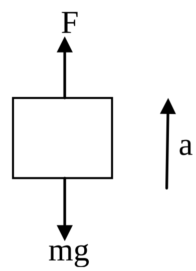
Q1.

A rope exerts a force $\vec{F}$ on a 20.0 kg crate in lifting it vertically upward above the floor. The crate starts from rest and accelerates upward at 5.00 m/s^2. How much work was done by the force $\vec{F}$ in raising the crate 4.00 m above the floor?

A) 1.18 kJ
B) 1.98 kJ
C) 2.50 kJ
D) 1.71 kJ
E) 0.704 kJ



Ans:

$$ma = F - mg \quad \Rightarrow F = m(a+g) = 296\text{ N}$$

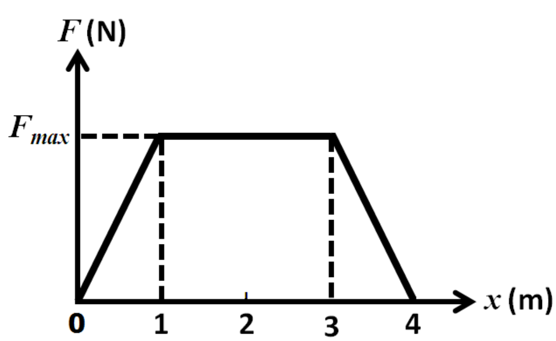
$$W = \vec{F}.\vec{d} = F.d = 296 \times 4.00 = 1184\text{ J} \Rightarrow 1.18\text{ kJ}$$

Q2.

A 0.50 kg object, moving along the *x*-axis, experiences the force shown in **Figure 1**. The object's velocity at *x* = 0.0 m is *v* = 2.0 m/s, and at *x* = 4.0 m is *v* = 8.0 m/s. What is F_{max}?

A) 5.0 N
B) 7.2 N
C) 9.7 N
D) 3.2 N
E) 1.8 N

Figure 1



Ans:

$$W = \Delta K = \frac{1}{2}\,m\,(v_4{}^2 - v_0{}^2)$$

$$= \frac{1}{2} \times 0.5 \times (64 - 4) = 15\text{ J}$$

From the graph : W = area

$$\Rightarrow W = \left(\frac{1}{2} \times 1 \times F_{max}\right) + (2 \times F_{max}) + \left(\frac{1}{2} \times F_{max}\right)$$

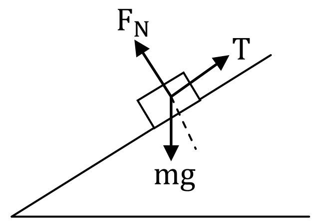
$$\Rightarrow W = 3\,F_{max}$$

$$\Rightarrow F_{max} = \frac{W}{3} = 5.0\text{ N}$$

Q3.

A constant tension force is used to pull a 50.0 kg box up a frictionless plane inclined at 30.0° relative to the horizontal. The tension force is parallel to the incline. The box is moved a distance of 30.0 m along the incline with a constant speed of 1.00 m/s. At what rate is work done by the tension force?

A) 245 W
B) 49.3 W
C) 98.0 W
D) 292 W
E) 495 W



Ans:

$\text{constant speed: } a = 0$

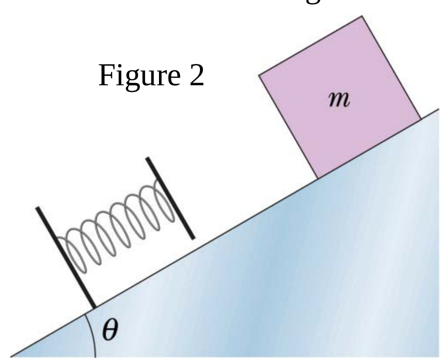
$$\Rightarrow T = mg\sin\theta = 50 \times 9.8 \times \frac{1}{2} = 245 \text{ N}$$

$$P_T = T.v = 245 \times 1.00 = 245 \text{ W}$$

Q4.

A 33 kg block starts from rest at the top of a 30° inclined frictionless plane and slides downward, as shown in **Figure 2**. At the bottom of the plane, it hits a spring, with spring constant 3.4 kN/m, which is rigidly attached to the plane. The block stops after compressing the spring by 37 cm. The distance the block travelled along the inclined plane is:

Figure 2



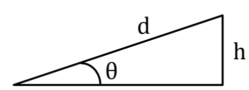
A) 1.4 m
B) 2.1 m
C) 3.8 m
D) 1.1 m
E) 5.0 m

Ans:

$$\Delta U_g + \Delta U_s + \overset{0}{\cancel{\Delta K}} = 0$$

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

$$h = \frac{kx^2}{2mg} = \frac{3.4 \times 10^3 \times (37)^2 \times 10^{-4}}{2 \times 33 \times 9.8} = 0.72 \text{ m}$$



$$h = d.\sin\theta$$

$$\Rightarrow d = \frac{h}{\sin\theta} = \frac{h}{\sin 30^\circ} = 2h = 1.4 \text{ m}$$

Q5.

A 12.5 kg crate slides along a horizontal frictionless surface at a constant speed of 4.0 m/s. The crate then slides down a frictionless incline and across a second horizontal rough surface, as shown in **Figure 3**. What is the coefficient of kinetic friction if the crate stops over a distance of 5.0 m along the lower surface?

A) 0.76
B) 0.60
C) 0.66
D) 0.30
E) 0.35

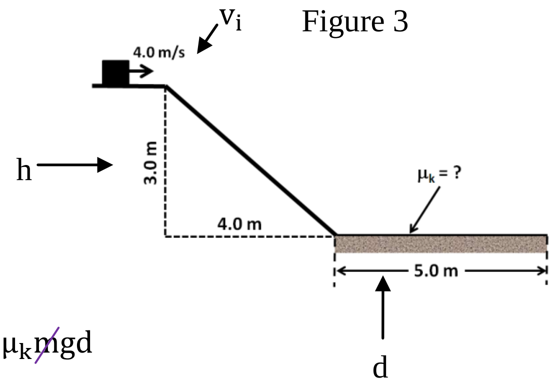


Figure 3

Ans:

$$\Delta u_g + \Delta K = W_{ext}$$

$$\cancel{-}\cancel{m}gh \cancel{-} \frac{1}{2}\cancel{m}v_i^2 = -W_f = -f_k \cdot d = \cancel{-}\mu_k \cancel{m}gd$$

$$\Rightarrow \mu_k = \frac{gh + \left(\frac{v_i^2}{2}\right)}{gd} = 0.76$$

Q6.

A light object and a heavy object are initially sliding with equal speeds along a horizontal frictionless surface. Then, they both slide up the same frictionless incline. Which object rises to a greater height?

A) They both slide to the same height.
B) The heavy object, because it has greater kinetic energy
C) The light object, because it has smaller kinetic energy.
D) The light object, because it weighs less.
E) The heavy object, because it weighs more.

Ans:

$$\Delta u_g + \Delta K = 0$$

$$mgh - \frac{1}{2} mv_i^2 = 0$$

$$\Rightarrow h = \frac{v_i^2}{2g} \longrightarrow \text{same}$$

Q7.

A 12 kg object is thrown vertically upward with an initial speed of 20 m/s. It rises to a maximum height of 18 m above the launch point. How much work is done by the dissipative (air) resistive force on the object during this ascent?

A) – 0.28 kJ
B) – 0.40 kJ
C) – 0.52 kJ
D) – 0.64 kJ
E) – 0.76 kJ

Ans:

$$\Delta K + \Delta U_g = W_{nc}$$

$$\Longrightarrow W_{nc} = -\frac{1}{2} m v_i^{2} + mgh$$

$$= \left(-\frac{1}{2} \times 12 \times 400\right) + (12 \times 9.8 \times 18) = -283.2\ \mathrm{J} \Rightarrow -0.28\ \mathrm{kJ}$$

Q8.

A 2.00 kg mass is located at $4.00\,\hat{\mathbf{i}} - 1.00\,\hat{\mathbf{j}}\,(\mathrm{m})$, and a 1.00 kg mass is located at $1.00\,\hat{\mathbf{i}} + 2.00\,\hat{\mathbf{j}}\,(\mathrm{m})$. Where must a 3.00 kg mass be located so that the center of mass of the system is located at $-1.00\,\hat{\mathbf{i}} + 1.00\,\hat{\mathbf{j}}\,(\mathrm{m})$?

A) $-5.00\,\hat{\mathbf{i}} + 2.00\,\hat{\mathbf{j}}\,(\mathrm{m})$
B) $-4.00\,\hat{\mathbf{i}} + 0.60\,\hat{\mathbf{j}}\,(\mathrm{m})$
C) $-2.00\,\hat{\mathbf{i}} + 2.00\,\hat{\mathbf{j}}\,(\mathrm{m})$
D) $-15.0\,\hat{\mathbf{i}} + 6.00\,\hat{\mathbf{j}}\,(\mathrm{m})$
E) $-8.00\,\hat{\mathbf{i}} + 3.20\,\hat{\mathbf{j}}\,(\mathrm{m})$

Ans:

$$M\vec{r}_{com} = m_1\vec{r}_1 + m_2\vec{r}_2 + m_3\vec{r}_3$$

$$\vec{r}_3 = \frac{1}{m_3}\left(M\vec{r}_{com} - m_1\vec{r}_1 - m_2\vec{r}_2\right)$$

$$= \frac{1}{3.00}\left(-6.00\,\hat{\imath} + 6.00\,\hat{\jmath} - 8.00\,\hat{\imath} + 2.00\,\hat{\jmath} - 1.00\,\hat{\imath} - 2.00\,\hat{\jmath}\right)$$

$$= -5.00\,\hat{\imath} + 2.00\,\hat{\jmath}\ (\mathrm{m})$$

Q9.

Four cars, A, B, C, and D with masses m_A, m_B, m_C, and m_D, respectively, begin accelerating from rest, at the same time. The same net force is exerted on each car. After 10 seconds, which car has the largest linear momentum if $m_A > m_B > m_C > m_D$?

A) They all have the same linear momentum.
B) Car A
C) Car B
D) Car C
E) Car D

Ans:

$$a = \frac{F}{m}$$

$$v = \cancel{v_i}^{\,0} + at = \frac{Ft}{m}$$

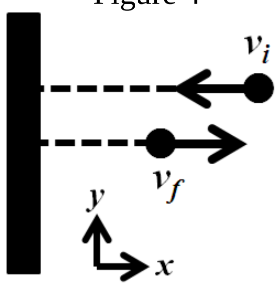
$$p = m.v = F.t \rightarrow \text{same}$$

Q10.

A 200 g ball strikes a wall, as shown in **Figure 6**, with a speed of 3.5 m/s and rebounds with only 50% of its initial kinetic energy. What is the impulse on the wall from the ball?

A) – 1.2 N.s
B) + 1.2 N.s
C) – 2.1 N.s
D) + 2.1 N.s
E) + 3.5 N.s

Figure 4



Ans:

$$K_i = \frac{1}{2}mv_i^2 = \frac{1}{2} \times 0.2 \times 3.5^2 = 1.225\ \text{J}$$

$$K_f = \frac{k_i}{2} = 0.6125\ \text{J}$$

$$K_f = \frac{1}{2}mv_f^2 \Rightarrow v_f = \sqrt{\frac{2K_f}{m}} = 2.47\ \text{m/s}$$

$$\text{For ball: } \Delta p = p_f - p_i = mv_f - mv_i = m(v_f - v_i)$$

$$= (0.2)[2.47 - (-3.5)] = 1.2\ \text{N.s}$$

$$\text{For the wall: } \Delta p = -1.2\ \text{N.s}$$

$$\text{impulse: } J = \Delta p = -1.2\ \text{N.s}$$

Q11.

A 900 kg car traveling with velocity + 15.0 $\hat{\mathbf{i}}$ (m/s) collides with a 750 kg car moving with velocity + 20.0 $\hat{\mathbf{j}}$ (m/s). After the collision, the two cars stick together. Just after the collision, what is the speed of the combined object and the direction of its velocity with respect to positive *x*-axis?

A) 12.2 m/s , 48.0°
B) 21.1 m/s , 28.0°
C) 32.2 m/s , 21.0°
D) 19.2 m/s , 48.0°
E) 18.2 m/s , 38.0°

Ans:

$$M\vec{V}_{com} = m_1\vec{v}_1 + m_2\vec{v}_2$$

$$\Rightarrow \vec{V}_{com} = \frac{1}{1650}(900 \times 15\,\hat{\imath} + 750 \times 20\hat{\jmath}) = 8.18\,\hat{\imath} + 9.09\,\hat{\jmath}\ \mathrm{m/s}$$

$$V_{com} = [(8.18)^2 + (9.09)^2]^{\frac{1}{2}} = 12.2\ \mathrm{m/s}$$

$$\theta = \tan^{-1}\left(\frac{9.09}{8.18}\right) = 48.0°$$

Q12.

A 0.62 kg object traveling at 2.1 m/s collides head-on with a 0.32 kg object traveling in the opposite direction at 3.8 m/s. If the collision is perfectly elastic, what is the final kinetic energy of the 0.62 kg object?

A) 1.1 J
B) 0.69 J
C) 0.47 J
D) 0.23 J
E) The kinetic energy of the object is unchanged.

Ans:

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2}v_{1i} + \frac{2m_2}{m_1 + m_2}v_{2i} = \left(\frac{0.62 - 0.32}{0.62 + 0.32}\right)(2.1) + \left(\frac{2 \times 0.32}{0.94}\right)(-3.8)$$

$$= 0.67 - 2.59 = -1.92\ \mathrm{m/s}$$

$$\Rightarrow K_{1f} = \frac{1}{2} \times 0.62 \times (1.92)^2 = 1.1\ \mathrm{J}$$

Q13.

An object is initially rotating at 20 rad/s. At $t = 0$, a constant torque is applied to the object, increasing its angular speed. From $t = 0$ to $t = 9.0$ s, it has rotated through 450 rad. The magnitude of its angular acceleration is:

A) 6.7 rad/s^2
B) 3.3 rad/s^2
C) 4.4 rad/s^2
D) 5.6 rad/s^2
E) 11 rad/s^2

Ans:

$$\theta = \omega_i t + \frac{1}{2}\alpha \times t^2$$

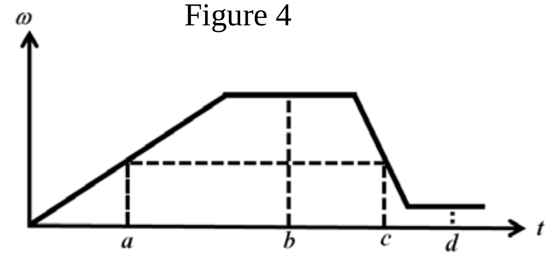
$$450 = (20 \times 9) + \left(\frac{1}{2} \times \alpha \times 81\right) = 180 + 40.5\,\alpha$$

$$\Rightarrow \alpha = 6.7\ \text{rad/s}^2$$

Q14.

Figure 4 is a graph of the angular speed of a rotating disk as a function of time. For a point on the rim of the disk, rank the instants **a**, **b**, **c**, and **d** according to the magnitude of the tangential acceleration, greatest first.

Figure 4



A) **c** then **a** then (**b** and **d**) tie
B) **b** then (**a** and **d**) tie then **c**
C) **d** then **c** then (**a** and **b**) tie
D) **a** then **c** then **b** then **d**
E) **a** then **b** then **c** then **d**

Ans:

$a_t = R.\alpha$

magnitude of α = slope of <u>ω vs. t</u>

at b <u>and</u> d : slope = 0

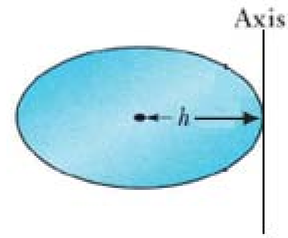
slope at c $>$ *slope at a*

Q15.

Figure 5 shows a disk that can rotate about an axis perpendicular to its plane with constant angular velocity ω. By what factor will the rotational kinetic energy of the disk change if the axis of rotation of the disk is shifted from the center to the edge of the disk, keeping ω constant.

A) 3
B) 1/3
C) 4
D) 1/4
E) 2

Figure 5



Ans:

$$K = \frac{1}{2} I\omega^2$$

ω is constant ⇒ K is proportional to I

$$I_{edge} = I_{com} + MR^2 = \frac{1}{2} MR^2 + MR^2 = \frac{3}{2} MR^2$$

$$K_{edge} = \frac{1}{2} I_{edge}\omega^2 = \frac{3}{4} MR^2\omega^2$$

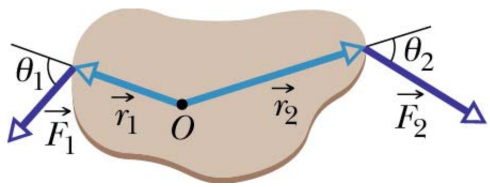
$$K_{com} = \frac{1}{2} I_{com}\omega^2 = \frac{1}{4} MR^2\omega^2$$

$$\Rightarrow \frac{K_{edge}}{K_{com}} = 3$$

Q16.

The body in **Figure 7** is pivoted at *O*, and two forces $\mathbf{F_1}$ and $\mathbf{F_2}$ act on it. If r_1 = 1.5 m, r_2 = 2.3 m, F_1 = 4.5 N, F_2 = 5.6 N, θ_1 = 75^o, and θ_2 = 60^o, what is the net torque about the pivot?

Figure 7



A) 4.7 N.m, clockwise
B) 4.7 N.m, counterclockwise
C) 18 N.m, clockwise
D) 18 N.m, counterclockwise
E) zero

Ans:

$\tau = r\,.\,F.\sin\theta$

$\tau_1 = r_1\,.\,F_1.\sin\theta_1$

$= 1.5 \times 4.5 \times \sin 75° = 6.5\ \text{N.m} \rightarrow \text{counter} - \text{clockwise}$

$\tau_2 = r_2\,.\,F_2.\sin\theta_2$

$= 2.3 \times 5.6 \times \sin 60° = 11.2\ \text{N.m} \rightarrow \text{clockwise}$

since $|\tau_2| > |\tau_1|$:

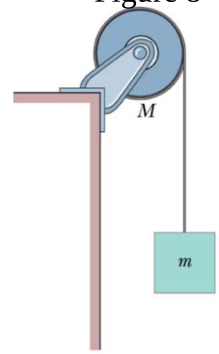
$\tau_{net} = \tau_2 - \tau_1 = 4.7\ \text{N.m} \rightarrow \text{clockwise}$

Q17.

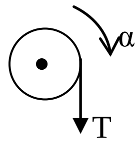
A uniform disk, of mass M = 2.0 kg and radius R = 20 cm, is mounted on a fixed horizontal axle, as shown in Figure 8. A block, of mass m = 1.0 kg, hangs from a massless cord that is wrapped around the rim of the disk. The block is allowed to fall. Find the magnitude of the tension in the cord. The cord does not slip and there is no friction at the axle.

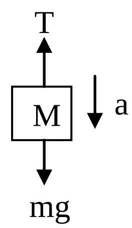
A) 4.9 N
B) 3.9 N
C) 3.3 N
D) 6.1 N
E) 1.4 N

Figure 8



Ans:





Disk:

$$\tau = I\alpha$$

$$\cancel{R}.T = \frac{1}{2} M\cancel{R}^2 . \frac{a}{\cancel{R}}$$

$$\Rightarrow a = \frac{2T}{M} \longrightarrow (1)$$

Block:

$$ma = mg - T$$

$$a = g - \frac{T}{m} \longrightarrow (2)$$

From (1) $\longrightarrow$ (2):

$$\frac{2T}{M} = g - \frac{T}{m}$$

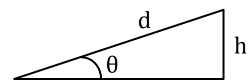
$$T\left(\frac{1}{m} + \frac{2}{M}\right) = g$$

$$T = \frac{mMg}{M + 2m}$$

$$= \frac{1.0 \times 2.0 \times 9.8}{2.0 + 2.0} = 4.9 \text{ N}$$

Q18.

A uniform solid ball rolls smoothly along a floor, and then rolls up a ramp inclined at 30°. It momentarily stops when its center of mass has rolled 1.2 m along the ramp. What is the initial speed of the center of mass of the ball?



A) 2.9 m/s
B) 4.0 m/s
C) 2.0 m/s
D) 6.0 m/s
E) 8.0 m/s

Ans:

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

$$K = K_r + K_t = \frac{1}{2} I_{com}\omega^2 + \frac{1}{2} Mv_{com}{}^2 = \left(\frac{1}{2} \times \frac{2}{5} MR^2 \times \frac{v_{com}{}^2}{R^2}\right) + \frac{1}{2} Mv_{com}{}^2$$

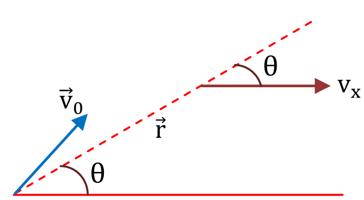
$$= \frac{7}{10} Mv_{com}{}^2$$

$$\frac{7}{10} \cancel{M}v_{com}{}^2 = Mgh = Mg.d.\sin\theta = \frac{1}{2} \cancel{M}gd$$

$$v_{com}{}^2 = \frac{10}{14} gd = \frac{5gd}{7} \Rightarrow v_{com} = 2.9 \text{ m/s}$$

Q19.

A 2.00 kg projectile is launched from the origin of an *xy* coordinate system with a velocity of 10.0 m/s making an angle of 45.0° with the positive *x* axis. If the maximum height is 2.55 m, what is the angular momentum of the projectile, about the origin, when it reaches the maximum height?



A) – 36.1 $\hat{\mathbf{k}}$ kg.m²/s
B) + 36.1 $\hat{\mathbf{k}}$ kg.m²/s
C) + 24.6 $\hat{\mathbf{k}}$ kg.m²/s
D) – 24.6 $\hat{\mathbf{k}}$ kg.m²/s
E) zero

Ans:

At maximum height:

$$\vec{r} = x\hat{i} + h\hat{j}$$

$$\vec{v} = v_x\hat{i} \Rightarrow \vec{p} = mv_x\hat{i}$$

$$\vec{l} = \vec{r} \times \vec{p} = (x\hat{i} + h\hat{j}) \times (mv_x\hat{i}) = -hmv_x\hat{k}$$

$$= -(h.m.v_i.\cos\theta_i)\hat{k} = -36.1\hat{k} \text{ kg.m}^2/\text{s}$$

Q20.

A 2.0 kg disk, having a radius of 10 cm, rotates at 100 rad/s on a frictionless axle. A 500 g particle falls from above and sticks to the edge of the disk. What is disk's angular speed just after the particle hits it?

A) 67 rad/s
B) 100 rad/s
C) 1.0 rad/s
D) 50 rad/s
E) 33 rad/s

Ans:

$$L_i = I_d\,\omega_i$$

$$L_f = \left(I_d + I_p\right)\omega_f$$

$$L_i = L_f$$

$$I_d\,\omega_i = \left(I_d + I_p\right)\omega_f$$

$$\therefore \omega_f = \left(\frac{I_d}{I_d + I_p}\right)\omega_i$$

$$I_d = \frac{1}{2}MR^2 = \frac{1}{2} \times 2 \times (0.1)^2 = 0.01\ \text{kg m}^2$$

$$I_p = mR^2 = \frac{1}{2} \times (0.1)^2 = 0.005\ \text{kg m}^2$$

$$\therefore \omega_f = \frac{0.01}{0.015} \times 100 = 67\ \text{rad/s}$$