**Q1.**

Negative work is done by a constant force $\vec{F}$ on a particle during a straight-line displacement $\vec{d}$ if,

**A)** $\vec{F} = 2\hat{i} - 3\hat{j}$ **and** $\vec{d} = 2\hat{i} + 4\hat{j}$

B) the angle between $\vec{F}$ and $\vec{d}$ is 90°

C) the angle between $\vec{F}$ and $\vec{d}$ is 60°

D) $\vec{F} = 2\hat{i} - 3\hat{j}$ and $\vec{d} = -4\hat{j}$

E) $\vec{F} = -2\hat{i} - 3\hat{j}$ and $\vec{d} = -2\hat{i}$

**Ans:**

**A**

---

**Q2.**

A 12.0 N force with a fixed orientation does work on a particle as the particle moves through the x-y plane with displacement $\vec{d} = (3.00\hat{i} - 4.00\hat{j})$ m. What is the angle between the force and the displacement if the change in the particle's kinetic energy is 30.0 J

A) 60.0°

B) 27.0°

C) Zero

D) 156°

E) 90.0°

**Ans:**

$$\vec{d} \cdot \vec{F} = |\vec{d}||\vec{F}|cos\theta = \Delta K$$

$$\Rightarrow \sqrt{3^2+4^2} \cdot 12cos\theta = 30$$

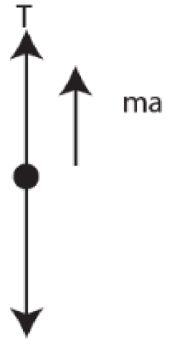
$$\theta = \cos^{-1}\left(\frac{30}{60}\right) = 60^\circ$$

---

**Q3.**

A helicopter lifts a 60 kg astronaut 15 m vertically from the ocean by means of a cable. The acceleration of the astronaut is $g/10$ vertically up. How much work is done on the astronaut by the force from the helicopter? Consider the initial speed of the astronaut as zero and ignore air resistance.

A) $9.70\times10^3$ J
B) $2.50\times10^3$ J
C) $3.20\times10^3$ J
D) $6.40\times10^3$ J
E) $1.20\times10^3$ J




**Ans:**

$$T = mg + ma = 60 \times \frac{11\,g}{10}$$

$$W_a = \Delta\vec{y} \cdot T = 15 \times 66 \times 9.8 = 9702 \text{ J}$$

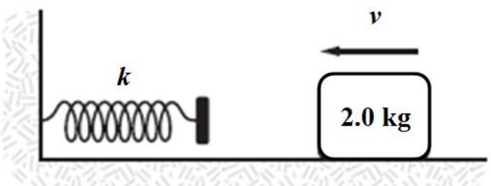
---

**Q4.**

**Figure 1** shows a block of mass 2.0 kg moving on a horizontal frictionless surface and an uncompressed spring with one end attached to a wall. The speed of the block before it touches the spring is 6.0 m/s. How fast is the block moving at the instant the spring has been compressed 15 cm? The spring constant $k$ of the spring is 2.0 kN/m.

A) 3.7 m/s
B) 4.4 m/s
C) 9.2 m/s
D) 5.4 m/s
E) 1.2 m/s

**Figure 1**




**Ans:**

$$\Delta K + \Delta U_s = 0$$

$$\frac{1}{2}mv^2 - \frac{1}{2}mv_0^2 + \frac{1}{2}kx^2 = 0$$

$$v = \sqrt{v_0^2 - \frac{k}{m}x^2} = \sqrt{6^2 - \frac{2000}{2} \times \left(\frac{15}{100}\right)^2} = 3.7\ m/s$$

---

**Q5.**

An 1800 kg car starts from rest on a straight horizontal road and gains a speed of 72 km/h in 30 s. The average power required of the car during the 30 s interval and the instantaneous power at the end of the 30 s interval are, respectively;

A) $1.2\times10^4$ W and $2.4\times10^4$ W
B) $3.2\times10^4$ W and $2.0\times10^4$ W
C) $1.2\times10^4$ W and $3.2\times10^4$ W
D) $2.4\times10^4$ W and $1.0\times10^4$ W
E) $3.2\times10^4$ W and $6.0\times10^4$ W

**Ans:**

$$v = 72\,km/h = \frac{72\times1000}{60\times60} = 20\ m/s$$

$$P_{av} = \frac{\Delta K}{\Delta t} = \frac{\frac{1}{2}mv^2 - 0}{\Delta t} = \frac{1}{2}\times\frac{1800\times20^2}{30} = 12000\,W$$

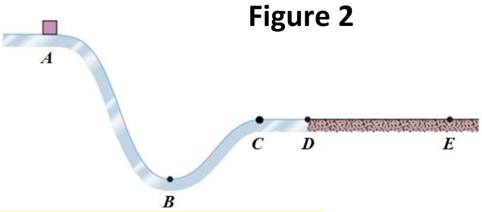
$$P_{in} = vF = vma = vm\left(\frac{v}{t}\right) = m\,v^2/t = 1800\times\frac{20^2}{30} = 24000\,W$$

---

**Q6.**

In **Figure 2**, a block slides from *A* to *D* along a frictionless ramp, and then passes through horizontal region *DE*, where a frictional force acts on it. Which one of the following statements about the block is **FALSE**?

**Figure 2**




A) Its mechanical energy remains constant in region DE
B) Its kinetic energy increases in region AB
C) Its mechanical energy remains constant in region AB
D) Its kinetic energy remains constant in region CD
E) Its mechanical energy remains constant in region BC

**Ans:**

**A**

---

**Q7.**

The summit (the highest point) of Mount Everest is $8.9\times10^3$ m above sea level and an 85 kg climber climbs to the summit starting from sea level. How many candy bars, at $1.3\times10^5$ J per bar, would supply an energy equivalent to the energy spent (lost) by the climber against the gravitational force on him?

A) 57
B) 84
C) 32
D) 74
E) 12

**Ans:**

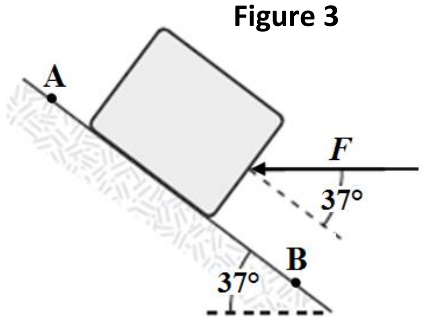
$$\#\ candy\ bars = \frac{mgh}{1.3\times10^5} = \frac{85\times9.8\times8900}{1.3\times10^5} = 57$$

---

**Q8.**

A 4.0-kg block is lowered down a 37° rough incline a distance of 5.0 m from point A to point B. A force $\vec{F}$ of magnitude 10 N is applied to the block between A and B as shown in **Figure 3**. The kinetic energy of the block at A is 10 J and at B is 20 J. How much work is done on the block by the force of friction between A and B?

**Figure 3**




A) − 68 J
B) − 58 J
C) − 95 J
D) − 83 J
E) − 43 J

**Ans:**

$$W_a + W_f = \Delta K + \Delta U_g$$

$$\vec{d}\cdot\vec{F} + W_f = (20-10) + \cancel{U_g}^{\,0} - U_{og}$$

$$-50cos37° + W_f = 10 - mgh$$

$$W_f = 50cos37° + 10 - 4\times9.8\times5sin37° = -68°$$

---

**Q9.**

Car A with mass 2400 kg is moving along a straight horizontal road at 80 km/h towards East. Car B with mass 1600 kg moving along a straight horizontal road at 60 km/h towards North. The magnitude and direction of the velocity of the center of mass of the two cars are, respectively:

A) 54 km/h and 27° North of East

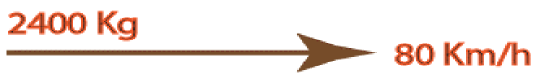
B) 54 km/h and 39° North of East

C) 65 km/h and 45° North of East

D) 65 km/h and 11° North of East

E) 15 km/h and 53° South of East

**Ans:**




$$V_{com,x} = \frac{2400 \times 80}{4000} = 48\ km/h$$


$$V_{com,y} = \frac{1600 \times 60}{4000} = 24\ km/h$$

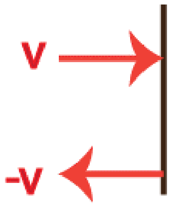
$$|V_{com}| = \sqrt{48^2 + 24^2} = 53.7\ km/h$$

$$\theta = \tan^{-1}\left(\frac{24}{48}\right) \approx 27°$$

**Q10.**

Suppose a gangster sprays Superman's chest with bullets each of mass 3.00 g at the rate of 100 bullets/min, and the speed of each bullet is 500 m/s. If the bullets rebound straight back with no change in speed, what is the magnitude of the average force on Superman's chest?

A) 5.00 N
B) 7.50 N
C) 2.50 N
D) 7.00 N
E) 9.00 N




**Ans:**

$$|F| = \frac{\Delta p}{\Delta t} = \frac{\Delta(2Mv)}{\Delta t} = 2v\frac{\Delta M}{\Delta t}$$

$$|F| = 2v\frac{\Delta(Nm)}{\Delta t} = 2mv\frac{\Delta N}{\Delta t}$$

$$= 2 \times \frac{3}{1000} \times 500 \times \frac{100}{60} = 5N$$

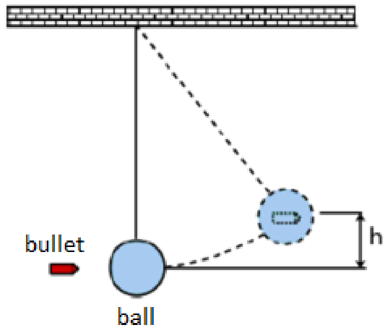
---

**Q11.**

**Figure 4** shows a ball of mass 1.20 kg hanging from a rope of negligible mass to make a pendulum. A 20.0 g bullet strikes the ball with a speed of *v*. The bullet embedded in the ball and center of mass of the ball + bullet rises a vertical distance of *h* = 26.0 cm, before coming to rest. Find the value of *v*. (Ignore air resistance)

A) 138 m/s
B) 340 m/s
C) 246 m/s
D) 520 m/s
E) 817 m/s

**Figure 4**




**Ans:**

$$\cancel{(m+M)}gh = \frac{1}{2}\cancel{(m+M)}V^2$$

$$V = \sqrt{2gh}$$

$$mv + 0 = (m+M)V$$

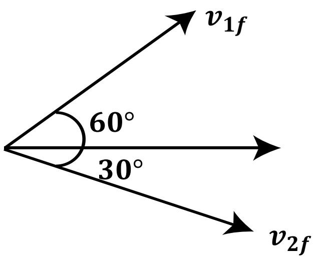
$$v = \left(1 + \frac{M}{m}\right)\sqrt{2gh} = \left(1 + \frac{1.2}{0.02}\right)\sqrt{2 \times 9.8 \times 0.26} = 137.7\ m/s$$

---

**Q12.**

Proton A with a speed of 500 m/s collides elastically with proton B initially at rest. The two protons then move along perpendicular paths, with proton A path at 60.0° from its original direction. What is the speed of the proton A after collision?

A) 250 m/s
B) 120 m/s
C) 750 m/s
D) 300 m/s
E) 570 m/s




**Ans:**

$v_{1i} = 500\ m/s,\ \ v_{2i} = 0$

Vertical Direction

$$v_{1f} sin60° = v_{2f} sin30°$$

$$v_{1f}\frac{\sqrt{3}}{2} = v_{2f}\frac{1}{2}$$

$$v_{2f} = \sqrt{3}v_{1f}$$

Horizontal Direction

$$v_{1f} cos60° + v_{2f} cos30° = 500$$

$$v_{1f}\frac{1}{2} + \sqrt{3}v_{1f}\frac{\sqrt{3}}{2} = 500$$

$$2v_{1f} = 500$$

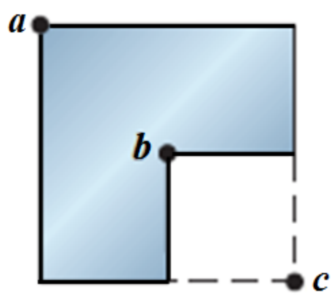
$$v_{1f} = 250\ m/s$$

---

**Q13.**

**Figure 5** shows a uniform metal plate that had been square before 25% of it was snipped off (removed). Three lettered points are indicated. Rank them according to the rotational inertia of the plate around a perpendicular axis through them, **greatest first**.

**Figure 5**




A) c,a,b
B) a,b,c
C) b,a,c
D) all tie
E) b,c,a

**Ans:**

**A**

**Q14.**

A particle is rotating in a horizontal plane about a fixed axis. The radius of its circular path is 10.0 m and it starts to rotate at constant angular acceleration from rest at time *t* = 0. The angular speed of the particle reaches 36.0 revolutions per minutes at *t* = 8.00 s. When *t* = 5.00 s, what is the magnitude of the particle's radial acceleration?

A) 55.5 m/s$^2$
B) 30.7 m/s$^2$
C) 90.4 m/s$^2$
D) 13.7 m/s$^2$
E) 45.2 m/s$^2$

**Ans:**

$$a_t = \alpha\, r$$

$$t = 8\, s \quad ; \quad \omega = \frac{36 \times 2\pi}{60}$$

$$\omega_0 = 0$$

$$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\omega}{t} = \frac{6 \times 2\pi}{10 \times 8}$$

$$a_t = \frac{12\pi}{80} \times 10$$

$$a_r(t) = \omega^2(t) r \quad \Rightarrow a_r(5) = \omega^2(5) r$$

$$\omega(t) = 0 + \alpha t$$

$$\omega(5) = \frac{12\pi}{80} \times 5 = \frac{3\pi}{4}$$

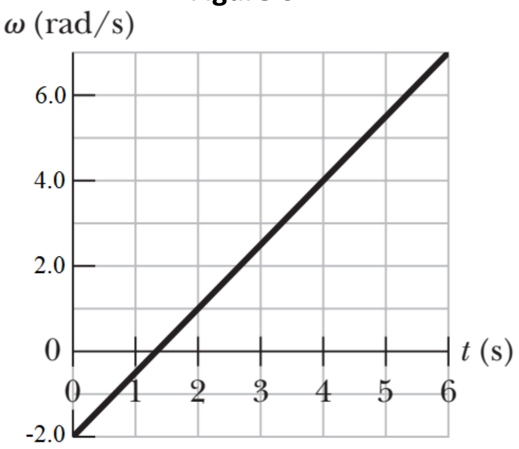
$$a_r(5) = \left(\frac{3\pi}{4}\right)^2 \cdot 10 = 55.5\, m/s$$

**Q15.**

**Figure 6** gives angular speed versus time for a thin rod that rotates around one end on a horizontal plane. At $t$ = 4.0 s, the rod has a rotational kinetic energy of 1.6 J. How much average power is required to rotate the rod from $t$ = 4.0 s to $t$ = 6.0 s?

A) 1.7 W
B) 2.3 W
C) 4.4 W
D) 5.6 W
E) 7.5 W

**Figure 6**




**Ans:**

$$K(4) = 4$$

$$\frac{1}{2}I\omega^2(4) = 1.6$$

$$\frac{1}{2}I \times 4^2 = 1.6$$

$$I = \frac{1.6}{16} \times 2 = 0.2\ kg.m^2$$

$$P_{avg} = \frac{W_a}{\Delta t} = \frac{\Delta K}{\Delta t}$$

$$P_{avg} = \frac{K(6) - K(4)}{6 - 4} = \frac{\frac{1}{2}I\omega^2(6) - 1.6}{2} = \frac{\frac{1}{2} \times 0.2 \times 7^2 - 1.6}{2} = 1.65\ W$$

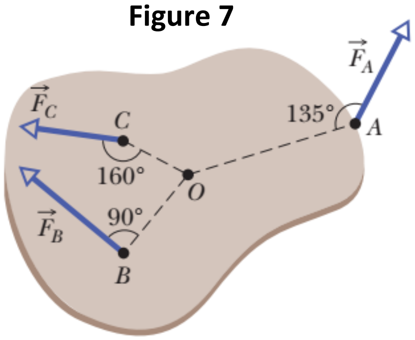
---

**Q16.**

The body in **Figure 7** is in horizontal plane and is pivoted at O. Three forces act on it: $F_A$ = 11 N at point A, 8.0 m from O; $F_B$ = 16 N at B, 4.0 m from O; and $F_C$ = 22 N at C, 3.0 m from O. What is the net torque about O?

A) 21 N.m
B) 11 N.m
C) 36 N.m
D) 72 N.m
E) 48 N.m

**Figure 7**




**Ans:**

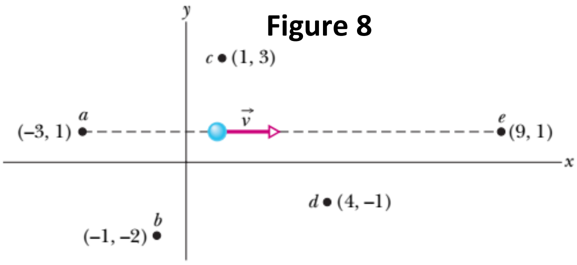
$$\tau = 8 \times 11 \times sin45° + 22 \times 3sin20° - 4 \times 16sin90° = 20.8\ N.m$$

---

**Q17.**

**Figure 8** shows a particle moving at constant velocity and five points with their *xy* coordinates. Rank the points according to the magnitude of the angular momentum of the particle measured about them, **greatest first**.

A) b, (c and d tie), (a and e tie)
B) a, (c and d tie), b, e
C) e, a, b, d, c
D) a, b, c, d, e
E) e, (a and d tie), (b and c tie)




**Ans:**

$$|L_a| = |L_e| = 0$$

$$|L_c| = 2mv$$

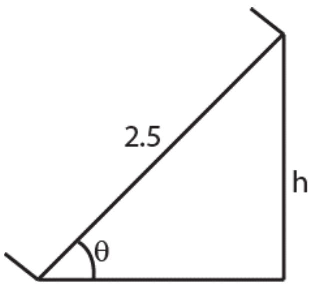
$$|L_d| = 2mv$$

$$|L_b| = 3mv$$

**Q18.**

An inclined plane at an angle of 30° is 2.5 m long. Starting from rest, a solid sphere rolls down without slipping from the top of the inclined plane. Find the speed of the center of mass of the sphere at the bottom of the inclined plane.

A) 4.2 m/s
B) 2.5 m/s
C) 1.6 m/s
D) 7.5 m/s
E) 9.1 m/s




**Ans:**

$$h = 2.5 sin30° = 1.25\ m$$

$$\Delta K + \Delta U_g = 0$$

$$K_T + K_R - mgh = 0$$

$$\frac{1}{2}mv^2 + \frac{1}{2}I\omega^2 = mgh \Rightarrow \frac{1}{2}mv^2 + \frac{1}{2}\cdot\frac{2}{5}mR^2\frac{v^2}{R^2} = mgh$$

$$\frac{7}{10}v^2 = gh \Rightarrow v = \sqrt{\frac{10gh}{7}} = \sqrt{\frac{10 \times 9.8 \times 1.25}{7}} = 4.2\ m/s$$

**Q19.**

A 3.0-kg particle has a position vector given by $\vec{r} = 2.0t^2\hat{i} + 3.0\hat{j}$ where $\vec{r}$ is in meters and $t$ is in seconds. The magnitudes of angular momentum of the particle about the origin at *t = 2.0* s, and the torque on the particle about the origin at *t* = 2.0 s are respectively:

A) 72 kg.m²/s and 36 N.m
B) 12 kg.m²/s and 36 N.m
C) 32 kg.m²/s and 72 N.m
D) 72 kg.m²/s and 24 N.m
E) 24 kg.m²/s and 24 N.m

**Ans:**

$\vec{L} = \vec{r}(2) \times mv(2)$

$= (8\hat{\imath} + 3\hat{\jmath}) \times 24\hat{\imath}$

$= 72(\hat{\jmath} \times \hat{\imath}) = -72\hat{k}$

$\tau = \vec{r}(2) \times ma$

$= (8i + 3j) \times 12\hat{\imath} = 36\ N.m$

---

**Q20.**

The rotational inertia of a collapsing spinning star drops to $\frac{1}{3}$ its initial value. What is the ratio of the new rotational kinetic energy to the initial rotational kinetic energy?

A) 3
B) 6
C) 1
D) 9
E) 5

**Ans:**

$I_i\omega_i = I_f\omega_f$

$\frac{I_i}{I_f} = \frac{\omega_f}{\omega_i}$

$$\frac{K_{Rf}}{K_{Ri}} = \frac{\frac{1}{2}I_f\omega_f^2}{\frac{1}{2}I_i\omega_i^2} = \frac{I_f}{I_i} \cdot \frac{I_i^2}{I_f^2} = \frac{I_i}{I_f} = \frac{I_i}{\frac{1}{3}I_i} = 3$$