EmSAT Achieve Physics

Public Test Specification

Test Description: EmSAT Achieve Physics measures test taker proficiency in Physics and determines their readiness for college. EmSAT Achieve Physics consists of five major domains: (1) Mechanics; (2) Electromagnetism; (3) Waves and Optics; (4) Modern Physics; and (5) Thermal Physics. The exam is adaptive. Exam content and difficulty is customized to the individual test taker. When a test taker answers a question correctly, they will be given more difficult content; when they answer a question incorrectly, they will be given easier content. This process of continuous adjustment delivers optimized content for each test taker throughout the exam, maximizing their opportunity to perform at their best and providing a more accurate measure of their ability. Test takers should do their best to answer each question correctly; once a question is answered, they will not be able to go back and change the answer.

Test Duration:	120 minutes
Questions:	50 questions
Content Areas:	1. Mechanics 2. Electromagnetism 3. Waves and Optics 4. Modern Physics 5. Thermal Physics
Task Types:	Multiple Choice
Calculators	Allowed

EmSAT Achieve Physics	
Score	**Score Descriptors**
1500+	**High Proficiency:** Students at this level are well-prepared for first-year physics courses at the university level.
1100-1475	**Proficient:** Students at this level are at a satisfactory level of preparation to begin first-year physics courses at the university level.
900-1075	**Borderline Proficient:** Students at this level are minimally prepared for first-year physics courses at the university level and may need additional support in some areas.
700-875	**Basic:** Students at this level do not have sufficient mastery of prerequisite knowledge for first-year courses in physics at the university level and will likely need some additional support.
500-675	**Needs Improvement:** Students at this level need additional instructional support in basic physics concepts and skills before beginning any first-year physics courses.
< 500	**Little knowledge of basic science:** Students at this level lack knowledge and skills of basic science concepts.

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Appendix 1: Content Areas

Below are the major sections and related content specifications that grade 12 students should be able to demonstrate mastery of to meet the expectations of this test.

I. Mechanics

This domain measures examinee understanding on Translational Motion, Rotational Motion and Fluids Mechanics.

A. Translational Motion

The examinee should be able to analyze, interpret and describe the motion of objects in 1D and 2D Translational Motion in term of kinematics and dynamics laws and laws of conservation: conservation of energy and conservation of momentum.

A.1 Examinee should be able to apply all the laws of kinematics and dynamics to interpret, analyze and describe translational motion for objects in different arrangements and situations. This section may include:

1. Distance and Displacement
2. Speed and Velocity
3. Acceleration
4. Kinematic Equations
5. Graphs of Motion
6. Forces
7. Newton's Laws of Motion
8. Newton's Law of Universal Gravitation
9. Falling Objects
10. Projectiles

A.2 Examinee should be able to evaluate the work done by a force or multiple forces on a given system to the changes in that system total energy and power and apply the law of conservation of energy to describe, analyze and solve problems that are difficult to analyze using Newton's Laws of Motion. This section may include:

1. Work
2. Energy
3. Power

A.3 Examinee should be able to use the law of conservation of 1D and 2D linear momentum to describe, analyze and solve the motion of situations that are difficult to analyze using Newton's Laws of Motion such as collisions and explosions in 1D and 2D. This section may include:

1. Center of Mass
2. Linear Momentum and Impulse

B. Rotational Motion

Examinee should be able to analyze, interpret and describe the rotational motion of an extended rigid object about a fixed axis in term of kinematics and dynamics laws and laws of conservation: conservation of angular energy and conservation of angular momentum.

B.1 Examinee should be able to apply all the laws of kinematics and dynamics to interpret, analyze and describe rotational motion of an extended rigid object about a fixed axis in different arrangements and situations. This section may include:

1. Rotational Kinematics
2. Moment of Inertia
3. Torque
4. Angular Momentum
5. Newton's Second Law for Rotation
6. Circular Motion
7. Static Equilibrium

B.2 Examinee should be able to relate the work done by torque(s) on a given system to the changes in that system total angular energy and use the law of conservation of angular energy to describe, analyze and solve problems that are difficult to analyze using Newton's Laws of Motion. This section may include:

1. Rotational Work
2. Rotational Energy
3. Simple Machines

C. Fluids Mechanics

Examinee should be able to analyze, interpret and describe the properties of fluids at rest and in motion using fluids mechanics laws such as Pascal's Principle, Archimedes' Principle and Bernoulli's Equation.

C.1 Examinee should be able to analyze, predict and describe the properties of fluids at rest (Hydrostatics). This section may include:

1. Density and Pressure.
2. Pascal's Principle.
3. Archimedes' Principle.

C.2 Examinee should be able to analyze, predict and describe the properties and the behavior of ideal fluids in motion (Hydrodynamics). This section may include:

1. Fluids Flow
2. Bernoulli's Equation

II. Electromagnetism

This domain measures examinee understanding of static and current electricity, magnetism and the interaction between electricity and magnetism (electromagnetism).

A. Electricity

Examinee should be able to demonstrate an understanding of all the phenomena and application related to static and current electricity.

A.1 Examinee should be able to analyze and explain the phenomena and properties related to stationary or slow-moving electric charges. This section may include:

1. Electric Charge
2. Electrostatic Force
3. Electric Feld
4. Electric Flux
5. Electrostatic Potential
6. Electrostatic Energy
7. Capacitors, Capacitance and Dielectrics

A.2 Examinee should be able to describe the motion of electric charges in conductors and distinguish between practical DC and AC circuits in term of characteristics and applications. This section may include:

1. Electric Current
2. Electromotive Force
3. Resistance, Resistivity, and Ohm's Law
4. Electric Power and Joule's Heating
5. Direct Current (DC) and Alternating Current (AC) Electric Circuits

B. Magnetism

Examinee should be able to demonstrate an understanding of the concept of magnetism and magnetism related phenomena and explain how electricity could be generated from magnetism.

B.1 Examinee should be able to analyze, explain and describe all phenomena associated with natural magnets and electromagnets such as magnetic field, magnetic forces, magnetic flux, and magnetic torque. This section may include:

1. Magnet and Electromagnet Properties
2. Magnetic Field
3. Magnetic Flux
4. Magnetic Force
5. Magnetic Torque

B.2 Examinee should be able to explain the concept electromagnetic induction that electricity could be generated from magnetism and use it to explain the operation of electromagnetic induction applications such as transformers and electric generators. This section may include:

1. Electromagnetic Induction Laws
2. Inductance
3. Transformers

III. Waves and Optics

This domain measures examinee understanding of oscillations, waves (Mechanical waves and electromagnetic waves) and optics (geometric optics and physical optics).

A. Waves

Examinee should be able to analyze, interpret and describe different types of oscillations and explain how repeated oscillations cause periodic waves (travelling wave or standing waves) with unique properties and characteristics.

A.1 Examinee should be able to distinguish and analyze different types of oscillations: ideal oscillations, damping oscillations and forced oscillations and describe them mathematically and graphically and identify the conditions for each type of oscillations.
This section may include:

1. Undamped Simple Harmonic Motion
2. Damped Oscillations
3. Driven (Forced) Oscillations and Resonance

A.2 Examinee should be able to describe and represent different mechanical waves properties and characteristics mathematically and graphically and analyze the wave behavior of these waves such as standing waves, doppler effect, superposition and reflection.
This section may include:

1. Mechanical Waves Characteristics.
2. Mechanical Waves Behavior
3. Sound in Motion (Doppler Effect)

B. Optics

Examinee should be able to analyze and describe the behavior and the properties of light, along with its interactions with matter and with the instruments which are used to detect it.

B.1 Examinee should be able to analyze, describe and explain the phenomena of light wave where ray approximation of geometric optics is not valid such as interference, diffraction, and polarization.

This section may include:

1. Electromagnetic Waves
2. Polarization
3. Interference
4. Diffraction

B.2 Examinee should be able to use ray diagrams to analyze, identify and describe the image properties and characteristics that are formed by different types of mirrors and thin lenses and explain the operation of different optical instruments and devices.

This section may include:

1. Reflection
2. Refraction
3. Mirrors
4. Thin Lenses

IV. Modern Physics

This domain measures examinee understanding the concepts and the implications of the branch of physics that was developed in the early 20th century and onward such as the theory of relativity and quantum physics.

A. The Theory of Relativity

Examinee should be able to distinguish between the special theory of relativity and the general theory of relativity and use them to explain many modern physics phenomena such as nuclear physics, astronomy and cosmology.

A.1 Examinee should be able to explain the implications of Einstein's General Theory of Relativity. This section may include:

1. Equivalence Principle
2. Frames of Reference

A.2 Examinee should be able to explain the implications of Einstein's Special Theory of Relativity and describe how Newtonian mechanics failed to explain properly the motion of objects whose speeds approach that of light. This section may include:

1. Einstein's Special Theory of Relativity Postulates
2. Einstein's Special Theory of Relativity Consequences: (Length, Mass, Time, Energy, etc)

B. Atomic Physics

Examinee should be able to use the quantum theory to explain the nature and behavior of matter and energy on the atomic level that the classical physics failed to such as light wave-particle duality and the modern atomic structure model.

B.1 Examinee should be able to describe and explain the dual nature of light and matter and explain the experiments that proved the light-matter duality. This section may include:

1. Matter Waves: De Broglie Wavelength
2. Heisenberg Uncertainty Principle

B.2 Examinee should be able to explain how the quantum physics theory helped in understanding the modern atomic model (Bohr Model). This section may include:

1. Blackbody Radiations
2. Photoelectric Effect
3. The Compton Effect
4. Atomic Models and Atomic Spectra
5. Quantum Physics Application.

C. Nuclear Physics

Examinee should be able to describe the atomic nuclei and their constituents, interactions and radiations when they are unstable.

C.1 Examinee should be able to describe the properties and the structure of the atomic nucleus and distinguish between natural transmutation and artificial transmutation. This section may include:

1. Nuclear Structure and Properties
2. Radioactivity
3. Nuclear Reactions

C.2 Examinee should be able to describe the nature of the particles that constitute matter and radiation and distinguish between elementary particles and composite particles. This section may include:

1. Elementary Particles.
2. Composite Particles.

V. Thermal Physics

This domain measures examinee of understanding thermal physics concepts and quantities and thermodynamics systems, processes and laws.

A. Temperature and Heat

Examinee should be able to define fundamental physical quantities (internal energy, temperature, heat) that characterize thermodynamic systems.

A.1 Examinee should be able to define and measure temperature in different temperature scales and describe how temperature change alters materials dimensions (thermal expansion). This section may include:

1. Temperature Scales
2. Thermal Equilibrium
3. Thermal Expansion

A.2 Examinee should be able to distinguish between heat (thermal energy transfer) and temperature and describe how phase change and heat transfer occur. This section may include:

1. Quantity of Heat and Specific Heat Capacity
2. Calorimetry and Phase Changes
3. Mechanisms of Heat Transfer

B. Thermodynamics

Examinee should be able to describe ideal gases and their behavior using the kinetic molecular theory of gases and use thermodynamic laws to characterize and define thermodynamics systems processes and directions.

B.1 Examinee should be able to use the kinetic-molecular theory to explain the empirical gas laws (observations) and the behavior of ideal gases. This section may include:

1. Ideal Gas Laws.
2. Kinetic Molecular Theory.

B.2 Examinee should be able to use laws of thermodynamics to define physical quantities that characterize thermodynamics systems in equilibrium such as temperature, energy and entropy and describe the relationships between these quantities. This section may include:

1. Zeroth Law of Thermodynamics (Absolute Zero)
2. First Law of Thermodynamics.
3. Second Law of Thermodynamics.

Appendix 2: Required Mathematics Knowledge and Skills.

A. Arithmetic:
   - **Candidates should be able to:**
     - Use decimal and scientific notations expressions.
     - Perform addition, subtraction, multiplications and divisions using signed and unsigned numbers.
     - Use scientific calculators to perform arithmetic operations.
     - Deal with means, powers including reciprocals and square roots, exponentials and logarithms (log and ln), sines, cosines, tangent and the inverse functions.
     - Specify appropriate number of significant figures.

B. Algebra:
   - **Candidates should be able to:**
     - Manipulate (rearrange) an equation in term of a specified quantity- change the subject of the equation.
     - Solve algebraic equations (find the solution) of first-degree (linear equation) and second-degree (quadratic equation) including equations that has logarithmic and exponential function.
     - Evaluate an equation by substitution (substituting the value of a given quantity).
     - Check the units' consistency of an equation.
     - Formulate an equation to represent models of physical situations/scenario).

C. Geometry and Trigonometry:
   - **Candidates should be able to:**
     - Find the areas, volumes and circumference of different of triangles (right angled, isosceles) circles, rectangles, cylinders and spheres.
     - Use Pythagoras' theorem, similarity of triangles, the angle sum of a triangle.
     - Use sines, cosines and tangents (especially for 0°, 30°, 45°, 60°, 90°).
     - Convert from degrees to radians and vice versa.

D. Vectors:
   - **Candidates should be able to:**
     - Perform vector addition, subtraction, multiplication.
     - Find the resultant of two coplanar vectors.
     - Resolve vectors into their perpendicular components.

E. Graphs:
   - **Candidates should be able to:**
     - Extract information from graphs as required.
     - Interpret the meaning of the graph variables and scales (units).
     - Find the slope, intercept and intersection for linear graphs and write linear equation form $y = mx + c$.
     - Find the line best fit for a set of data points presented graphically.
     - Find the area below a curve where the area has physical significance.

F. Integration and Derivative
   - **Candidates should be able to:**
     - Perform common derivatives such as:
       - Polynomials
       - Trig functions
       - Inverse trig functions
       - Exponential/Logarithm Functions
     - Perform common integrals such as:
       - Polynomials
       - Trig functions
       - Inverse trig functions
       - Exponential/Logarithm Functions
       - Miscellaneous
     - Perform integration using standard integration techniques such as:
       - u Substitution
       - Integration by Parts
       - Trig Substitutions
       - Partial Fractions

Appendix 3: Sample Questions

1.

During beta minus decay a neutron decays into a proton, an electron and a charge-less particle.
What is the name of this charge-less particle?

خلال انحلال جسيمات بيتا السالبة، يتحلل النيوترون إلى بروتون وإلكترون و جسيم غير مشحون.
ما إسم هذا الجسيم غير المشحون؟

A. Antineutrino ضد نيوترينو

B. Pi Meson ميزون Pi

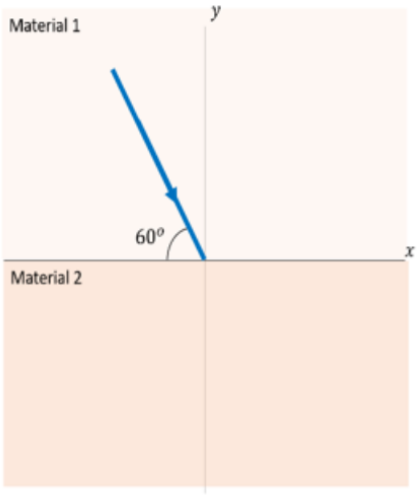
C. K Meson ميزون K

D. Sigma particle جسيم سيجما

2.

The figure below shows a light ray that travels from material 1 and arrives at the interface between material 1 and material 2. What is the angle of reflection?

الشكل ادناه يوضح سقوط شعاع ضوئي ينتقل من الوسط 1 إلى السطح الفاصل بينه وبين الوسط 2. ماهي زاوية الانعكاس؟



A. 30°

B. 60°

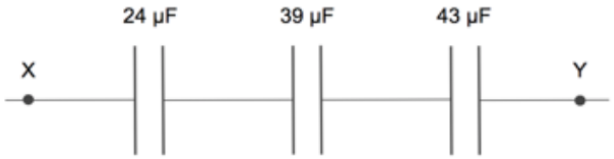
C. 120°

D. 150°

3.

Three capacitors are connected in series as shown in the following diagram.
What is the net capacitance between points X and Y?

تم وصل ثلاثة مكثفات على التوالي كما في الشكل. ما قيمة السعة المكافئة بين النقطتين X و Y؟



A. 11 μF

B. 16 μF

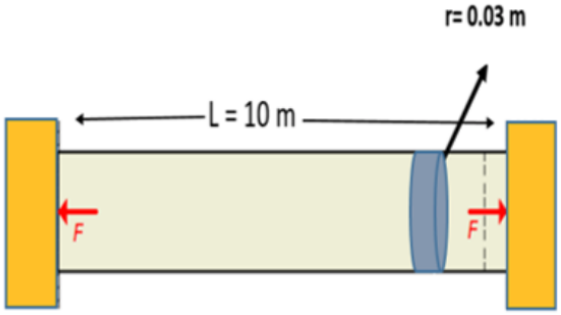
C. 28 μF

D. 103 μF

4.

The illustration shows a steel rod is fixed between two walls. The rod has a length (L=10 m) and a circular cross sectional area with radius (r=0.03 m).
How much force is generated by the rod on the wall if the temperature increases from 20°C to 40°C ?

الصورة تشير إلى قضيب من الحديد مُثبت بين حائطين. طول القضيب يساوي 10 متر ومساحة مقطع دائرية نصف قطرها 0.03 متر.
ما قيمة القوة الناتجة من القضيب على الحائط إذا زادت درجة حرارة القضيب من 20 درجة مئوية إلى 40 درجة مئوية؟



A. 1.34×10^5 N

B. 3.05×10^5 N

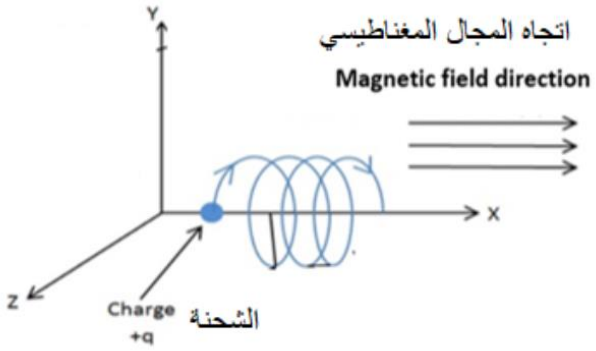
C. 2.88×10^5 N

D. 5.70×10^5 N

5.

A 20×10^{-6} C charge is moving at a constant speed of 5×10^{7} m/s through a magnetic field strength of 3T at an angle of 30° with the magnetic field direction. Find the magnetic force on this moving charge?

تتحرك شحنة قيمتها $20x10^{-6}$ كولوم بسرعة ثابتة $5x10^{7}$ متر/ثانية خلال مجال مغناطيسي منتظم شدته 3 تسلا وزاوية 30 درجة مع اتجاه المجال المغناطيسي. ما هي قيمة القوة المغناطيسية على الشحنة المتحركة؟



A. 1500 N

B. 2000 N

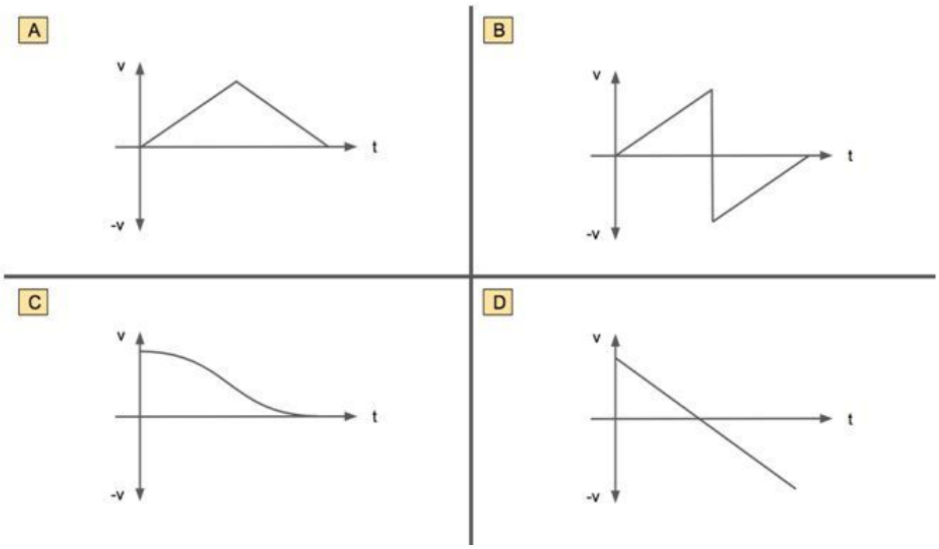
C. 1300 N

D. 4300 N

6.

A ball is thrown vertically up in the air and then caught again. Which velocity-time graph for the ball is correct?

تم قذف كرة عمودياً للأعلى ومن ثم إلتقاطها مرة أخرى. أيُ رسم بياني لسرعة الكرة مع الزمن صحيح؟



A. D

B. A

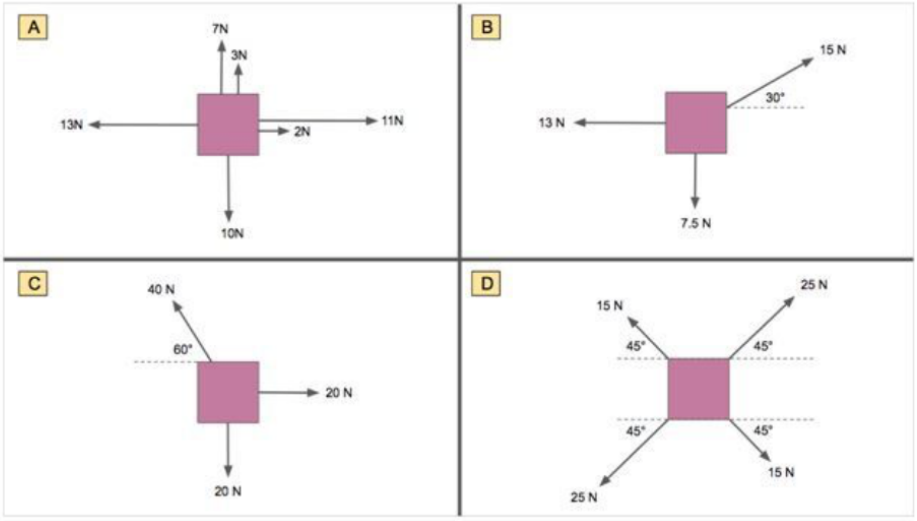
C. B

D. C

7.

In which of the four situations are the forces on the object **not** balanced?

في أيّ من الأشكال الأربعة تكون القوى المؤثرة على الجسم **غير** متزنة؟



A. C

B. A

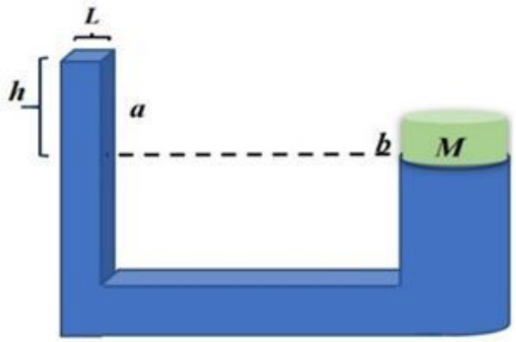
C. B

D. D

8.

A water piston has two sides , side *a* which has a square cross section of L = 0.25m, and side *b* of a circular cross section of radius r = 0.5 m .
What is the mass m need to be added to the square cross section to lift the mass M = 1000 kg on the circular cross section knowing that the height h = 1m?

مكبس ماء يحتوي على جانبين، الجانب a له مساحة مقطع مربعة بطول L =0.25 متر، والجانب b له مساحة مقطع دائرية بنصف قطر r =0.5 متر.
ما هي قيمة الكتلة m التي يجب إضافتها للجانب a ذو المساحة المربعة لرفع كتلة M = 1000 كغم على الجانب b ذو المساحة الدائرية إذا علمت أن الإرتفاع h= 1 متر.



A. 17kg — 17 كغم

B. 80kg — 80 كغم

C. 142kg — 142 كغم

D. 272kg — 272 كغم

9.

A proton is accelerated to 90% the speed of light in a particle accelerator. By what factor will the mass of the proton increase by?

تم تسريع بروتون إلى 90% من سرعة الضوء بواسطة مُسارع الجسيمات. ما المُعامل الذي سوف تزداد به كتلة البروتون؟

A. 2.29

B. 2.45

C. 2.84

D. 3.16

10.

The air pressure in a car tyre is measured to be 35 psi when at a temperature of 28°C and can be assumed to be an ideal gas. The car is then driven for some time and the internal air temperature then rises to 54°C. What will be the new tyre pressure?

ضغط الهواء في إطارات السيارة يساوي 35 psi عند درجة حرارة 28 درجة مئوية ويمكن اعتبار الهواء على أنه غاز مثالي. تحركت السيارة لبعض الوقت وارتفعت حرارة الهواء داخل الإطار إلى 54 درجة مئوية. ماذا سيكون ضغط الهواء الجديد في الإطارات؟

A. 38 psi

B. 32 psi

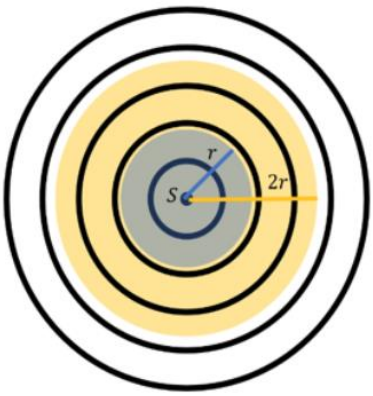
C. 36 psi

D. 40 psi

11.

The figure below shows a spherical wave that radiates from the source at S where the black circles represent the peaks of the wave. Assuming that I is the average intensity of the wave at the surface of the sphere of radius r. What is the average intensity of the wave at the surface of a sphere of radius 2r?

الشكل ادناه يوضح موجة كروية تنبعث من مصدر عند S حيث تمثل الدوائر السوداء قمم الموجة. افرض أن I تمثل متوسط شدة الموجة على سطح الكرة التي نصف قطرها r. ما هو متوسط شدة الموجة على سطح كرة نصف قطرها 2r ؟



A. $\frac{I}{4}$

B. $\frac{I}{2}$

C. $2I$

D. $4I$

12.

If the work function for silver is 4.70 eV, what is the minimum frequency of incident light that will cause photoemission of electrons?

إذا كانت دالة الشغل للفضة تساوي 4.70 إلكترون فولت، ما هو الحد الأدنى لتردد الضوء الساقط حتى يحدث إنبعاث ضوئي للإلكترونات؟

A. 1.13×10^{15} Hz

B. 1.52×10^{15} Hz

C. 2.15×10^{15} Hz

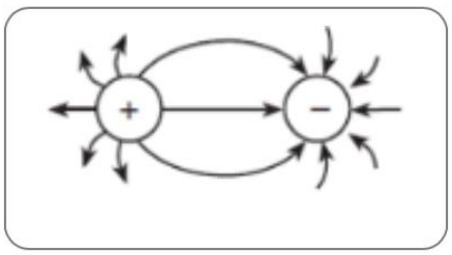
D. 2.74×10^{15} Hz

13.

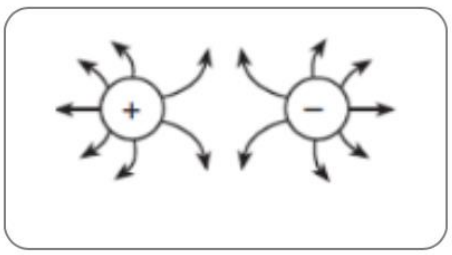
Which diagram represents the electric field between two oppositely charged conducting spheres?

أيُ من الأشكال أدناه يمثل مجال كهربي بين شحنتين متعاكستين على كرتين موصلتين؟

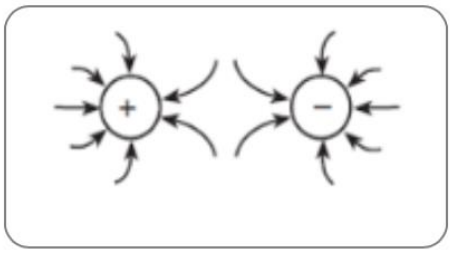
A.



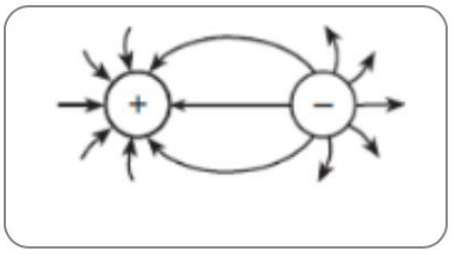
B.



C.



D.



14.

A cart travels with a constant nonzero acceleration along a straight line.

Which graph best represents the relationship between the distance the cart travels and time of travel?

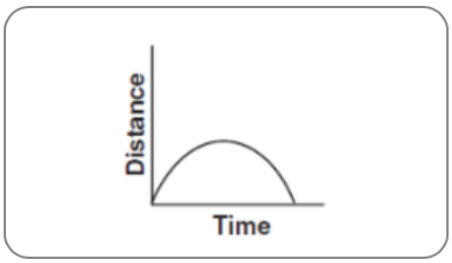
تُسافر سيارة بتسارع ثابت على خط مستقيم.

أي رسم بياني يُمثل بشكل أفضل العلاقة بين المسافة المقطوعة والزمن؟

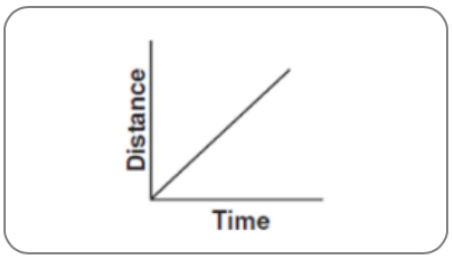
A.

B.

C.



D.



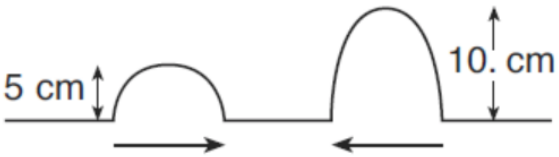
15.

The diagram below shows two pulses approaching each other in a uniform medium.

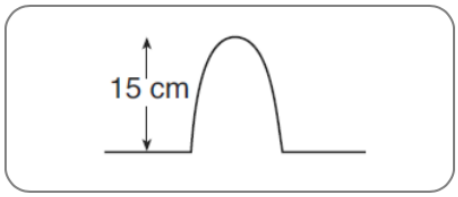
Which diagram best represents the superposition of the two pulses?

يشير الشكل أدناه إلى إقتراب نبضتين لبعضهما في وسط متجانس.

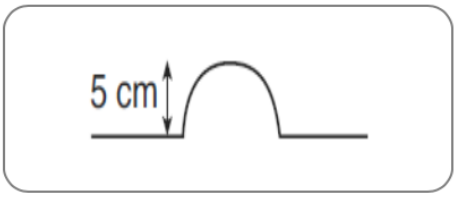
أي شكل يعطي أفضل تمثيل لمبدأ التراكب للنبضتين؟



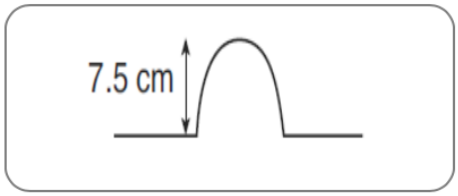
A.



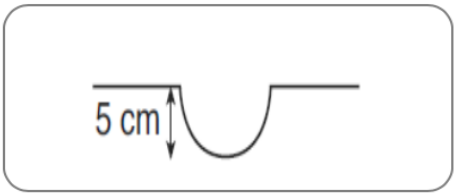
B.



C.



D.



16.

One vibrating 256 *Hz* tuning fork transfers energy to another 256 *Hz* tuning fork, causing the second tuning fork to vibrate.

What type of phenomenon is this?

تهتز شوكة رنانة بتردد 256 *Hz* بحيث تنقل الطاقة من هذه الشوكة إلى شوكة أخرى لها نفس التردد الطبيعي 256 *Hz* مما يجعلها تهتز.

ما اسم هذه الظاهرة؟

A. resonance الرنين

B. diffraction الحيود

C. refraction الإنكسار

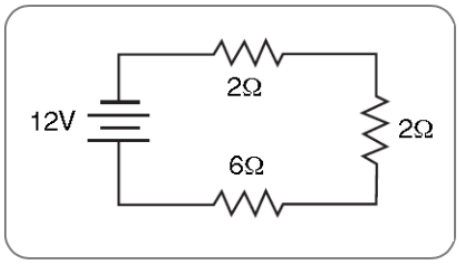
D. reflection الإنعكاس

17.

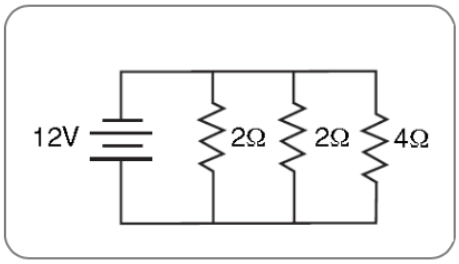
Which circuit has the largest equivalent resistance?

ايّ من الدارات الكهربية أدناه لها أكبر مقاومة مكافئة؟

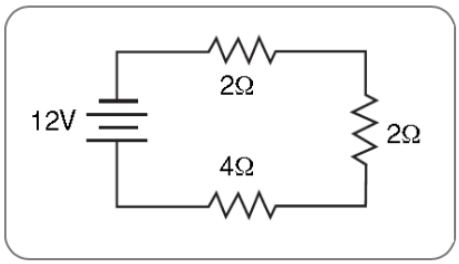
A.



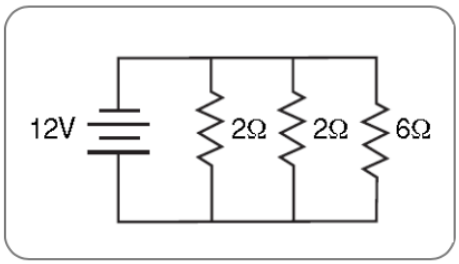
B.



C.



D.



Answer Key:

1. A
2. A
3. A
4. A
5. A
6. A
7. A
8. A
9. A
10. A
11. A
12. A
13. A
14. A
15. A
16. A
17. A