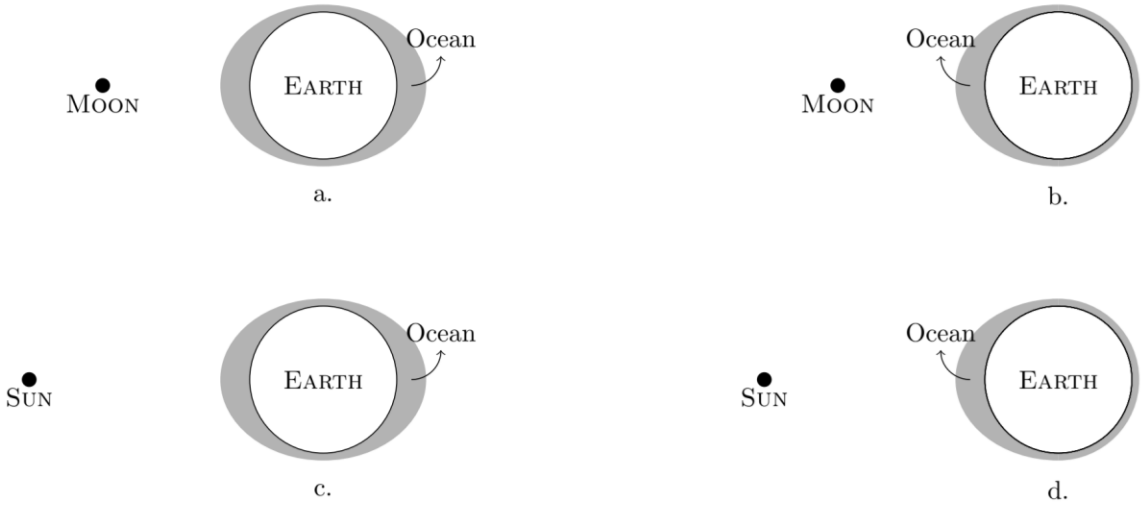
(E) 繞射（衍射）是光波特有的行為。其他的波，例如聲波，並不會呈現繞射（衍射）。
Diffraction is a particular behavior only for light waves. Other waves, such as sound waves, do not exhibit diffraction.

21. 關於潮汐，考慮下面這些示意圖：



何者最可以貼切描述潮汐？

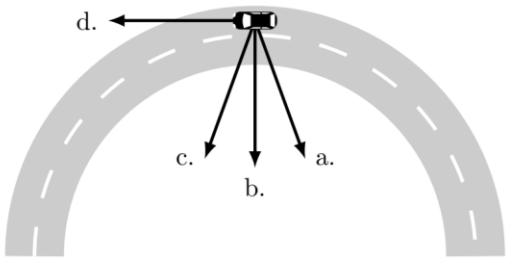
About the tides, consider the following sketches:



Which sketch best describes the situation of the tide.

(A) a.
(B) b.
(C) c.
(D) d.
(E) 以上皆非。 None of them makes sense.

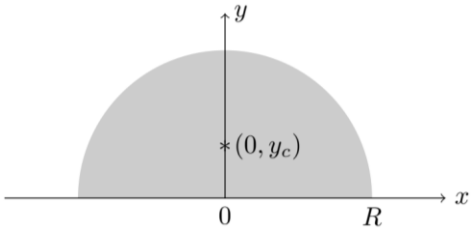
22. 一台汽車於圓環上行駛，如下圖所示：
A car is driving along a ring road as sketched below:



若汽車行駛速度正在加快，哪個箭頭可以是汽車的加速度方向？
Which of the arrows may indicate the acceleration vector if the car is speeding up?

(A) a.
(B) b.
(C) c.
(D) d.
(E) 以上皆非。None of them makes sense.

23. 考慮一個半圓盤，其質量均勻分布，星號表示質心所在位置：
Consider a semicircular disk of uniform mass distribution, with its center of mass marked by $*$:



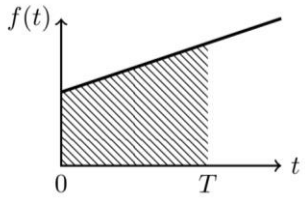
下列何者正確？
Which of the following is correct?

(A) $y_c = R/2$.
(B) $y_c = 2R/5$.
(C) $y_c = 3R/5$.
(D) $y_c = R/\pi$.
(E) $y_c = 4R/3\pi$.

24. 考慮一大氣壓、攝氏零度下的一摩爾理想氣體。若理想氣體常數為$R = 8.3\,\mathrm{J \cdot K^{-1} \cdot mol^{-1}}$，下列選項哪個最接近該氣體的體積？
Consider one mole of an ideal gas at 0°C and 1 atm. Given the ideal gas constant $R = 8.3\,\mathrm{J \cdot K^{-1} \cdot mol^{-1}}$, which of the following values is closest to the volume of the above mentioned gas?

(A) 20公升。20 L.
(B) 22公升。22 L.
(C) 24公升。24 L.
(D) 26公升。26 L.
(E) 28公升。28 L.

25. 直線運動中的物體，其f隨時間t的變化如下：
An object undergoes a motion in a straight line with f as a function of time t sketched in the following:



下列敘述何者不正確？
Which of the following is **incorrect**?

(A) 若f為速度，則所標示的陰影面積代表的是時間0到T物體所移動的距離。
If f is its velocity, the shaded area stands for the distance traveled from time 0 to T.
(B) 若f為位置，則物體所受淨力為零。
If f is its position, the net force acting on the object is zero.
(C) 若f為速度，則物體所進行的是等加速度運動。
If f is its velocity, the object is undergoing a uniform acceleration.
(D) 若f為位置，則速度保持定值。
If f is its position, the velocity remains constant.
(E) 若f為加速度，則所標示的陰影面積代表的是時間0到T所移動的距離。
If f is its acceleration, the shaded area stands for the distance traveled from time 0 to T.