SINGAPORE JUNIOR PHYSICS OLYMPIAD 2016

GENERAL ROUND

27 July 2016

3:00 pm – 4:30 pm

Time Allowed: **ONE HOUR THIRTY MINUTES**

INSTRUCTIONS

1. **Read the instructions on this page** but **DO NOT TURN the page** until you are told to do so by the invigilator.
2. This paper contains **50** multiple choice questions and **24** printed pages (including this cover page)
3. Each of the questions or incomplete statements is followed by five suggested answers or completions. **Select only the best** in each case and then **shade** the corresponding bubble on the answer sheet.
4. Use **2B pencil** only to shade the bubbles on the answer sheet, and make sure any stray markings are properly erased.
5. **Only** the **answer sheet** will be **marked**. Answers written anywhere else will not be marked.
6. **Fill in your NRIC number on the answer sheet now.** Write your name and school on the answer sheet now.
7. Answer **ALL** questions. Marks will **NOT** be deducted for wrong answers.
8. **Scientific calculators** are **allowed** in this test. **Graphing** calculators are **not** allowed.
9. A general data sheet is given on page 2. You may **detach the data sheet when the competition starts** so that you can refer to it easily.

GENERAL DATA SHEET

Acceleration due to gravity at Earth surface,	$g = 9.80 \text{ m s}^{-2} = \lvert\vec{g}\rvert$
Universal gas constant,	$R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$
Vacuum permittivity,	$\varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$
Atomic mass unit,	$u = 1.66 \times 10^{-27}$ kg
Speed of light in vacuum,	$c = 3.00 \times 10^{8} \text{ m s}^{-1}$
Speed of sound in air,	$v_s = 340 \text{ m s}^{-1}$
Charge of electron,	$e = 1.60 \times 10^{-19}$ C
Planck's constant,	$h = 6.63 \times 10^{-34}$ J s
Mass of electron,	$m_e = 9.11 \times 10^{-31} \text{ kg} = 0.000549\,u$
Mass of proton,	$m_p = 1.67 \times 10^{-27} \text{ kg} = 1.007\,u$
Rest mass of alpha particle,	$m_\alpha = 4.003\,u$
Boltzmann constant,	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
Avogadro's number,	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
Standard atmosphere pressure,	$P_0 = 1.01 \times 10^{5}$ Pa
Density of water,	$\rho_w = 1000 \text{ kg m}^{-3}$
Specific heat (capacity) of water,	$c_w = 4.19 \times 10^{3} \text{ J kg}^{-1} \text{ K}^{-1}$
Stefan-Boltzmann constant,	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

1. **A force is applied** to a box to push it across the horizontal floor at a **constant speed** of 4.0 m/s. Assume air resistance is negligible. What can you say about the **forces** acting on the box?

   (A) If the force applied to the box is doubled, the constant speed of the box will double to 8.0 m/s.

   (B) The magnitude of force applied to keep the box moving at a constant speed must be more than the magnitude of its weight.

   (C) The force being applied to the box to keep it moving at constant speed makes an action-reaction pair with the frictional force that resists its motion.

   (D) The magnitude of force applied to keep the box moving at a constant speed must be equal to the magnitude of the frictional forces that resist its motion.

   (E) The magnitude of force applied to keep the box moving at a constant speed must overcome i.e. be more than the magnitude of the frictional forces that resist its motion.

2. If the **force applied** to the box in the preceding problem is **suddenly discontinued**, the box will;

   (A) stop suddenly.

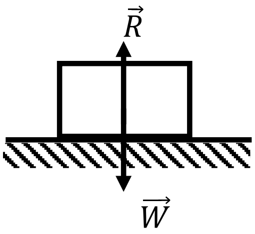
   (B) continue at a constant velocity.

   (C) suddenly start slowing to a stop.

   (D) increase its speed for a very short period of time, then start slowing to a stop.

   (E) continue at a constant speed for a very short period of time and then slow to a stop.

3. A box with mass m is lying motionless on a level surface. In the diagram, $\vec{R}$ is the ground reaction force or **normal force** on the box and $\vec{W}$ is the **weight** of the box. Which statement is **incorrect**?



   (A) According to Newton's 1st law of motion, $\vec{R} + \vec{W} = 0$ implies that the box will remain at rest.

   (B) According to Newton's 2nd law of motion, $\vec{R} + \vec{W} = 0$.

   (C) According to Newton's 3rd law of motion, $\vec{R} = -\vec{W}$.

   (D) According to Newton's law of universal gravitation, $\vec{W} = m\vec{g}$.

   (E) According to Newton's law of universal gravitation g is related to the mass and radius of earth.

4. A box is pulled using a string up a 0.1 radian slope at constant speed of 2.0 ms^{-1}. The string is cut **suddenly** and the box comes to a stop after moving up a further distance of 1.0 m. What is the value of the **coefficient** of friction?

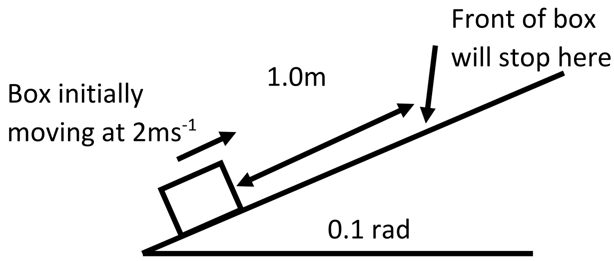
(A) 0.00

(B) 0.10

(C) 0.20

(D) 0.30

(E) The situation is impossible.



5. A train of mass 7.0×10^4 kg expends 60 kW of power to **travel down** a 2° incline at a constant velocity of 10 m s^{-1}. How much power is required for the same train to **travel up** the 2° incline at the same constant velocity of 10 m s^{-1}?

(A) 540 kW

(B) 480 kW

(C) 300 kW

(D) 240 kW

(E) 60 kW

6. Carts A and B are **initially at rest** on a frictionless, horizontal surface. A constant force F_0 is applied to each cart as it travels from its initial position. The **mass** of cart **A** is **more than** the mass of cart **B**. Consider the kinetic energy, E, and momentum, p, of the boxes at position X, a distance x_0 from the initial position. Subscripts A, B denote cart A or B. Which statement below is **correct**?

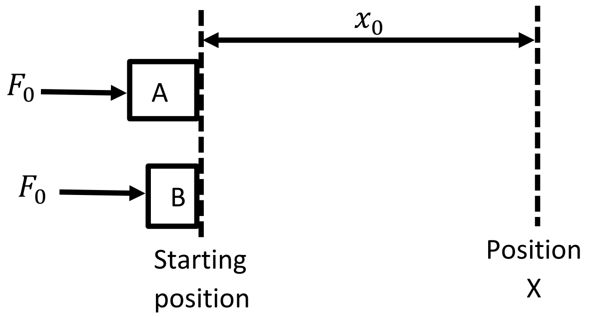
(A) $E_A < E_B, p_A < p_B$

(B) $E_A < E_B, p_A = p_B$

(C) $E_A > E_B, p_A < p_B$

(D) $E_A = E_B, p_A = p_B$

(E) $E_A = E_B, p_A > p_B$



7. An object, **1**, with mass m and another object, **2**, with twice the mass $2m$ are dropped from rest, at the same starting position from the top of a large container and fall in a straight line through motionless viscous liquid. Drag is significant and **assume that the two objects would eventually reach the same terminal velocity** v_T **if the container were tall** enough. Consider the case where the objects **do not** reach terminal velocity at the bottom of the container. Assume that the **same type** of drag acts on both objects. How does the time taken, t_1 and t_2 , for the objects **1** and **2** to reach the bottom compare?

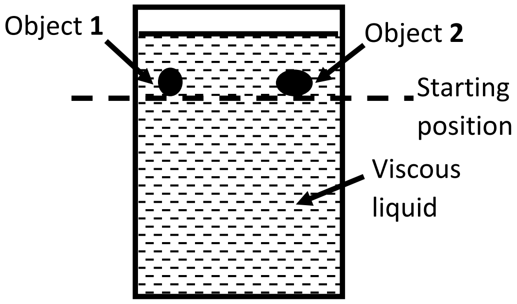
(A) $t_1 = t_2$

(B) $t_1 < t_2$

(C) $t_1 > t_2$

(D) $t_2 < t_1 < 2t_2$

(E) $t_1 < t_2 < 2t_1$



8. A train moving on straight horizontal tracks **slows down** from 66 ms^{-1} to 22 ms^{-1} at a **constant rate** of 2.0 ms^{-2}. What **distance** does it travel while slowing down?

(A) 490 m

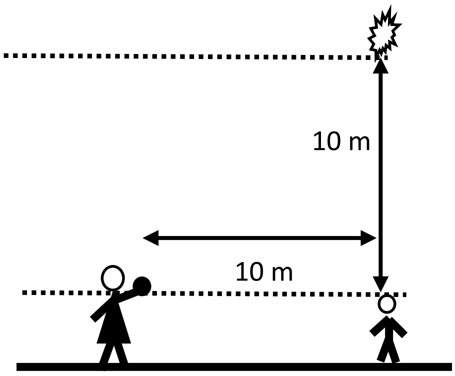
(B) 650 m

(C) 740 m

(D) 970 m

(E) 1100 m

9. A fruit drops from a tree. A boy, 1.5m tall, stands on the flat ground just under the fruit. The fruit was initially 10 m **above** the boy's head. A woman standing on the level ground 10 m from the boy immediately throws a ball from a height of 1.5 m **above the ground**, and deflected the fruit from its path towards the boy's head. Assume that air resistance and her reaction time are negligible. Calculate the **minimum speed** of the ball?



(A) 10 ms^{-1}

(B) 15 ms^{-1}

(C) 20 ms^{-1}

(D) 25 ms^{-1}

(E) 30 ms^{-1}

10. An electron is emitted from the surface of a metal plate at an angle of 30 degrees from the surface. The electron's initial **kinetic energy** is 3.2×10^{-19} J. A uniform electric field of $1000\ NC^{-1}$ is applied, direction as shown in the figure. What is the kinetic energy of the electron when it is **furthest** from the plate from which it was emitted?

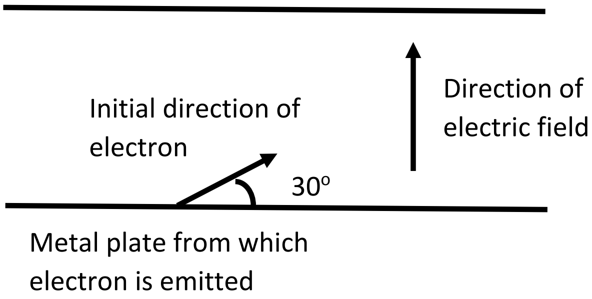
(A) 0 J

(B) 0.8×10^{-19} J

(C) 1.6×10^{-19} J

(D) 2.4×10^{-19} J

(E) 3.2×10^{-19} J



11. A projectile is launched at velocity v_0 into an ideal ballistic trajectory from the origin of a coordinate system. Given that: when the launch angle is varied, all the possible points that can be hit by the projectile are exactly contained within a **parabola** with equation $y = a + bx^2$ where y is the vertical height, x is the horizontal displacement from the origin, while a and b are constants. What **could** be the expression for a and b ?

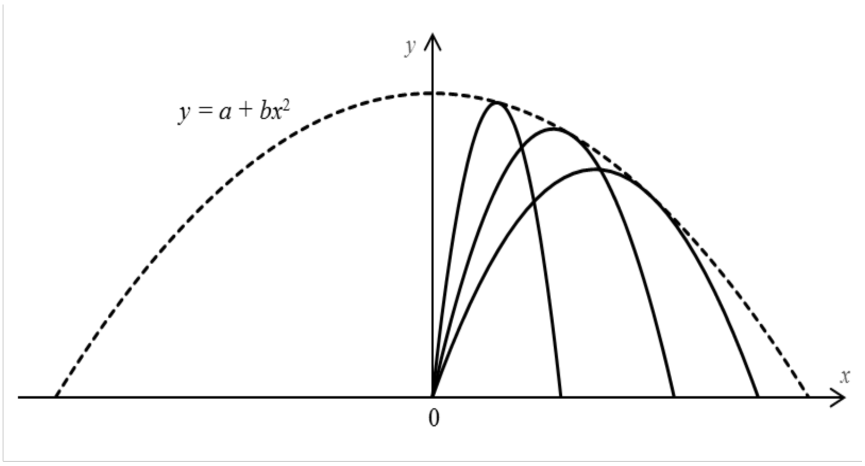
(A) $a = \frac{v_0^2}{2g}, b = \frac{g}{v_0^2}$

(B) $a = \frac{v_0^2}{2g}, b = \frac{g}{2v_0^2}$

(C) $a = \frac{v_0^2}{2g}, b = \frac{2g}{v_0^2}$

(D) $a = \frac{v_0^2}{g}, b = -\frac{g}{v_0^2}$

(E) $a = \frac{v_0^2}{2g}, b = -\frac{g}{2v_0^2}$



12. The upper end of a rope is fixed to a vertical wall. The upper end makes an angle of 30 degrees with the wall when the lower end is pulled by a horizontal force of 20N. What is the mass of the rope?

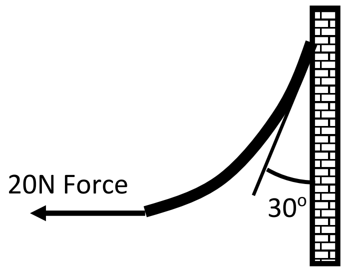
(A) 1.8kg

(B) 2.0kg

(C) 2.4kg

(D) 3.5kg

(E) 4.1kg



13. An ideal uniform spring of mass m kg, unstretched length L m and spring constant k Nm^{-1} stretches by an extension of x m when hung vertically. Which statement below is **correct**? (You **may** want to know that the sum of N terms in an arithmetic progression from 1 to N is $\frac{N(1+N)}{2}$)

(A) The top half of the spring with mass $\frac{m}{2}$ kg has an extension $\frac{x}{2}$ m .

(B) The top half of the spring with length $\frac{L+x}{2}$ m supports $\frac{mg}{2}$ N.

(C) The top half of the spring with mass $\frac{m}{2}$ kg has a spring constant of $\frac{k}{2}$ Nm^{-1} .

(D) The extension of the whole spring is $\frac{mg}{k}$ m

(E) The length of the whole spring is $L + \frac{mg}{2k}$ m

14. A ball with mass m is hung from the ceiling with a massless string of **length** l as shown in the diagram. It moves in **uniform circular motion** with angular velocity ω. What is the magnitude of **tension** in the string?

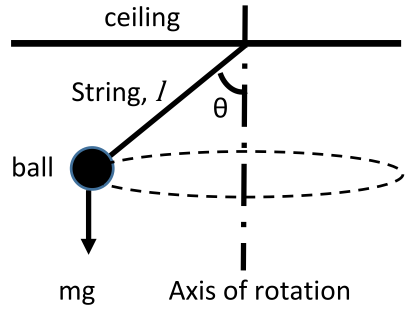
(A) $m\omega^2 l$

(B) $m\omega^2 l \cos\theta$

(C) $m\omega^2 l/\cos\theta$

(D) $m\omega^2 l \sin\theta$

(E) $m\omega^2 l/\sin\theta$



15. For the same situation as in the above question, with $m = 0.20kg$, $l = 0.80m$. What is the **angular velocity** in order for the string to maintain a constant angle of $\theta = 25°$ to the vertical?

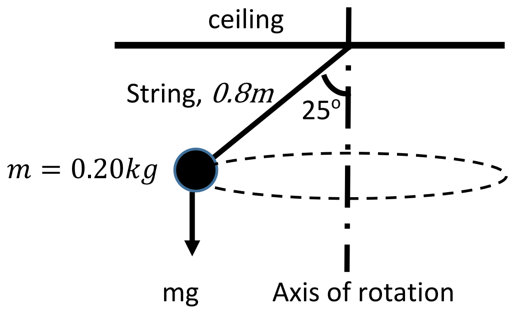
(A) 0.59 rad s^{-1}

(B) 1.2 rad s^{-1}

(C) 3.5 rad s^{-1}

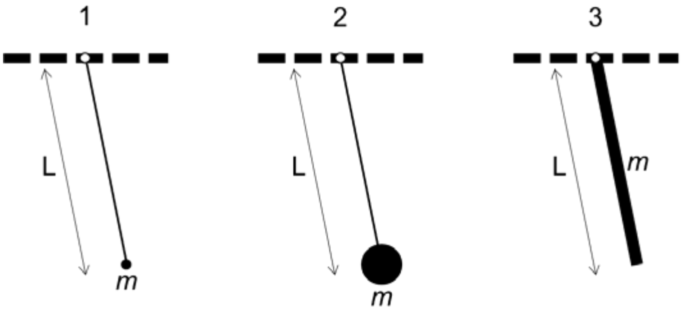
(D) 3.7 rad s^{-1}

(E) 5.4 rad s^{-1}



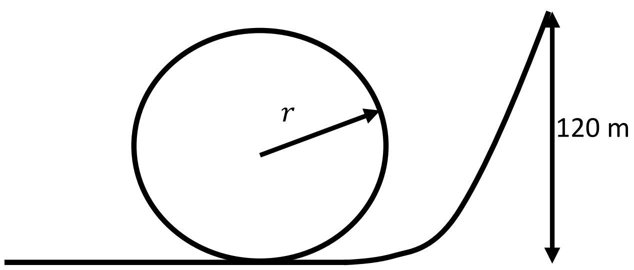
16. The diagram below shows 3 pendulums of length L. The first uses a point mass m suspended from a string of length L; the second uses a sphere with radius R and mass m suspended such that the centre of mass of the sphere is length L away from the pivot point; the last uses a rigid rod of length L and mass m pivoted at its end. Which of the following statements correctly describes the periods of these 3 pendulums?

(A) Period of 1 = 2 > 3
(B) Period of 2 > 1 > 3
(C) Period of 2 > 3 > 1
(D) Period of 3 > 1 > 2
(E) Period of 3 > 2 > 1



17. A 360kg roller coaster car is initially at rest at a height of 120m above the ground. It goes to the ground and does a circular loop of radius r . Assume that friction and energy losses are negligible, the car is small and is not attached to the track. What is the **maximum radius** r so that the roller coaster does not leave the track?

(A) 120m
(B) 60m
(C) 48m
(D) 42m
(E) 36m



18. Two masses $m_1 = 100kg$ and $m_2 = 200kg$ are attached to **a light, unstretchable**, string on a fixed rod as shown in the figure. Assume that friction is negligible. What is the acceleration of mass m_1 due to gravity?

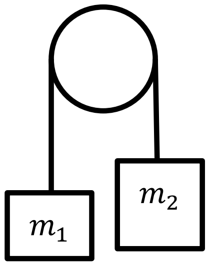
(A) 3.3 ms^{-2} upwards

(B) 4.9 ms^{-2} upwards

(C) 9.8 ms^{-2} downwards

(D) 9.8 ms^{-2} upwards

(E) 19.6 ms^{-2} upwards



19. In the figure, the two pulleys are at **both ends** are **fixed** in position and the pulley in **between** them is **free to move**. The masses m_1= 4.9 kg, m_2= 4.9 kg are attached to the ends of a long string and the string is placed across the two big pulleys. Then the small pulley with m_3 = 7.9 kg is gently placed on the initially horizontal string between the two big pulleys. Assume that the pulleys rotate smoothly and have negligible mass. Also assume that the string is long enough. What is the angle θ at equilibrium?

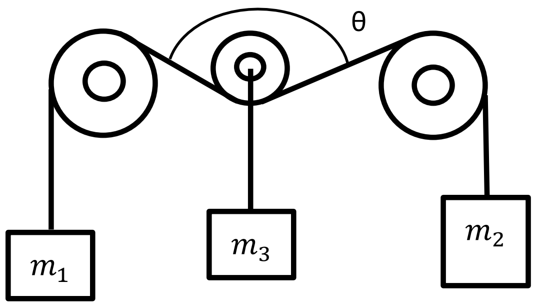
(A) 0.2 π rad

(B) 0.4 π rad

(C) 30^o

(D) 60^o

(E) It never reaches equilibrium.



20. A person on the **moon** surface shoots a bullet **vertically upwards** with a speed of 1200 ms^{-1}. Assume that the acceleration due to gravity on the moon's surface is $g_m = 0.160 \times g$, the radius of the moon is $r_m = 1700$ km and that air resistance is negligible. Calculate the **height** the bullet reaches above moon's surface. (Hint: the potential energy of a mass m may be taken as $GPE = -mg_m \frac{r_m^2}{r}$)

(A) 74 km
(B) 184 km
(C) 440 km
(D) 460 km
(E) 630 km

21. Initially, a 1 kg box was sliding on frictionless surface at a constant **velocity** of 4 ms^{-1} in the x-direction. A constant **force** of 1N was applied on the box in a **fixed direction** for a **time** duration of 5 s. After 5s the **speed** of the box is 3 ms^{-1}.What is the **magnitude** of the **change in momentum** of the box?

(A) 1 $kgms^{-1}$
(B) 2 $kgms^{-1}$
(C) 3 $kgms^{-1}$
(D) 4 $kgms^{-1}$
(E) 5 $kgms^{-1}$

22. A metal ball with volume V, density ρ_b is tied to a string and gently lowered into a measuring cylinder with honey. The density of honey is ρ_h. When the ball is **submerged**, the string is cut and the ball falls straight down. The measuring cylinder and honey has total mass M and is on a weighing machine which has a readout in kg. Assume that the ball quickly reaches terminal velocity and the honey does not overflow or splash. What is the **reading** on the weighing machine when the ball is falling at **constant velocity**?

(A) M

(B) $M + \rho_b V$

(C) $M + \rho_h V$

(D) $M + (\rho_b - \rho_h)V$

(E) $M + (\rho_h - \rho_b)V$

23. A ball is dropped on the floor and bounces up and down for an infinite number of times. When the ball is dropped from a height such that its center of mass is 5.00 m above its center of mass if it were just resting on the floor, it bounces back up to 1.25 m. Assume that **energy losses are negligible except during the bounce**. How much time does it take for the ball to stop bouncing from the time it was dropped? (Hint: for $0 < x < 1, x + x^2 + x^3 + \cdots = \frac{x}{1-x}$)

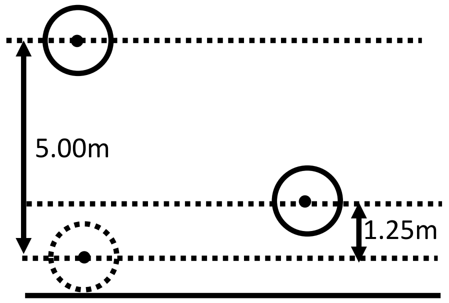
(A) 1s

(B) 2s

(C) 3s

(D) 4s

(E) It never stops bouncing



24. Case 1: A 80kg skater with speed u slides towards **stationary** skater with mass 20kg. They **hold hands** when they reach each other and continue as one. Case 2: the 20kg skater is moving and the 80 kg skater is stationary; the initial kinetic energy of the systems in both cases are the same. Assume friction is negligible. What is the ratio of the **change in kinetic energy** (i.e the amount of energy converted to other forms) of the system in case 1 to that in case 2? i.e. (case1:case 2)

(A) 4:1

(B) 2:1

(C) 1:1

(D) 1:2

(E) 1:4

25. A circular disc with an axle of **diameter** 2 cm, is attached with strings to the ceiling. The disc is rotated so that the strings wind up along the axle so that the disc is raised up to the ceiling. The string is long such that that when the disc is released from rest, its center of mass falls 2.0 m. The disc does not slip from the string. Assume that the axle is **massless** and the disc has all of its 5 kg mass at **radius** 3 cm. Estimate the acceleration of the center of mass of the disc near the bottom of the fall.

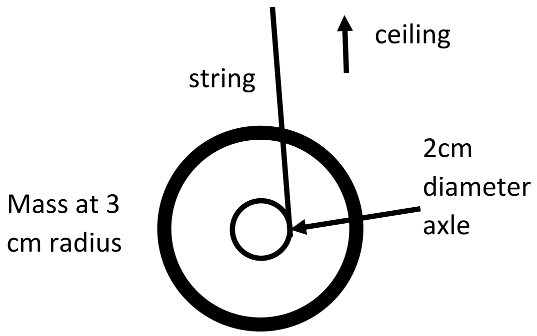
(A) g

(B) $2g/3$

(C) $g/3$

(D) $g/5$

(E) $g/10$



26. A 0.9 m diameter, water pipe brings water from a reservoir 20 m high to a 0.3 m diameter nozzle at ground level. Assume that viscous forces are negligible. What is the **maximum possible speed** of the water jet at the nozzle?

(A) 6.6 ms^{-1}

(B) 20 ms^{-1}

(C) 34 ms^{-1}

(D) 59 ms^{-1}

(E) 178 ms^{-1}

27. A fire piston consists of a cylinder and piston arrangement that traps air at 1 atm, 299K, in the cylinder. Initially the 0.010 m diameter piston is at a height 0.25 m above the bottom. The piston is suddenly pushed down so that it ends up at the height 0.010 m. The temperature of the air becomes 533K. Assume that air is an **ideal gas**, the piston is air tight. Calculate the **force due to the gas** in the cylinder acting on the piston at the height of 0.010 m.

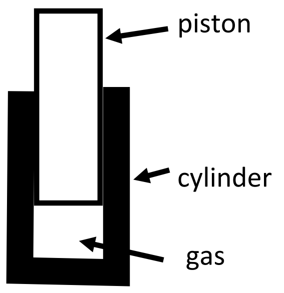
(A) 3500N

(B) 350N

(C) 110N

(D) 35N

(E) None of the above



28. The Singapore Navy's Archer class submarine are equipped with Stirling **<u>engines</u>**. The idealized Stirling cycle for **fixed quantity** of an **ideal gas** is shown in the diagram below. The parts of the cycle are labelled as: (i) **isothermal** (same temperature) process (ii) **isochoric** (same volume) process (iii) **isothermal** process and (iv) **isochoric** process. Which part(s) have heat flow **to** the gas?

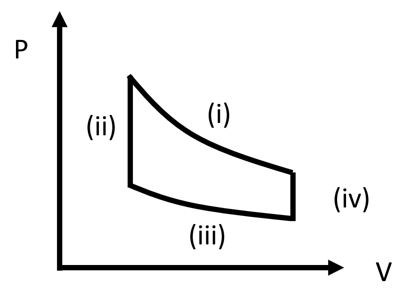
(A) (i) only

(B) (ii) only

(C) (i) and (ii)

(D) (ii) and (iii)

(E) (i) and (iv)



29. Assume the heat engine below is an ideal heat driven engine that has an efficiency $\eta_{th} = 1 - \frac{T_c}{T_H}$, where T_H is the temperature at which the heat **enters** the engine T_c the **cold temperature** which the engine **exhausts** the waste heat. The thermal conductivity of stainless steel is 19Wm^{-1}K^{-1}. Heat **enters** the heat engine through a 2.00 mm thick, 23.7cm^2 area stainless steel. Assume that the heat source can maintain a temperature of $T_{HS} = 613$°C (**note**: $T_{HS} \neq T_H$) and the environment can maintain a **cold temperature** of $T_c = 306$°C. Also assume that the working gas is able to achieve thermal equilibrium with the appropriate surface. What could be the maximum efficiency of the engine when it is doing work at the average rate of 1kJs^{-1} ?

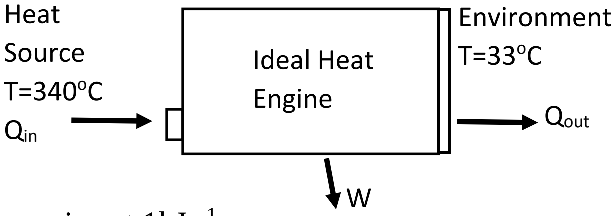
(A) 5%

(B) 10%

(C) 30%

(D) 50%

(E) It is not possible to operate the engine at 1kJs^{-1}



30. Three blocks A, B, C are arranged in a row on a frictionless surface. Blocks A and B are connected by a spring of spring constant 10 Nm^{-1} while blocks B and C are connected by a spring of spring constant 20 Nm^{-1}. Blocks A and C are pushed towards B and released in **such a way that blocks A and C oscillate but block B remains stationary**. If the mass of block A is 20kg, what is the mass of block C?

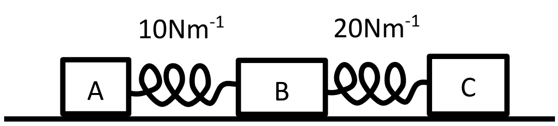
(A) 5kg

(B) 10kg

(C) 20kg

(D) 40kg

(E) 80kg



31. Suppose that the Earth is perfectly spherical, of uniform density, airless and non-rotating. A small smooth hole is drilled diametrically through the Earth, and a small mass m is dropped from the surface into one end of this hole. (Hint: The mass experiences a force towards the center of the Earth of magnitude $\left(\frac{mg}{R_E}\right)x$ when it is at a distance x from the center of the Earth, where R_E the radius of the earth is 6.4×10^6 m). How long will the mass take to reach the **center** of the Earth?

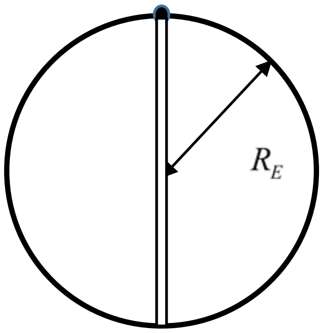
(A) 10,000 s

(B) 2,500 s

(C) 2,300 s

(D) 1,300 s

(E) 1,100 s



32. A loudspeaker is placed facing a wall a certain distance away. A constant tone of frequency f is played in the loudspeaker. A microphone is moved along the line between the loudspeaker and the wall, and the intensity of the sound detected by the microphone is measured at several locations. It is found that the **distance between positions** where a **minimum intensity** is recorded is 0.77 m. What is the frequency f?

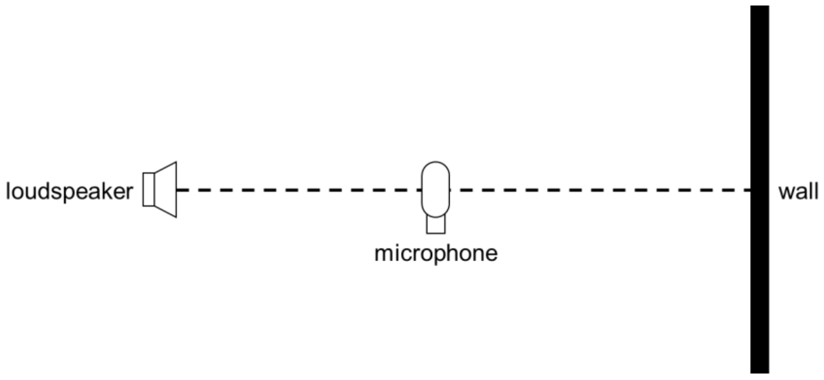
(A) 110 Hz

(B) 221 Hz

(C) 262 Hz

(D) 331 Hz

(E) 442 Hz



33. 4 point charges are arranged at the corners of a square of side length d. The charges are as indicated on the diagram. What is the electric potential V and the magnitude of the electrostatic force F felt by a point charge of –1e placed at the centre of the square?

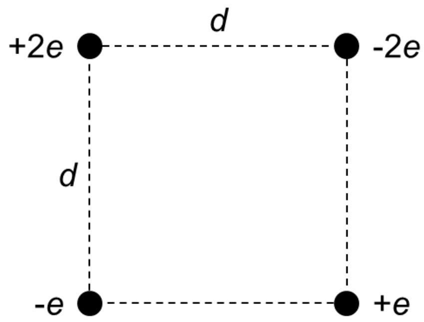
(A) $V = 0, F = \frac{1}{\sqrt{2}}\left(\frac{e^2}{\pi\varepsilon_0 d^2}\right)$

(B) $V = 0, F = \frac{e^2}{\pi\varepsilon_0 d^2}$

(C) $V = 0, F = 0$

(D) $V = \frac{1}{\sqrt{2}}\left(\frac{e}{\pi\varepsilon_0 d}\right), F = 0$

(E) $V = \frac{1}{\sqrt{2}}\left(\frac{e}{\pi\varepsilon_0 d}\right), F = \frac{1}{\sqrt{2}}\left(\frac{e^2}{\pi\varepsilon_0 d^2}\right)$



34. An ion of neon-20, $^{20}_{10}Ne^+$ (mass 20.0 u) and an ion of neon-22, $^{22}_{10}Ne^+$ (mass 22.0 u), each with a charge of $+1.60\times10^{-19}$ C, enter perpendicularly into a rectangular region with a magnetic field of 2.00 T directed out of the page as shown in the diagram below. The ions enter at the same point and have the **same initial velocity** of 2.0×10^5 ms^{-1}. The ions are deflected by the magnetic field and impact a detector as shown. What is the **distance between** their impact points on the detector?

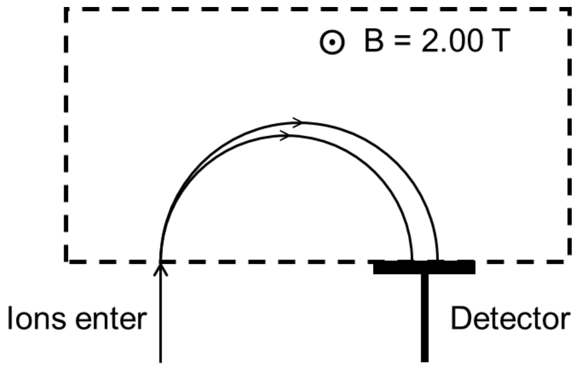
(A) 2.08 mm

(B) 4.15 mm

(C) 8.30 mm

(D) 20.8 mm

(E) 41.5 mm



35. A capacitor is **initially** charged to voltage V (i.e. the potential difference across its terminals is V) and charge Q . The energy stored in the capacitor is initially E. It discharges through an inductor such that **finally**, the voltage is **half** the original i.e. $V/2$. The final charge and energy stored in the capacitor is ___________,__________respectively.

(A) Q , E

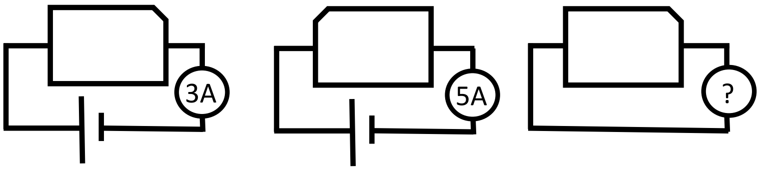
(B) Q , $E/2$

(C) $Q/2$, $E/2$

(D) $Q/4$, $E/2$

(E) $Q/2$, $E/4$

36. A black box consists of a battery with **EMF less than 12 volts** and a resistor connected in series with the two ends of the circuit sticking out of the black box. If the ends of the black box are connected to a power supply of 12V, the current flowing through is 5A. If the connection to the black box is **reversed**, the current flowing through is 3A. What will be the current flowing through if the ends of the black box are **connected by a wire**?



(A) 1.0A

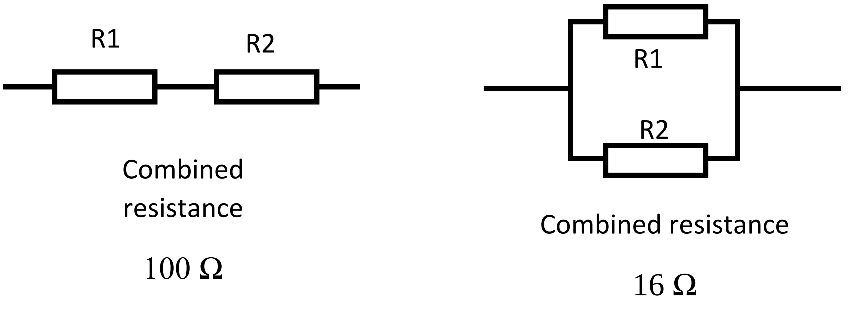
(B) 1.5A

(C) 2.0A

(D) 2.4A

(E) 4.0A

37. Two resistors when connected in series have a combined resistance of 100 Ω. When the same 2 resistors are connected in parallel they have a combined resistance of 16 Ω. What is the **difference** in their resistance?



(A) 42 Ω

(B) 60 Ω

(C) 68 Ω

(D) 82 Ω

(E) 84 Ω

38. A 9.0 V battery with internal resistance of 18 Ω and a 2.5 V battery with 0.50 Ω internal resistance are available. We would like to choose **only one** of the batteries for heating up a resistor. What is the **maximum** electrical power which either of the batteries can **supply to a resistor**?

(A) 2.3 W

(B) 3.1 W

(C) 4.5 W

(D) 9.0 W

(E) 13 W

39. The following graph shows the I-V characteristics of the 2 **nonlinear** resistors A and B. If A and B are connected in series to an ideal 6 V DC source, what is the current flowing in the circuit?

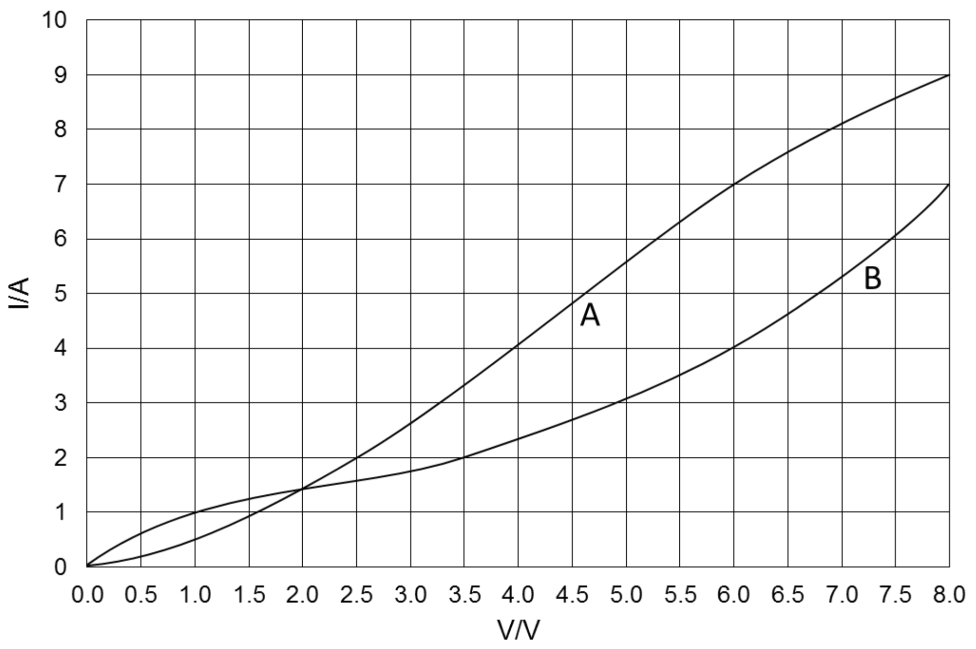
(A) 11 A

(B) 7 A

(C) 4 A

(D) 3 A

(E) 2 A



40. The circuits below contain **identical** bulbs and batteries. It is known that the bulbs resistance increase with temperature. Compare the brightness of bulbs A and B in circuit 1 to the brightness of bulb A' and B' in circuit 2.

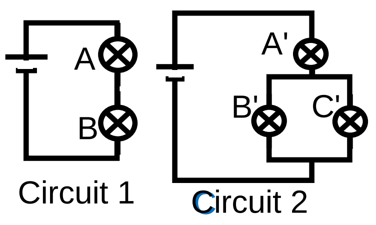
(A) A > A', B > B'

(B) A > A', B < B'

(C) A = A', B < B'

(D) A < A', B = B'

(E) A < A', B > B'



41. Two infinitely long wires lie perpendicular to each other and carry current in the directions shown in the diagram. The amount of current carried by each wire is also indicated. What is the **direction** and **strength** of the magnetic field at point Y, located 0.05 m from each wire?

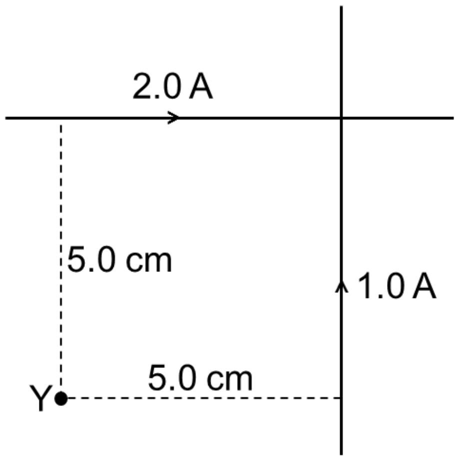
(A) 4.0×10^{-6} T, into paper

(B) 4.0×10^{-6} T, out of paper

(C) 1.2×10^{-5} T, into paper

(D) 1.2×10^{-5} T, out of paper

(E) 0 T



42. A bar magnet attached to the end of a spring performs **simple harmonic motion** <u>**above**</u> a coil of wires as shown in the diagram. The other end of the spring is attached to a fixed force sensor which was **zeroed** when the magnet was at its equilibrium position. The **EMF across the coil of wires** and the force are plotted against time. Which of the following statement is true?

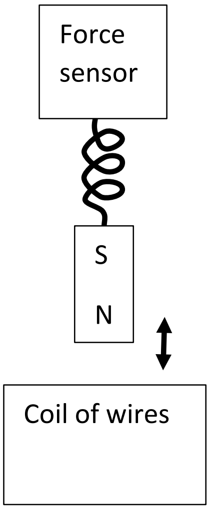
(A) The magnitude of the EMF is maximum when the force is zero.

(B) The magnitude of the EMF is maximum when the magnitude of the force is maximum.

(C) The magnitude of the EMF is zero when the magnitude of the force is maximum.

(D) The magnitude of the EMF is zero when the force is zero.

(E) The EMF also has a perfectly sinusoidal waveform.



43. Robert is given a tiny light source, an $f = 25cm$ focal length lens and a screen. The light source and screen are initially at the ends of a 1m long optical rail and the lens is mounted between the light source and screen and may move freely between them. The components are all at the same fixed height above the rail and may not be removed from the 1m long rail. Robert's task is to find a way to **magnify** the light source and project a **real image** on to the screen using **only** the equipment given and without breaking or illegally modifying the equipment. The distance between the light source and the lens is called u and the distance between the lens and the screen is called v. The setup **constrains** $u + v \leq 1m$. Which of the following is good advice for Robert?

(A) Make u as small as possible i.e. almost touching the lens and make v as large as possible.

(B) Make u as large as possible and make v as small as possible.

(C) Make u slightly larger than f and adjust v to get a clear image.

(D) Make u slightly smaller than f and adjust v to get a clear image.

(E) Just give up.

44. Two biconvex lenses with focal lengths 15.0 cm and 10.0 cm are placed 20.0 cm apart. An object is placed 25.0 cm away from the 15.0 cm lens as shown in the diagram. What **type** of image is formed and what **distance** is it **from the second lens**?

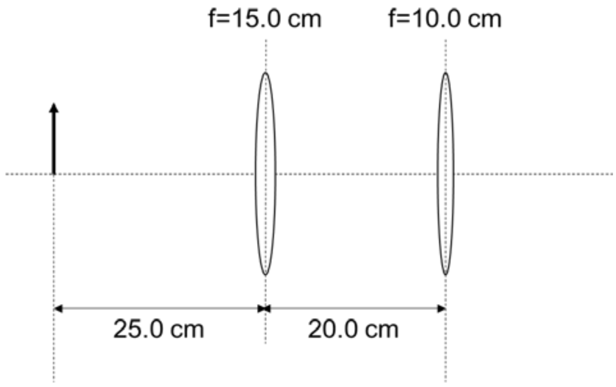
(A) Real, 6.36 cm

(B) Virtual, 6.36 cm

(C) Real, 13.6 cm

(D) Real, 23.3 cm

(E) Virtual, 23.3 cm



45. Two identical resistors are connected in parallel to a 120 V DC source. In this configuration, **each resistor** consumes 100 W of power. What is the amount of power **supplied** if the **two resistors** are connected in series to a 240 V DC source?

(A) 25 W

(B) 50 W

(C) 100 W

(D) 120 W

(E) 200 W

46. A thin rod is travelling at a velocity of 0.800c relative to an observer. **To the observer**, the rod is measured to be 4.00 m long and **angled** 15.0° to the direction of its travel. What is the **proper length** of the rod?

(A) 6.43 m

(B) 6.46 m

(C) 6.52 m

(D) 6.67 m

(E) 6.81 m

47. A 0.020 kg white mouse leaps up steps 0.2 m at a time. Assume the mouse is a **spherical blackbody** with **surface temperature** of 303K and density of water and takes 0.15 s to prepare for the next leap i.e takes 0.15s between landing and the next leap. Also assume that the surroundings is a black body at a temperature of 298K. For the mouse, calculate the ratio of the average power associated with the gain in potential energy in leaping up the stairs to that associated with heat loss due to radiation.

(A) 1000:1

(B) 100:1

(C) 10:1

(D) 1:1

(E) 1:10

48. The table below gives some information about various nuclides. Based on the table, we can say that Strontium-90 in its ground state, ${}^{90}_{38}Sr$ _____________.

(A) may naturally α decay

(B) may naturally $\beta -$ decay

(C) may naturally $\beta +$ decay

(D) may naturally γ decay

(E) may be stable

nuclide	Binding/A[keV]	Atomic Mass [µ AMU]	Mass Excess [keV]
${}^{90}_{38}Sr$	8696	89907730	-85949
${}^{90}_{39}Y$	8693	89907144	-86495
${}^{90}_{37}Rb$	8632	89914798	-79365
${}^{86}_{36}Kr$	8712	85910611	-83266

49. It is possible to fuse two nuclei of deuterium, ${}^{2}_{1}H$ together to produce helium-3, a neutron and some energy i.e. ${}^{3}_{2}He + n^0 + 3.27\text{MeV}$. Consider the situation where a deuteron with 0.10 MeV kinetic energy fuses with a stationary deuterium nucleus. What **could** be the **maximum kinetic energy** that the neutron can have?

(A) 0.94 MeV

(B) 1.39 MeV

(C) 2.45 MeV

(D) 2.86 MeV

(E) 3.37 MeV

50. The following diagram shows the energy levels of a certain atom. Which of the following emission lines could **NOT** be produced solely from transitions between the energy levels?

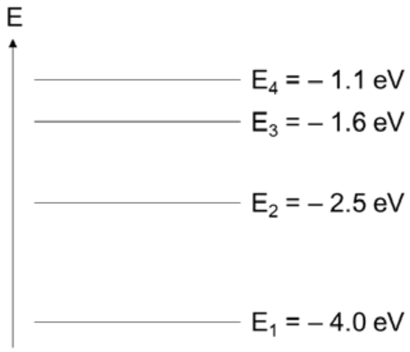
(A) 2490 nm

(B) 1380 nm

(C) 829 nm

(D) 622 nm

(E) 518 nm



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