

# **Secondary School Mathematics & Science Competition 2015**

# **Physics**

Date	: 1 May, 2015	Total no. of pages	: 26
Time allowed	: 12:00 - 1:15 pm (1 hour 15 minutes)	Total marks	: 50

1. Write your Candidate Number, Exam Centre Number, Seat Number, Name in English, Name of School, Form, Language and Subject in the spaces provided on the Part A MC Answer Sheet and the Part B Answer Sheet.

2. When told to open this question paper, you should check that all the questions are there. Look for the words 'END OF PAPER' after the last question.

- 3. Answer ALL questions in both Part A and Part B.
- 4. Part A (Multiple Choice Questions) (35marks)
  - (a) You are advised to use an **HB** pencil to mark all your answers on the MC Answer Sheet.
  - (b) Each question carries one mark.
  - (c) You should mark only **ONE** answer for each question. If you mark more than one answer, you will receive **NO MARK** for that question.
- 5. Part B (Short Questions) (15 marks)
  - (a) Answers should be written in the space provided on the Part B Answer Sheet.
- 6. No mark will be deducted for wrong answers.
- 7. The diagrams in this paper are not necessarily drawn to scale.

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### Part A: Multiple Choice Questions (35 marks)

1. A car starts from rest with uniform acceleration *a*. After a certain time, its acceleration becomes -a. It continues to travel until it stops finally. If the total displacement of the car is *L*, what is the total time of travel?



2.



An object starts from rest and moves with uniform acceleration along a straight line. The graph above shows how the displacement of the object varies with the square of time. Find the acceleration of the object.

- A.  $0.5 \text{ ms}^{-2}$
- B. 1 ms<sup>-2</sup>
- C.  $2 \text{ ms}^{-2}$
- D.  $4 \text{ ms}^{-2}$



Figure (a)

3.

Figure (a) shows a simple pendulum, which consists of a metal bob suspended by a light string. The bob is displaced to one side at position A so that the string makes an angle  $2\theta$  with the vertical. It is then released from rest (Figure (b)). Assuming that friction and air resistance are negligible, which of the following correctly shows all the forces acting on the metal bob when the string makes an angle  $\theta$  with the vertical?



4. As shown in the diagram, a beam of length 3 m and negligible mass is supported by two trestles A and B at the ends as shown. A gymnast of mass 48 kg stands at the middle point M of the beam initially and gradually moves to point X on the beam, at a distance of 1 m from *A*. Find the change of the force exerted on the beam by the trestle B before and after the movement by the gymnast.



- A. Decreased by 78.5 N.
- B. Decreased by 157 N.
- C. Kept constant at 157 N.
- D. Kept constant at 235 N.
- 5. The figure shows two forces of 25 N acting on a steering wheel of a car in different directions. The diameter of the steering wheel is 50 cm. Find the moment of the couple acting on the steering wheel.



- A. 0 Nm
- B. 6.3 Nm
- C. 12.5 Nm
- D. 25 Nm



As shown in the diagram, two metal balls A and B are initially placed at the same height. Ball A is dropped vertically while ball B is projected horizontally at the same time. Which of the following statements about the motion of two balls are correct?

- (1) Both balls reach the ground at the same time.
- (2) Both balls have the same vertically acceleration.
- (3) Both balls have the same horizontal velocity
- A. (1) and (2) only
- B. (1) and (3) only
- C. (2) and (3) only
- D. (1), (2) and (3)
- 7. If the average angular velocities of the second arm, minute arm and hour arm of the clock are X , Y and Z respectively, find the ratio of X : Y : Z.



A. 
$$1: \frac{1}{60}: \frac{1}{720}$$
  
B.  $\frac{1}{720}: \frac{1}{60}: 1$   
C.  $1: \frac{1}{60}: \frac{1}{3600}$   
D.  $\frac{1}{3600}: \frac{1}{60}: 1$ 



A man pulls a suitcase of mass 20 kg with a force at an angle of  $60^{\circ}$  to the horizontal. The suitcase moves at a constant velocity. Find the normal reaction acting on the suitcase, given that the frictional force acting on the suitcase is 15 N.

- A. 170.2 N
- B. 187.5 N
- C. 196.2 N
- D. 226.2 N

9.



Two blocks A and B, of masses 2 kg and 3 kg respectively, are placed on a smooth horizontal table as shown above. A horizontal constant force of 10 N is applied to block B so that the two blocks move to the left with uniform acceleration. What is the magnitude of the contact force between A and B?

- A. 0 N
- B. 4 N
- C. 5 N
- D. 10 N



A ball is projected upwards near a high wall and travels through a parabolic path as shown in Figure (a). The ball reaches the top of the wall finally. Figure (b) shows the velocity-time graph (v - t graph) for the motion of the ball. Taking the downward direction as positive, find the height of the wall.



Figure (b)

- A. 2 m
- B. 2.5 m
- C. 4.5 m
- D. 6.5 m



An artificial satellite is at a height H above the surface of the Earth. Given the radius of the Earth is  $R_0$ , and the acceleration due to gravity near the Earth's surface is  $g_0$ . Find the acceleration of the artificial satellite due to gravity.

A. 
$$g_0 \times \left(\frac{R_0 + H}{R_0}\right)$$
  
B.  $g_0 \times \left(\frac{R_0}{R_0 + H}\right)$   
C.  $g_0 \times \left(\frac{R_0 + H}{R_0}\right)^2$   
D.  $g_0 \times \left(\frac{R_0 + H}{R_0}\right)^2$ 



The above graph shows the variation of the kinetic energy *E* of an object with the square of its velocity  $v^2$ . What is the momentum of the object when it is moving at a velocity 5 ms<sup>-1</sup>?

- A. 16 kgms<sup>-1</sup>
- B. 20 kgms<sup>-1</sup>
- C. 24 kgms<sup>-1</sup>
- D. 32 kgms<sup>-1</sup>
- 13. The figure shows a man standing on a bathroom scale in the lift. Which of the following statements about the reading of the bathroom scale is correct?



- A. The reading of the bathroom scale will increase if the lift is moving upwards with constant speed.
- B. The reading of the bathroom scale will decrease if the lift is moving downwards with constant speed.
- C. The reading of the bathroom scale will increase if the lift is moving downwards with increasing speed.
- D. The reading of the bathroom scale will decrease if the lift is moving upwards with decreasing speed.

- 14. Pair of forces  $F_A$  and  $F_B$  are indicated in each of the following cases. Which of them is an example of action-and-reaction pairs according to the Newton's third law?

B.

A.



C.



D.



- $\uparrow F_A$  = tension in the spring that holds the metal object
- $\downarrow F_B =$  weight of the object

- $\rightarrow F_A$  = weight of the man
- $\leftarrow F_B = \text{attractive force acting on the Earth}$ by the man
- $\uparrow F_A = \text{normal reaction acting on the metal}$ block by the table
- $\downarrow F_B$  = weight of the metal block
- $\rightarrow F_A$  = The centripetal force acting on the rubber bung by hand
- $\leftarrow F_B = \text{The centrifugal force acting on}$ the rubber bung by hand

- 15. In 1909, Rutherford, performed the  $\alpha$  particle scattering experiment. Which of the following conclusions <u>*CANNOT*</u> be deduced from the results of the experiment?
  - A. Most of the volume occupied by an atom is empty space.
  - B. All the positive charges are concentrated in a small volume at the center of the atom.
  - C. There are some neutral particles at the center of the atom.
  - D. The negatively charged electrons orbit around the nucleus.

16.









A  $\beta$  source in Figure (a) is taken from a wooden box as shown in Figure (b). The  $\beta$  source is placed in front of the window of the GM tube as shown in Figure (c), and an initial count rate of 360 Bq is recorded. After 8 hours, the measurement is repeated and the recorded count rate drops to 180 Bq. Given the background count rate is 120 Bq, find the half-life of the  $\beta$  source.



- A. 16 hours
- B. 8 hours
- C. 4 hours
- D. 2 hours



Energy is transferred to two substances *X* and *Y* of equal mass at the same rate. The figure above shows the temperature-time graph. Initially both substances are at the solid state. Which of the following statements are correct?

- (1) Y has a higher specific heat capacity in the liquid state.
- (2) *X* has a higher boiling point.
- (3) X has a higher specific latent heat of fusion.
- A. (1) and (2) only
- B. (1) and (3) only
- C. (2) and (3) only
- D. (1), (2) and (3)
- 18. A student mixes 1 kg of water at 45 °C with 1.5 kg of grape juice at 20 °C. Find the final temperature of the mixture. Specific heat capacities of water and grape juice are 4200 J kg<sup>-1</sup> °C<sup>-1</sup> and 3400 J kg<sup>-1</sup> °C<sup>-1</sup>, respectively. Assume there is no energy lost to the surrounding.
  - A. 30.1 °C
  - B. 31.3 °C
  - C. 32.5 °C
  - D. 33.7 °C



A student uses a vibrator to generate a transverse wave on a string. Figure (a) shows the shape of the string at a certain instant. Figure (b) shows the displacement-time graph of a certain particle on the string. Which of the following expressions represents the speed of the wave?

- A.  $\frac{4ac}{9}$ B.  $\frac{a}{c}$ C.  $\frac{c}{b}$ D. 3bc
- 20. A spring has a <u>NON-NEGLIGIBLE</u> mass uniformly distributed along its length. It is suspended from the ceiling on one side, and a mass is hung from its lower end. A pulse is generated in the spring. Which of the following statements is/are correct?
  - (1) The travelling speed of the pulse increases as it travels upwards.
  - (2) The amplitude of the pulse increases as it moves upwards.
  - (3) The time for the pulse to travel from the top to the bottom, and from the bottom to the top, are identical.

mass

- A. (2) only
- B. (3) only
- C. (1) and (2) only
- D. (1) and (3) only

21. A longitudinal wave is travelling from left to right in a medium. The figure below shows the positions of the particles in the medium where a wave passes by at a certain instant and their equilibrium positions.

a b ●●	c ●	d ●	)	e ●	:	f ●	g ●	hij ●●●	k •			m ●	positions of the particles at a certain instant
a	Ե	c	d	e	f	g	h	i	j	k	1	m	equilibrium positions
●	●	●	●	●	●	●	●	●	●	●	●	●	

Which of the following statement(s) is/are *INCORRECT*?

- (1) The distance between particles e and m is equal to one wavelength.
- (2) Particles a and i are momentarily at rest.
- (3) Particles a and i are moving to the left.
- A. (1) only
- B. (2) only
- C. (1) and (2) only
- D. (2) and (3) only

<sup>22.</sup> The diagram shows a wave travelling from region *P* to *Q*. Find the ratio  $\frac{\text{wave speed in } P}{\text{wave speed in } Q}$ .



- A.  $\cos 20^{\circ}$
- $\frac{\cos 40^{\circ}}{B.}$  B.  $\frac{\cos 40^{\circ}}{2}$
- $\begin{array}{c} \cos 20^{\circ} \\ \text{C.} \quad \sin 20^{\circ} \end{array}$
- $\frac{\sin 20}{\sin 40^{\circ}}$
- D.  $\frac{\sin 40^{\circ}}{\sin 20^{\circ}}$

23. In the figure below, plane mirror *AB* is vertical, and plane mirror *BC* inclines at an angle  $\theta$  to the vertical. A beam of light *L* strikes *AB* at the angle of incidence  $\alpha$ . What must be the value of  $\alpha$  in order that the emerging beam *L'* is horizontal?



- Α. θ
- B.  $90^{\circ} \theta$
- C. 2*θ*
- D.  $180^{\circ} 2\theta$

24. The diagram below shows a wave propagating from left to right through a uniform string with a decreasing amplitude. Which of the following statements about particles a, b and c on the string are correct?



- (1) Particle a is moving up, particle b is instantaneously at rest and particle c is moving down.
- (2) All particles are moving at the same frequency.
- (3) Particle *c* is moving faster than particle *a*.
- A. (1) and (2) only
- B. (1) and (3) only
- C. (2) and (3) only
- D. (1), (2) and (3).
- 25. A guitar string, fixed on both ends, is of length 60 cm. Which of the followings is <u>NOT</u> a possible wavelength of a stationary wave on the string?
  - A. 120 cm
  - B. 80 cm
  - C. 60 cm
  - D. 20 cm



The above diffraction pattern is obtained when a beam of blue light is directed towards a single slit. Which of the following figure best shows the diffraction pattern, if the blue light source is replaced by a red light source?



27. Three uncharged metal boxes *A*, *B* and *C* are placed as shown in the following figure. A positively-charged rod is brought near box *A* and held fixed there. If box *B* is earthed momentarily, which of the following correctly describes the charge on boxes *A*, *B* and *C*?



28. Six positive point charges (1 to 6) with magnitudes shown are placed at the corners of a regular hexagon. A point charge q is now placed at the centre of the hexagon. If the magnitude of the electric force on q due to charge 1 only is F, what is the magnitude of the resultant electric force acting on q?



- A. 0
- B. *F*
- C.  $2F \cos 30^{\circ}$
- D. 2*F*

29.



A charged particle moves from A to B in an electric field along a curved path as shown. If the point charge is subject to electric force only, which of the following statements **must** be correct?

- (1) The particle carries negative charge.
- (2) The acceleration of the particle at A is higher than that at B.
- (3) The speed of the particle at A is zero.
- A. (1) only
- B. (2) only
- C. (1) and (3) only
- D. (2) and (3) only
- 30. The network of resistors shown below consists of four identical resistors of resistance *R* and one 24  $\Omega$  resistor. The equivalent resistance between *P* and *Q* is 12  $\Omega$ . If the resistance of each of the four identical resistors is reduced to *R*/2, what is the equivalent resistance between *P* and *Q*?



- Α. 4 Ω
- B. 6Ω
- C. 8Ω
- D. 10 Ω



The rechargeable cell of a mobile phone shown has a capacity of 2500 mAh. The capacity shows the quantity of charge that the cell can store. The cell is used to operate a mobile phone continuously for 20 hours. Assume that its voltage remains constant at 1.2 V during operation, estimate the average power of the mobile phone.

- A. 150 mW
- B. 300 mW
- C. 1.04 W
- D. 45 W
- 32. A 6 V battery and a 12 V battery, both of negligible internal resistance, are connected in series with two resistors of 2  $\Omega$  and 4  $\Omega$  as shown in the following figure. What is the voltage across *AB*?



- A. 0 V
- B. 4 V
- C. 8 V
- D. 12 V



The figure above shows the magnetic field in a region. Which of the following statements is correct?

- A. If a point charge moves along PQ, the force that it experiences increases.
- B. If an iron grain moves along PQ, the force that it experiences increases.
- C. If a point charge moves along the arc *AB*, it will not experience any force.
- D. If an iron grain moves along the arc *AB*, it will not experience any force.

34. In the following figure, a simple magnetic tape playback system is reading the magnetic pattern on a tape. The arrows show the orientations of the magnetic materials on the tape. At which of the following positions is the galvanometer reading the greatest?



As shown in the figure above, 4 conducting frames (a, b, c, and d) are made of conducting wire of same material with the sides of lengths either L or 2L. When the frames enter an uniform magnetic field on the right side with the same speed, the potential differences between M and N on each of the frames are  $V_a$ ,  $V_b$ ,  $V_c$  and  $V_d$  respectively. Which of the following order about  $V_a$ ,  $V_b$ ,  $V_c$  and  $V_d$  are correct?

- $A. \quad V_a < V_b < V_c < V_d$
- $\mathbf{B}. \quad V_{\mathrm{a}} < V_{\mathrm{b}} < V_{\mathrm{d}} < V_{\mathrm{c}}$
- $\mathbf{C}. \quad V_{\mathrm{a}} = V_{\mathrm{b}} < V_{\mathrm{c}} = V_{\mathrm{d}}$
- D.  $V_{a} < V_{d} < V_{b} < V_{c}$

**Part B:** Short Questions (15 marks) (Please answer ALL questions)

Note: Show your solutions with steps and answers in Part B Answer Sheet.





Peter places a tennis ball with mass 60 g on the top of a basketball of mass 600 g, as shown in Figure 1. The line joining the centers of gravity of the two balls is perpendicular to the floor. The centers of gravity of the tennis ball and the basketball are 1.7 m and 1.54 m above the ground, respectively.

Both balls are then released from rest and fall vertically under gravity. The basketball hits the ground first and then rebounds with the same speed to collide the falling tennis ball, as shown in Figure 2. After the collision, the basketball stops moving and the tennis ball rebounds to a higher position (Figure 3).

The diameters of the tennis ball and the basketball are 8 cm and 24 cm, respectively. It is assumed that air resistance is negligible, and all the collisions are elastic.

- (a) Referring to Figure 2, calculate the speed of the center of gravity of the basketball just before hitting the ground.
   (2 marks)
- (b) Referring to Figure 3, calculate the speed of the center of gravity of the tennis ball after colliding with the basketball. (2 marks)
- (c) Referring to Figure 3, how high does the center of gravity of the tennis ball reach after hitting the basketball?(2 marks)

(d) In practice, the tennis ball seldom rebounds vertically but is generally projected at an angle  $\theta$  with the vertical. Referring to Figure 4, how high can the center of gravity of the tennis ball reach if  $\theta = 20^{\circ}$ ? (2 marks)



Figure 4



On a rainy night, a driver is going to start his car. Before that, he switches on the two headlights and the rear window heater for the sake of good sighting. Each headlight draws a current of 4 A and the window heater draws a current of 2 A. A voltmeter is connected across the terminals of the car battery.

- (a) The voltmeter reading drops from 14.6 V to 13.6 V when the headlights and rear window heater are switched on. What is the internal resistance of the battery? (2 marks)
- (b) When the driver turns on the starter, the motor starter draws a current of 90 A. What is the voltmeter reading then? (3 marks)
- (c) What is the current through each headlight while the motor starter is in use? What happens to the brightness of each headlight? Explain briefly. (2 marks)

## **END OF PAPER**

# List of data, formulae and relationships

#### Data

molar gas constant	$R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$	
Avogadro constant	$N_{\rm A} = 6.02 \times 10^{23}  {\rm mol}^{-1}$	
acceleration due to gravity	$g = 9.81 \text{ m s}^{-2}$ (close to the Ea	urth)
universal gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$	
speed of light in vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$	
charge of electron	$e = 1.60 \times 10^{-19} \mathrm{C}$	
electron rest mass	$m_{\rm e} = 9.11 \times 10^{-31}  \rm kg$	
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$	
permeability of free space	$\mu_0 = 4\pi \times 10^{-7} \text{ H m}^{-1}$	
atomic mass unit	$u = 1.661 \times 10^{-27} \text{ kg}$	(1 u is equivalent to 931 MeV)
astronomical unit	$AU = 1.50 \times 10^{11} \text{ m}$	
light year	$ly = 9.46 \times 10^{15} m$	
parsec	$pc = 3.09 \times 10^{16} m = 3.26 ly =$	= 206 265 AU
Stefan constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$	
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$	

# **Rectilinear motion**

For uniformly accelerated motion:

$$v = u + at$$
  

$$s = ut + \frac{1}{2}at^{2}$$
  

$$v^{2} = u^{2} + 2as$$

### **Mathematics**

Equation of a straight line	y = mx + c
Arc length	$= r\theta$
Surface area of cylinder	$=2\pi rh+2\pi r^2$
Volume of cylinder	$=\pi r^2 h$
Surface area of sphere	$=4\pi r^2$
Volume of sphere	$=\frac{4}{3}\pi r^3$

For small angles,  $\sin \theta \approx \tan \theta \approx \theta$  (in radians)

Astronomy and S	pace Science	Energy and Use of Energy		
$U = -\frac{GMm}{r}$	gravitational potential energy	$\frac{Q}{t} = k \frac{A(T_{\rm H} - T_{\rm C})}{d}$	rate of energy transfer by conduction	
$P = \sigma A T^{4}$ $\left  \Delta f \right  \approx \frac{v}{2} \approx \left  \Delta \lambda \right $	Stefan's law	$U = \frac{k}{d}$	thermal transmittance U-value	
$ f_0  c  \lambda_0 $		$P = \frac{1}{2} \rho A v^3$	maximum power by wind turbine	
Atomic World		Medical Physics		
$\frac{1}{2}m_0 v_{\max}^2 = hf - \phi$	Einstein's photoelectric equation	$\theta = \frac{1.22\lambda}{d}$	Rayleigh criterion (resolving power)	
$E_{\rm n} = -\frac{1}{n^2} \left\{ \frac{m_{\rm e} e^4}{8h^2 \varepsilon_0^2} \right\}$	$e = -\frac{13.6}{n^2} eV$	power $=\frac{1}{f}$	power of a lens	
h h	energy level equation for hydrogen atom	$L = 10 \log \frac{I}{I_0}$	intensity level (dB)	
$\lambda = \frac{n}{p} = \frac{n}{mv}$	de Broglie formula	$Z = \rho c$	acoustic impedance	
$\theta \approx \frac{1.22\lambda}{d}$	Rayleigh criterion (resolving power)	$\alpha = \frac{I_{\rm r}}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$	intensity reflection coefficient	
		$I = I_0 e^{-\mu x}$	transmitted intensity through a medium	

A1.
$$E = mcAT$$
energy transfer during beating  
and coolingD1. $F = \frac{Q.Q_{e}}{4\pi\kappa_{0}r^{2}}$ Coulomb's lawA2. $E = lAm$ of statecorrery transfer during change  
gasD2. $E = \frac{Q}{4\pi\kappa_{0}r^{2}}$ electric field strength due to a point chargeA3. $pV = nRT$ equation of state for an ideal  
gasD3. $V = \frac{Q}{4\pi\epsilon_{0}r^{2}}$ electric potential due to a point chargeA4. $pV = \frac{1}{3}Nmc^{2}$ kinetic theory equationD4. $E = \frac{V}{d}$ electric field between parallel plates  
(numerically)A5. $E_{K} = \frac{3RT}{2N_{A}}$ molecular kinetic energyD5. $I = nAvQ$ general current flow equationD6. $R = \frac{M}{A}$ resistance and resistivityB1. $F = m \frac{\Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$ forceD7. $R = R_{1} + R_{2}$ resistors in seriesB2.moment  $-F \times d$ moment of a forceD8. $\frac{1}{R} = \frac{1}{R_{1}} + \frac{1}{R_{2}}$ resistors in parallelB3. $E_{P} = mgh$ gravitational potential energyD10. $F = BU \sin \theta$ force on a moving charge in a magnetic fieldB4. $E_{K} - \frac{1}{2}mr^{2}$ kinetic energyD10. $F = BU \sin \theta$ force on a usurent-currying conductor in a  
magnetic fieldB5. $P = Fv = \frac{W}{t}$ mechanical powerD11. $F = BU \sin \theta$ force on a usurent-currying conductor in a  
magnetic field due to a long straight wire  
 $114.$ B6. $a = \frac{V^{2}}{r} = a^{2}r$ centripet accelerationD12. $V = \frac{BU}{RQt}$ Hall voltageB7. $F = \frac{Gm_{1}m_{2}}{r^{2}}$