IIT-JAM-PHYSICS 2023

Unit Test : Mechanics

Time : 70 Minutes **Date : 24-07-2022**

M.M. : 60

Instructions:

- **Section-A** contains 10 Multiple Choice Questions (MCQ). Each question has 4 choices (a), (b), (c) and (d), for its answer, out of which **ONLY ONE** is correct. For each correct answer you will be awarded **3 marks**. For each incorrect answered **1 mark** will be deducted.
- **Section-B** contains 5 Multiple Select Questions (MSQ). Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which **ONE or MORE than ONE** is/are correct. For each correct answer you will be awarded **3 marks**, there is no negative marking in this section.
- **Section-C** contains 5 Numerical Answer Type (NAT) questions which contain **3 Marks** for each, and there is no negative marking.

[SECTION - A — MULTIPLE CHOICE QUESTIONS (MCQ)]

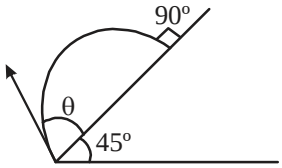
1. A particle is projected over a triangle from one extremity of its horizontal base to the other suchthat the particle goes just over its vertex as shown in the figure below:

If 'θ' be the angle of projection w.r.t. the horizontal, then $\tan\theta$ is equal to,

(a) $\tan\alpha + \tan\beta$ (b) $(\tan\alpha + \tan\beta)\left(1-\frac{\alpha}{\beta}\right)$

(c) $\frac{1}{2}(\tan\alpha + \tan\beta)$ (d) $(\tan\alpha - \tan\beta)$

2. A ball is thrown up from an incline plane of 45° such that it hits back the incline normally to it (as shown in the figure below).



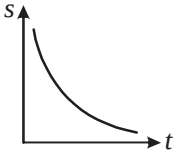
The value of 'θ' is,

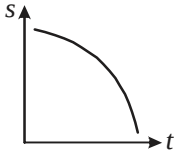
(a) $\tan^{-1}(1/4)$ (b) $\tan^{-1}(1/2)$ (c) $\cot^{-1}(1/4)$ (d) $\cot^{-1}(1/2)$

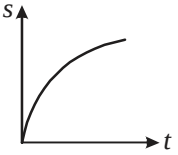
3. A spaceship of mass 10^3 kg floating in space starts ejecting fuel at a rate of 1 kg/s and with a speed of 10 m/s w.r.t. itself. The speed of the spaceship after ten minutes will be approximately equal to

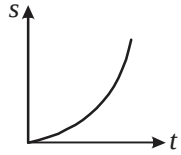
(a) 3.12 m/s (b) 6.24 m/s (c) 9.16 m/s (d) 10.45 m/s

4. Some displacement (s) – time (t) curves for motion in one-dimension are shown below:

(I) 

(II) 

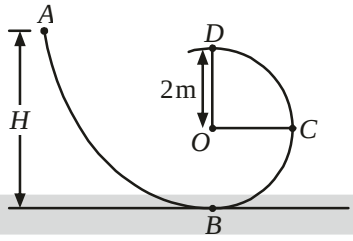
(III) 

(IV) 

Which of the graphs denote positive acceleration ?

(a) (I) and (III) (b) (I) and (IV) (c) (II) and (IV) (d) (II) and (III)

5. A particle of unit mass is dropped from point A at a height $H = 3$ m. If the track is frictionless and the radius of the circular part BCD is $r = 2$m, then the height upto which it will rise along the circle after crossing B is, ($g = 10$ m/s^2)



(a) 3 m (b) 4 m (c) 2 m (d) 8/3 m

6. A particle of mass 1 kg is thrown vertically upwards with speed 10 m/sec from the top a tower which is at a height of 10 m from the ground. Assume that it hits ground along vertically downward direction and the co-efficient of restitution is $e = (2/3)$. If it keeps on bouncing back and each collision is of 0.1 sec duration, then the force on the floor for first collision is equal to,

(a) $10\sqrt{3}$ N (b) $20\sqrt{3}$ N (c) $100\sqrt{3}$ N (d) $\frac{500}{\sqrt{3}}$ N

7. A particle with mass $m(t) = m_0\, e^{-\lambda t}$ moving with initial speed v_0 experiences a resistive force of $F_d = -\beta v^2$, at $t = 0$, where β is a positive constant and 'v' is the instantaneous speed of the particle. Its speed at $t = \frac{1}{\lambda}$ will be equal to,

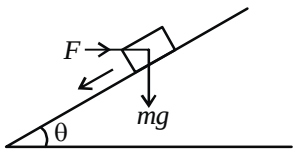
(a) $\left[\frac{1}{v_0} + \frac{\beta}{m_0\lambda}(e-1)\right]^{-1}$ (b) $\left[\frac{1}{ev_0} + \frac{\beta}{2\lambda m_0}(e-e^{-1})\right]^{-1}$

(c) $\left[\frac{1}{v_0} + \frac{\beta}{2m_0\lambda}(1-e)\right]^{-1}$ (d) $\left[\frac{1}{ev_0} - \frac{\beta}{2m_0\lambda}(e-e^{-1})\right]^{-1}$

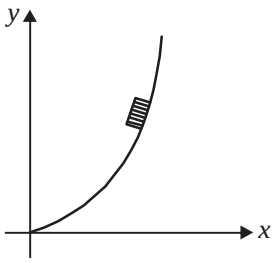
8. In figure below, coefficient of friction between block and inclined plane is μ. If F = 0, the object accelerates down the plane with acceleration a. What should be the value of F for the object to accelerate downwards with $a/2$?

(a) $\frac{mg\sin\theta - \mu mg\cos\theta}{2(\mu\sin\theta + \cos\theta)}$ (b) $\frac{2(\mu\sin\theta - \cos\theta)}{mg\sin\theta + \mu mg}$

(c) $\frac{mg\sin\theta + mg\cos\theta}{\mu\sin\theta - \cos\theta}$ (d) $\frac{2(\mu\sin\theta + \cos\theta)}{mg\sin\theta - \mu\, mg\cos\theta}$



9. A block of mass m is placed on a rough surface with a vertical cross-section of $y = \frac{x^3}{6};\ (x \geq 0)$ as shown in the figure below:



If the co-efficient of friction between the block and the surface is 0.5, then the maximum height above ground at which the block can be placed without slipping is,

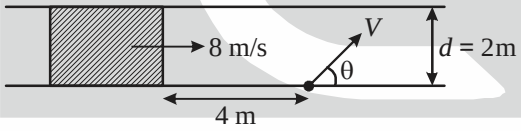
(a) $\frac{1}{6}$ (b) $\frac{1}{3}$ (c) $\frac{2}{5}$ (d) $\frac{4}{5}$

10. If $\hbar$, G, c and k_B respectively denote reduced Planck's constant, gravitational constant, speed of light and Boltzmann constant, then Planck's temperature can be expressed as

(a) $\sqrt{\frac{\hbar c^5}{k_B^2 G}}$ (b) $\sqrt{\frac{\hbar c^3}{k_B^2 G}}$ (c) $\sqrt{\frac{G}{\hbar c^4 k_B^2}}$ (d) $\sqrt{\frac{\hbar k_B^2}{G c^3}}$

[SECTION - B — MULTIPLE SELECTIVE QUESTIONS (MSQ)]

11. A truck is moving with a speed of 8 m/s and is as wide as the road. A man starts crossing the road when he is at a distance of 4 m from the truck by starting to run at a constant speed 'V' moving at an angle 'θ' with the road as shown in the figure below:



Which of the following option(s) is/are ***correct*** ?

(a) The necessary speed to cross safely will be minimum for $\theta = \tan^{-1}(2)$.

(b) The necessary speed to cross safely will be minimum for $\theta = \frac{1}{2}\tan^{-1}(2)$.

(c) The minimum required speed is $V = 3.57$ m/sec.

(d) The minimum required speed is $V = 1.79$ m/sec.

12. A constant force F acts on a cart of mass m on which rain starts falling at a rate of 'α' at $t = 0$. If the speed of the system is v_0 at $t = 0$, then which of the following option(s) is/are ***correct*** at time t_0 ?

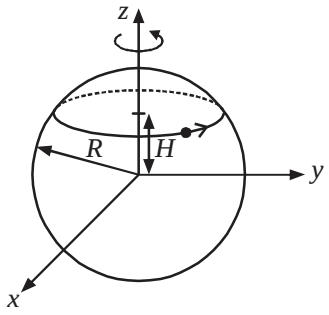
(a) The impulse imparted by the force is Ft_0.

(b) The impulse imparted by the force is $Ft_0/2$.

(c) The speed of the cart becomes $\frac{Ft_0 + mv_0}{m + \alpha t_0}$.

(d) The speed of the cart becomes $\frac{mv_0 - Ft_0}{m + \alpha t_0}$.

13. A man of mass '*m*' runs anticlockwise as seen from above in a circular path on the surface of a sphere maintaining a constant height *H* from the *x*-*y* plane. If he starts running from *x*-*z* plane and his speed is equal to a constant *V*, then which of the following statement(s) is/are correct with respect to the (r, θ, ϕ) co-ordinate system ?



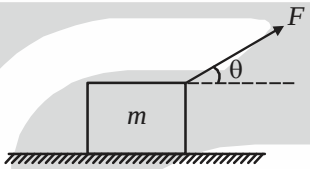
(a) Its velocity can be expressed as: $\vec{V} = -V\hat{\phi}$

(b) The position of the particle at time '*t*', obeys $\phi(t) = \dfrac{Vt}{\sqrt{R^2 - H^2}}$.

(c) The radius of the circular track is, $\sqrt{R^2 - H^2}$.

(d) The component of weight along $\hat{r}$ is, $\dfrac{mgH}{R}$.

14. At the moment $t = 0$, the force $F = kt$ is applied to a small body of mass *m* resting on smooth horizontal plane (*k* is constant). The permanent direction of this force forms an angle θ with the horizontal. Which of the following option(s) is/are ***correct*** ?



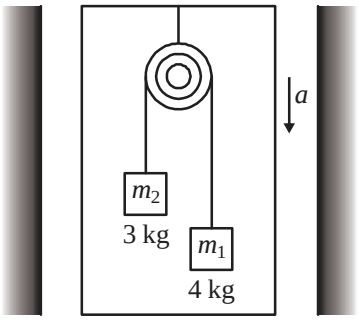
(a) The body will break off the plane at $t = \dfrac{mg}{k \sin\theta}$.

(b) The velocity of the body at the moment of its breaking off the plane will be $v = \dfrac{mg^2}{2k}\left(\dfrac{\cos\theta}{\sin^2\theta}\right)$.

(c) The distance travelled by the body upto the moment of its breaking off the plane will be $s = \dfrac{m^2 g^3 \cos\theta}{6k^2 \sin^3\theta}$.

(d) The distance travelled by the body upto the moment of its breaking off the plane will be $s = \dfrac{m^2 g^3 \cos\theta}{3k^2 \sin^3\theta}$.

15. A pulley fixed to the ceiling of a lift carries a thread whose ends are attached to the loads of masses 4 kg and 3 kg. The lift starts going down with an acceleration of $a = 4$ m/s^2 relative to the shaft on the lift. Which of the following option(s) is/are ***correct*** ?



(a) The acceleration of the load 4 kg relative to the shaft of the lift is 0.83 m/s^2.

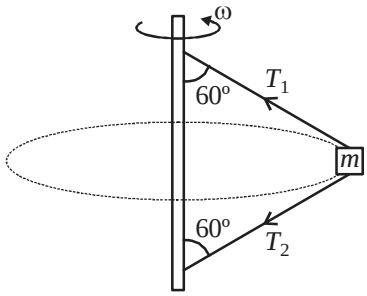
(b) The acceleration of the load 4 kg relative to the lift is 4.83 m/s^2.

(c) The tension in the string connecting the masses to the pulley is 19.89 N.

(d) The tension in the string connecting the masses to the pulley is 9.8 N.

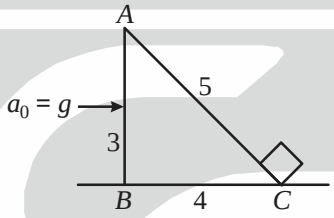
[SECTION - C — NUMERICAL ANSWER TYPE QUESTIONS (NAT)]

16. A small block is connected to one end of two identical massless strings of length 5/3 cm with the other ends fixed to a vertical rod as shown in the figure below:



For a given value of angular velocity ω the ratio of tensions is $T_1 : T_2 = 4:1$. 'ω' is equal to _____ $\times 10^{-1}$ rad/sec. [g = 9.8 m/s^2] [Answer should be nearest integer]

17. A block is placed on an inclined plane moving towards right with an acceleration $a_0 = g$, where AC = 5m and all surface are smooth.



If a block is placed at C with zero initial speed and the time taken by the block to move from C to A is $\sqrt{\alpha}$ sec, then α is equal to _____. [g = 10 m/s^2] [Answer should be an integer]

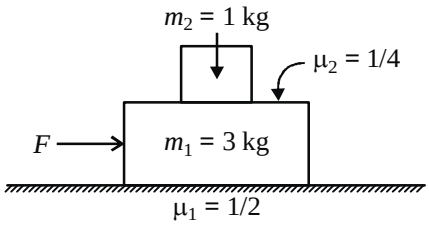
18. A raindrop falling through a cloud accumulates mass at a rate of kmv, where $k > 0$ and m is the instantaneous mass. If m_0 is its initial mass and its speed is given by,

$$v(t) = \sqrt{\frac{g}{k}} \tanh\left(\sqrt{kg}\, t\right)$$

then the time at which its mass doubles is equal to _____ $\left(1/\sqrt{kg}\right)$. [Upto two decimal places]

$\left[\text{Given}: \int \tanh(x)\, dx = \ln\left[\cosh(x)\right] + c \text{ and } \cosh^{-1}(2) = 1.317\right]$

19. Considering the figure below, the maximum value of F that can be applied without the upper block sliding is _____ N. [Answer should be an integer]



20. The speed of a particle moving along a circle of radius 1 m is given by $v(t) = (\alpha t^2 + 2)$ m/sec, where $\alpha = 2$ m/sec^3 and 't' is in seconds. The magnitude of total acceleration at t = 2 sec is _____ m/sec^2. [Upto 2 decimal place]

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ANSWER KEY

SECTION-A : MULTIPLE CHOICE QUESTIONS (MCQ)

1. (a)	**2.** (b)	**3.** (c)	**4.** (b)	**5.** (d)
6. (d)	**7.** (b)	**8.** (a)	**9.** (a)	**10.** (a)

SECTION-B : MULTIPLE SELECTIVE QUESTIONS (MSQ)

11. (a), (c)	**12.** (a), (c)	**13.** (b), (c), (d)	**14.** (a), (b), (c)	**15.** (c)

SECTION-C : NUMERICAL ANSWER TYPE QUESTIONS (NAT)

16. (44)	**17.** (5)	**18.** (1.30 to 1.35)
19. (30)	**20.** (100.30 to 100.35)	