

Final Exam Review Solutions

1. $A = B^n C^m$

$$\Rightarrow [A] = [B]^n [C]^m$$

$$\Rightarrow LT = (L^2 T^{-1})^n (L T^2)^m$$

$$\Rightarrow L' T' = L^{2n} T^{-n} L^m T^{2m}$$

$$\Rightarrow L' T' = L^{2n+m} T^{-n+2m}$$

Comparing exponent powers, we have $2n+m=1$ — ①

$$-n+2m=1 \quad \text{--- ②}$$

Multiply eqn. ② by 2 and add to eqn. ①:

$$2n+m=1$$

$$-2n+4m=2$$

$$\oplus \quad \frac{0+5m=3}{\underline{\underline{m=3/5}}}$$

Multiply eqn ① by -2 and add to eqn. ②:

$$-4n-2m=-2$$

$$-n+2m=1$$

$$\oplus \quad \frac{-5n+0=-1}{\underline{\underline{n=1/5}}}$$

D

1

2. $x(t) = 6t^2$

Option 1: Do calculus! $v(t) = \frac{dx}{dt} = 12t$, $a(t) = \frac{dv}{dt} = 12 \text{ m/s}^2$

Option 2: Compare with kinematic eqn: $x(t) = x_0 + v_0 t + \frac{1}{2} a t^2$

$$\Rightarrow x_0 = 0, v_0 = 0, \frac{1}{2} a = 6 \Rightarrow a = 12 \text{ m/s}^2$$

Important note: Option 1 is general; option 2 only works if $x(t) \propto t$ or $x(t) \propto t^2$.

Since this is 1D motion, the path is a straight line. t can be negative — nothing sacred about $t > 0$.

E

3. v_{y0} ↑ $↓ g = 10 \text{ m/s}^2$

B

$$\begin{aligned} \text{Use } y - y_0 &= v_{y0}t - \frac{1}{2}gt^2 \\ &= (50 \text{ m/s})(1 \text{ s}) - \frac{1}{2}(10 \text{ m/s}^2)(1 \text{ s})^2 \\ &= 50 \text{ m} - 5 \text{ m} \\ &= \underline{45 \text{ m}} \end{aligned}$$

4. A: The bomber's constant velocity matches the v_x of the bomb's velocity at all times (in the absence of air resistance), so the bomber is over the target when the bomb strikes.

B: The acceleration of the bomb is equal to $a_y = -9.8 \text{ m/s}^2$ and so, it is constant.

C: There's absolutely no correlation between the horizontal velocity of the plane and the vertical velocity of the bomb. The vertical velocity gained by the bomb falling through height H is equal to $v_y = \sqrt{2gH}$. It is equal to the horizontal speed v_0 of the bomber only if $2gH = v_0^2$ or $H = \frac{v_0^2}{2g}$. For all other heights of the bomber, the vertical velocity of the bomb will be either greater than, or less than, the horizontal velocity of the bomber.

2

D: The bomb indeed travels in a parabolic path

E: The time of flight is got from the 2nd kinematic equation:

$$y - y_0 = v_{y0}t - \frac{1}{2}gt^2$$

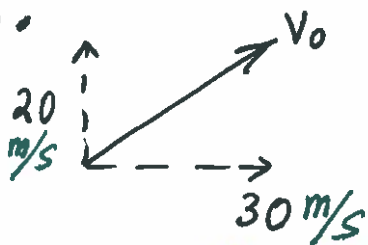
$$0 - H = 0 - \frac{1}{2}gt^2$$

$$\Rightarrow t = \sqrt{\frac{2H}{g}}$$

C

which is independent of the horizontal speed of the plane.

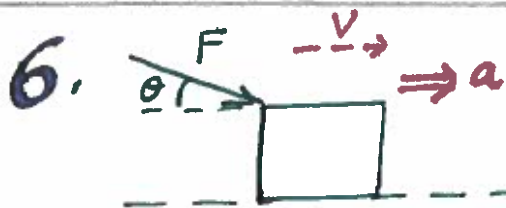
5. Time to reach highest point:



$$v_y = 0 = v_{y0} - gt \Rightarrow t = \frac{v_{y0}}{g} = \frac{20 \text{ m/s}}{10 \text{ m/s}^2} = 2 \text{ s}$$

Therefore, the total time of flight will be twice this, or 4s. In this time, the horizontal distance covered by the projectile would be:

$$x - x_0 = v_{x0} T = (30 \text{ m/s})(4 \text{ s}) = \underline{120 \text{ m.}} \quad \boxed{D}$$

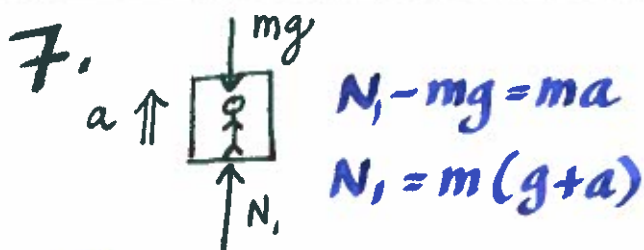


Since there is no friction, we do not need to worry about the normal force from the floor. So the N2L in

\hat{x} direction gives:

$$\Sigma F_x = ma_x \Rightarrow F \cos \theta = ma_x$$

$$\Rightarrow a_x = \frac{F \cos \theta}{m} = \frac{(20 \text{ N}) \cos 20^\circ}{2.5 \text{ kg}} = \underline{0.75 \text{ m/s}^2} \quad \boxed{B}$$



$$N_1 - mg = ma$$

$$N_1 = m(g + a)$$

This describes either:

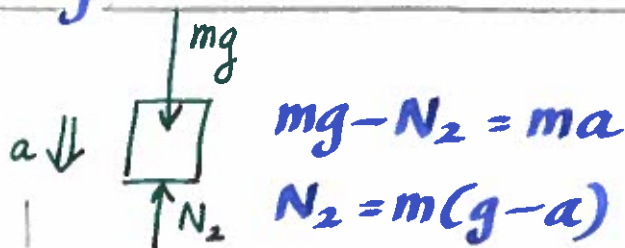
- elevator moving up w/ increasing speed

OR

- elevator moving down w/ decreasing speed

these scenarios will result in high scale readings

\boxed{B}



$$mg - N_2 = ma$$

$$N_2 = m(g - a)$$

This describes either:

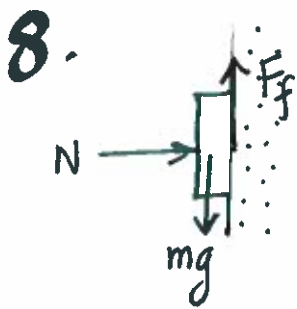
- elevator moving down w/ increasing speed

OR

- elevator moving up w/ decreasing speed

these scenarios will result in low scale readings

$\boxed{3}$



First, we must determine if the book even moves. Let's find the maximum static friction force. If this force is LESS than the weight, the book will accelerate downward.

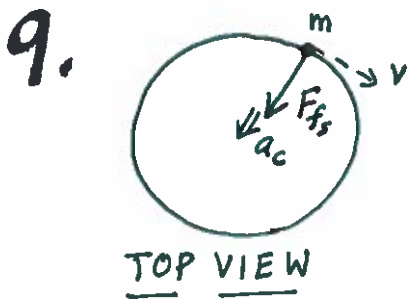
$$F_{f_{s_{max}}} = \mu_s N = (0.6)(5.0\text{ N}) = 3.0\text{ N}$$

$$W = mg = (0.5\text{ kg})(9.8\text{ m/s}^2) = 4.9\text{ N}.$$

So the book will accelerate downward. In this event, the friction force will be the kinetic friction:

$$F_{f_k} = \mu_k N = (0.8)(5.0\text{ N}) = \underline{\underline{4.0\text{ N}}}.$$

E



Since the car is on the verge of skidding, the static friction force is maximized.

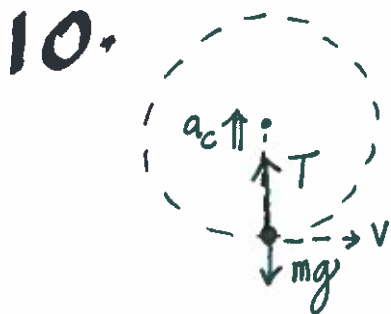
$$F_{f_{s_{max}}} = \mu_s N = \mu_s mg = ma_c$$

$$\Rightarrow \mu_s g = a_c = \frac{v^2}{R}$$

If the speed is doubled, the left hand side will remain the same only if the radius is quadrupled.

4

B



N2L for circular motion yields:

$$\sum F_{-\hat{r}} = ma_c$$

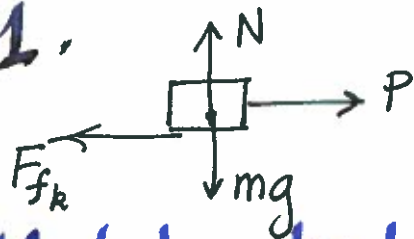
$$T - mg = m \frac{v^2}{R}$$

$$\therefore T = m \left(g + \frac{v^2}{R} \right) = (2\text{ kg}) \left(10 \frac{\text{m}}{\text{s}^2} + \frac{16 \frac{\text{m}^2}{\text{s}^2}}{1.0\text{ m}} \right)$$

$$= \underline{\underline{52\text{ N}}}$$

E

11.



$$\sum F_y = 0 \Rightarrow N = mg$$

$$\sum F_x = 0 \Rightarrow P = F_{fk} = \mu_k N = \mu_k mg$$

Work done by dog team $W_{DT} = \vec{P} \cdot \vec{\Delta D} = P \Delta x \cos 0^\circ$
 $= \mu_k mg \Delta x$

Evaluating, $W_{DT} = (0.05)(5000\text{N})(1000\text{m})$
 $= (0.05)(5 \times 10^6 \text{J}) = 0.25 \times 10^6 \text{J}$
 $= \underline{\underline{2.5 \times 10^5 \text{J}}}$

B12. Method 1: Work-kinetic energy theorem:

$$W_F = Fd \cos 0^\circ = \Delta K = 0 - \frac{1}{2}mv^2 \Rightarrow F = -\frac{mv^2}{2d}$$

(minus sign because F is opposing the displacement)

Method 2: Kinematics + N2L

Use $\triangle 3$ $v_f^2 = v_0^2 + 2ad \Rightarrow 0^2 = v_0^2 + 2ad \Rightarrow a = -\frac{v_0^2}{2d}$

N2L: $F = ma = -\frac{mv_0^2}{2d}$

5Method 3: Impulse-momentum theorem + kinematics:

First, use $\triangle 4$: $x - x_0 = \frac{v_f + v_0}{2} \cdot t$

$$\Rightarrow d = \frac{0 + v_0}{2} \cdot t \Rightarrow t = \frac{2d}{v_0}$$

E

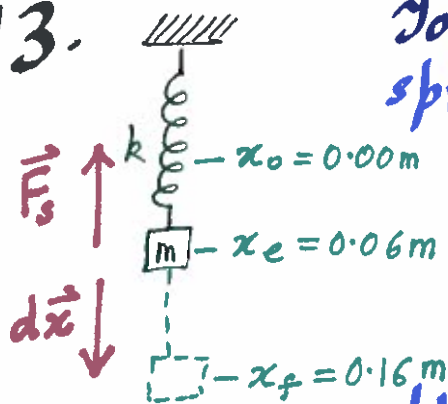
This is the time needed to stop the ball.

By impulse-momentum,

$$J = \int F dt = F_{avg} \cdot \Delta t = \Delta p = p_f - p_i$$

$$\Rightarrow F_{avg} \cdot t = 0 - mv_0 \Rightarrow F_{avg} = -\frac{mv_0}{t} = -\frac{mv_0^2}{2d}$$

13.



To find the spring constant: $k(x_e - x_0) = mg$

$$\Rightarrow k = \frac{mg}{x_e - x_0} = \frac{(2 \text{ kg})(9.8 \text{ m/s}^2)}{0.06 \text{ m} - 0.00 \text{ m}}$$

$$= 326.7 \text{ N/m}$$

$$dW_{F_s} = \vec{F}_s \cdot d\vec{x} = F_s dx \cos 180^\circ$$

$$= -kx dx$$

$$\therefore W_{F_s} = -k \int_{x_e}^{x_f} x dx = -\frac{1}{2} k (x_f^2 - x_e^2)$$

$$= -\frac{1}{2} (326.7 \frac{\text{N}}{\text{m}}) \left((0.16 \text{ m})^2 - (0.06 \text{ m})^2 \right)$$

$$= -\frac{1}{2} (326.7 \text{ Nm}) (0.0256 - 0.0036)$$

$$= -3.5937 \text{ J} \approx \underline{\underline{-3.6 \text{ J}}}$$

Important Note:

There's an easy way to mess up this calculation and that is to say

$$W_{F_s} = -\frac{1}{2} k \Delta x^2$$

$$= -\frac{1}{2} k (x_f - x_e)^2$$

$$= -\frac{1}{2} (326.7 \text{ Nm}) (0.10 \text{ m})^2$$

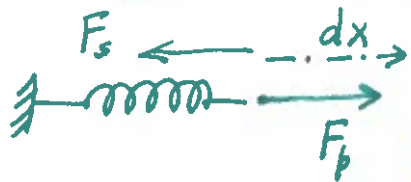
$$= -1.63 \text{ J}$$

Fortunately, it is not one of the incorrect answers, so this work, if you did it this way, won't impact you.

Why is this incorrect? This way of calculating work only works if the spring is initially uncompressed. That's not the case for a vertically hung spring with weight attached, as it already possesses equilibrium potential energy.

6

14. Work done by person $W_{F_p} = \int F_p dx \cos 0^\circ$



Now, by the work-kinetic energy theorem,

$$\sum W_{\text{net}} = W_{F_s} + W_{F_p} = \Delta K = 0$$

since the spring is at rest initially and finally (this is true for massive springs as well, such as the phosphor-bronze tapered springs we used in Lab II, in-class option).

$$\therefore W_{F_p} = -W_{F_s} = -\int_{x=0}^{x=L} F_s dx \cos 180^\circ \quad (\text{since } F_s \text{ \& } dx \text{ are opposed})$$

E

$$= \int_0^L Ax dx = \underline{\underline{\frac{1}{2} AL^2}}$$

7

15. A: A conservative force's work is the negative change in the Potential energy associated with it:

$$W_F = -\Delta U = -(U_f - U_i)$$



For a closed path, $i = f$, so $W_F \equiv 0$.



(Note the particle can move any integer number of times around, the work would still be zero.)

B: The work-kinetic energy theorem is true of any force be it conservative or not conservative.

C: Any force obeys Newton's 2nd law, cons. or non-cons.

D: Any pair of action and reaction forces together will satisfy N3L, cons. or non-cons.

E: Friction is NOT the only non-conservative force, so this would be a logically weak answer... there are many more non-conservative forces that a conservative force is not a member of that large set.

16. The relationship between a conservative force and its change in potential energy is

$$\Delta U = -W_F = -\int_{x_i}^{x_f} \vec{F} \cdot d\vec{r}$$

$$\therefore U_f - U_i = -\int_0^x F(x) dx \cos 0^\circ$$

$$U(x) - U(0) = -\int_0^x 8x^3 dx = -\frac{8}{4} x^4 \Big|_0^x$$

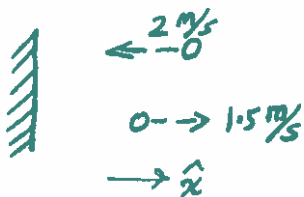
$$\therefore U(x) = U(0) - 2x^4$$

We are given that $U(0) = 0$. Therefore, $U(x) = \underline{\underline{-2x^4}}$. B

17. (i) $\vec{p} = m\vec{v}$, so $[p] = [m][v] = \text{kg} \frac{\text{m}}{\text{s}} = \text{kg} \frac{\text{m}}{\text{s}^2} \cdot \text{s} = \underline{\underline{\text{N} \cdot \text{s}}}$

(ii) $\vec{F} = \frac{d\vec{p}}{dt}$, so $[p] = [F][dt] = \underline{\underline{\text{N} \cdot \text{s}}}$. C

18.



C

$$\Delta \vec{p} = \vec{p}_f - \vec{p}_i$$

$$= m(\vec{v}_f - \vec{v}_i)$$

$$= (1.0 \text{ kg})(+1.5 \text{ m/s} - (-2.0 \text{ m/s})) \hat{i}$$

$$= \underline{\underline{3.5 \text{ N} \cdot \text{s} \hat{i}}} \quad (\hat{i} : \text{away from wall})$$

D

19. Using the impulse-momentum theorem,

$$\vec{J}_y = \Delta \vec{p}_y = m(\vec{v}_{fy} - \vec{v}_{iy})$$

$$= m(v_0 - (-v_0)) \hat{j}$$

$$= 2mv_0 \hat{j}$$



E

But $\vec{J}_y = \vec{F}_{y, \text{avg}} \cdot \Delta t_{\text{coll}}$. Unless we are given the collision time (deformation of net), we cannot determine $\vec{F}_{y, \text{avg}}$.

20. A. Not true, for example an L-shaped object's COM lies outside it

B. All the mass may be represented by the COM for the purposes of finding how the body responds to external forces and torques. But the mass is not located at the COM. As an example, the COM of a ring is in its middle, which happens to be empty.

C. From $\frac{d\vec{P}_{CM}}{dt} = \vec{F}_{CM} = \vec{0}$, we can only conclude that $\vec{P}_{CM} = \text{constant}$, or the COM could be moving at a constant velocity even if the forces externally are absent.

D. While for a uniform cylinder this is true, for any generic cylinder, it need not be true. E

21. $\textcircled{4} \xrightarrow{3\text{ m/s}}$ $\textcircled{8} \begin{matrix} \vdots \\ v=0 \end{matrix}$ $\textcircled{4}\textcircled{8} \xrightarrow{v_f}$ mass \propto weight, so we can simply use weights in conservation of momentum:

$$\sum g_E \vec{P}_i = \sum g_E \vec{P}_f$$

$$\Rightarrow (4\text{ N})(3\text{ m/s}) + (8\text{ N})(0\text{ m/s}) = (12\text{ N})\vec{v}_f$$

$$\Rightarrow \vec{v}_f = \frac{(4\text{ N})(3\text{ m/s})}{(12\text{ N})} = \underline{\underline{1.0\text{ m/s}}}$$

A 9

22. In the absence of external forces (frictionless, level ice, so no \hat{x} or \hat{y} forces), momentum is conserved. Since initial momentum is zero, final momentum will also be zero.

$$m_h \cdot v_h + m_{PB} v_{PB} = 0 \Rightarrow m_h \Delta x_h + m_{PB} \Delta x_{PB} = 0$$

$$\Rightarrow \Delta x_{PB} = -\frac{m_h}{m_{PB}} \Delta x_h = -\frac{W_h}{W_{PB}} \Delta x_h = -\left(\frac{640\text{ N}}{3200\text{ N}}\right)(\Delta x_h)$$

$$\Rightarrow \Delta X_{PB} = -0.2 \Delta X_h \quad \text{---} \textcircled{1}$$

But, $\Delta X_{PB} - \Delta X_h = 20\text{m}$

$$\Rightarrow \Delta X_h = \Delta X_{PB} - 20\text{m}$$

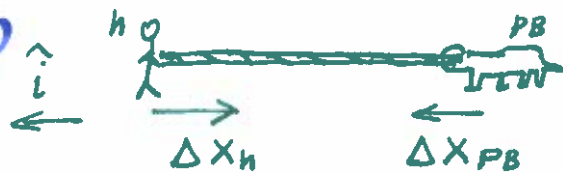
$$\textcircled{1}: \therefore \Delta X_{PB} = -0.2 \Delta X_h$$

$$= -0.2 (\Delta X_{PB} - 20\text{m})$$

$$= -0.2 \Delta X_{PB} + 4\text{m}$$

$$\Rightarrow 1.2 \Delta X_{PB} = 4\text{m}$$

$$\Rightarrow \Delta X_{PB} = \frac{4}{1.2} \text{m} = \underline{\underline{3\frac{1}{3} \text{m}}}$$



Check: We know the COM of the hunter-Polar Bear system will not move, so we must have

$$(m_h \Delta X_h = -m_{PB} \Delta X_{PB}) g_E$$

$$(640\text{N})(-16\frac{2}{3}\text{m}) = -(3200\text{N})(3\frac{1}{3}\text{m}) \quad \checkmark$$

B

10

23. The rotation kinematics eqn Δ is suitable to employ here: $\omega_f = \omega_i + \alpha t$

$$\textcircled{B} \Rightarrow \alpha = \frac{\omega_f - \omega_i}{t} = \frac{24 \text{ rad/s} - 36 \text{ rad/s}}{6.0 \text{ s}} = \underline{\underline{-2 \frac{\text{rad}}{\text{s}^2}}}$$

24. Since α is a function of time, we have to integrate:

$$\Delta \omega = \int_0^t \alpha dt \Rightarrow \omega(t) - \omega(0) = \int_0^t 6t^2 dt = \frac{6t^3}{3} = 2t^3$$

Given: $\omega(0) = 0$. So, $\omega(t) = 2t^3$.

Integrate again: $\Delta \theta = \int_0^t \omega(t) dt = \int_0^t 2t^3 dt = \frac{2t^4}{4}$

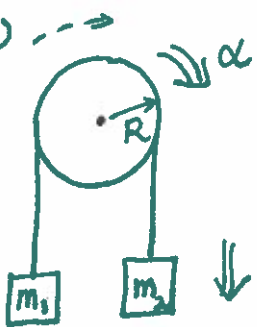
$$\Rightarrow \theta(t) - \theta(0) = \frac{t^4}{2}$$

Given: $\Delta\theta = 10 \text{ rev} = (10 \text{ rev}) \left(\frac{2\pi \text{ rad}}{1 \text{ rev}} \right) = 20\pi \text{ rad}$.

B $\therefore \frac{t_f^4}{2} = 20\pi \Rightarrow t_f^4 = 40\pi \Rightarrow t_f = (40\pi)^{1/4} \approx 3.35 \text{ s}$.

Going back to $\omega(t_f) = 2t_f^3 = 2(3.35 \text{ s})^3 \approx \underline{\underline{75.06 \text{ rad/s}}}$

25. ω α Method: Energy of the pulley will be



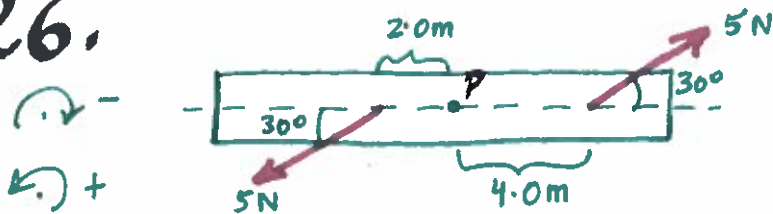
$$K_{\text{rot}} = \frac{1}{2} I \omega^2$$

Due to no-slip, we have $\omega = \frac{v}{R}$.

Substituting, $K_{\text{rot}} = \frac{1}{2} \frac{I v^2}{R^2} = \frac{1}{2} \frac{(4.5 \times 10^{-3} \text{ kg}\cdot\text{m}^2)(2.0 \text{ m/s})^2}{(0.03 \text{ m})^2}$

D $= \frac{(4.5)(4)}{2 \cdot 9 \cdot 10^{-4}} \text{ kg m}^2/\text{s}^2 = \underline{\underline{10.0 \text{ J}}}$

26.



$$\tau_P = +r_1 F_1 \sin 30^\circ + r_2 F_2 \sin 30^\circ$$

11

$$\tau_P = (2.0 \text{ m})(5 \text{ N}) \frac{1}{2} + (4.0 \text{ m})(5 \text{ N}) \frac{1}{2} = 5 \text{ N}\cdot\text{m} + 10 \text{ N}\cdot\text{m} = \underline{\underline{15 \text{ N}\cdot\text{m}}}$$

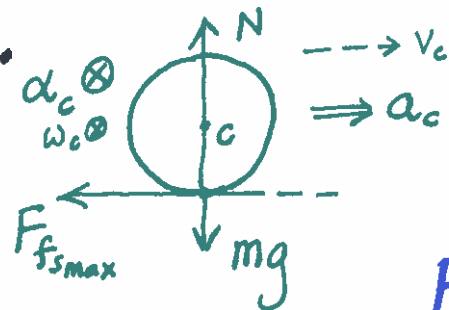
D

27. α_P F $\tau_P = I_P \alpha_P \Rightarrow \alpha_P = \frac{F \cdot R \cdot \sin 90^\circ}{I_P}$

$$\alpha_P = \frac{(8.0 \text{ N})(0.25 \text{ m})}{5.0 \text{ kg}\cdot\text{m}^2} = 0.4 \frac{\text{kg m/s}^2 \cdot \text{m}}{\text{kg m}^2} = \underline{\underline{0.4 \text{ rad/s}^2}}$$

B

28.



$$\tau_{\max c} = F_{fs\max} \cdot R \cdot \sin 90^\circ = I_c \alpha_c$$

$$\alpha_c = \frac{a_c}{R} \text{ (no-slip)}$$

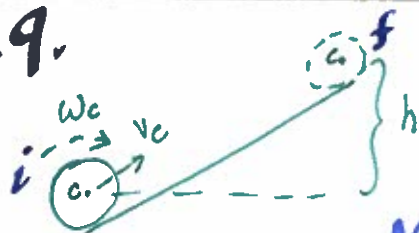
$$F_{fs\max} = \mu_s N = \mu_s mg, \quad I_c = \frac{1}{2} m R^2$$

Putting things together,
$$a_c = \alpha_c R = \frac{F_{fs\max} \cdot R^2}{I_c} = \frac{\mu_s mg \cdot R^2}{\frac{1}{2} m R^2} = 2\mu_s g$$

Substituting,
$$a_c = 2(0.4)g = \underline{\underline{0.8g}}$$

D

29.



$$K_{ti} + K_{ri} = U_{gf} \text{ (TME conserved)}$$

$$\frac{1}{2} m v_c^2 + \frac{1}{2} I_c \omega_c^2 = mgh$$

No-slip: $\omega_c = \frac{v_c}{R}$. Let $I_c = \eta m R^2$.

12

Then
$$\frac{1}{2} m v_c^2 + \frac{1}{2} \eta m R^2 \cdot \frac{v_c^2}{R^2} = mgh \Rightarrow h = \frac{v_c^2}{2g} (1 + \eta) \text{ --- } \textcircled{1}$$

It's clear from $\textcircled{1}$ that the object with the largest η goes highest for the same starting CM speed, v_c .

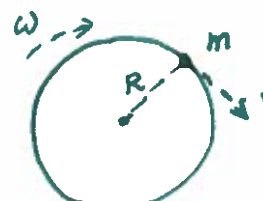
hoop: $I = m R^2 \Rightarrow \eta = 1$ disk: $I = \frac{1}{2} m R^2 \Rightarrow \eta = \frac{1}{2} = 0.5$

sphere (assuming solid) $I = \frac{2}{5} m R^2 \Rightarrow \eta = 0.4$

So the descending order of h 's: hoop, disk, sphere

A

Remark: In the exam, we will be specific about whether the uniform sphere is a solid sphere or a hollow sphere. Had the problem said hollow sphere, then the winning order of heights attained would've been different, since $\eta = \frac{2}{3} = 0.67$ for a hollow sphere!

30.  Option 1, $v = R\omega$



$$L = |\vec{r} \times \vec{p}| = R p \sin 90^\circ = m v R$$

$$= m \omega R^2$$


Option 2 $L = I\omega = mR^2\omega$.
 In either case, $L = (2.0\text{kg})(0.5\text{m})^2(12\text{rad/s}) = \underline{6\text{ J}\cdot\text{s}}$ A

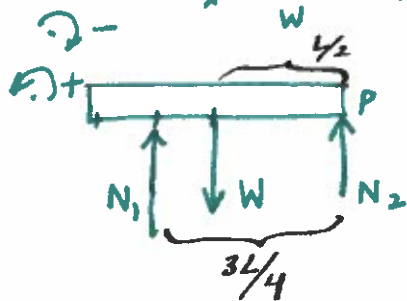
31. We have $K_{\text{rot}} = \frac{1}{2} I \omega^2 = \frac{L^2}{2I}$. Hence, since angular

momentum is conserved, $L_i = L_f$, so we have

$$\frac{K_{\text{rot}f}}{K_{\text{rot}i}} = \frac{L_f^2 / 2I_f}{L_i^2 / 2I_i} = \frac{I_i}{I_f}$$


B

The final rotational inertia is clearly greater, since mass points of the arms move away from the axis of rotation. So $I_f > I_i$, and this means $K_{\text{rot}f} < K_{\text{rot}i}$.

32.  Since $N_x + N_y = W$, and $N_x = N_y = 120\text{N}$, we conclude that plank weight $W = 240\text{N}$.



The torques about P must be zero:

$$+W \cdot \frac{L}{2} - N_1 \cdot \frac{3L}{4} = 0$$

$$\Rightarrow N_1 = W \cdot \frac{L}{2} \cdot \frac{4}{3L} = \frac{2}{3} W = \frac{2}{3} (240\text{N})$$

$$= \underline{160\text{N}}$$

But $N_2 = W - N_1$, so $N_2 = 240 - 160 = \underline{80\text{N}}$

(Note: $N_1 = F_x$ and $N_2 = F_y$ in the problem!) D

33. We have $a(t) = -\omega_{\text{SHM}}^2 x(t)$, so acceleration is proportional to the displacement. Note that if B
 $x = A \cos(\omega t + \phi)$, $v = -A\omega \sin(\omega t + \phi)$, so when displacement is maximum, velocity is actually minimum, so D is incorrect.

34. $x(t) = x_m \cos(\omega t + \phi)$

$$v(t) = \frac{dx}{dt} = -x_m \omega \sin(\omega t + \phi)$$

Given: $x(0) = 0 = x_m \cos \phi \Rightarrow \cos \phi = 0 \Rightarrow$

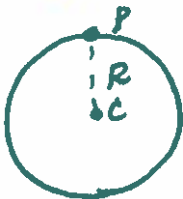
$$\phi = \frac{\pi}{2} \text{ or } \frac{3\pi}{2}$$

B

Given: $v(0) < 0 \Rightarrow \sin \phi > 0 \Rightarrow \phi = \frac{\pi}{2}$.

Remark. Had $v(0) > 0$ been the condition on the initial velocity, we would conclude $\sin \phi < 0$ and $\phi = \frac{3\pi}{2}$.

35.



The period of a physical pendulum is given by $T_{SHM} = 2\pi \sqrt{\frac{I_P}{mgd}}$. Here,

$$I_P = I_C + md^2, \quad d = R.$$

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For a ring, $I_C = mR^2$, so, $I_P = mR^2 + mR^2 = 2mR^2$.

Substituting, we find $T_{SHM} = 2\pi \sqrt{\frac{2mR^2}{mgR}} = 2\pi \sqrt{\frac{2R}{g}}$.

So the bigger the radius,

the bigger the period, and mass is irrelevant to the proper ordering of periods from least to greatest.

B

36. $y(x, t) = y_m \sin(kx + \omega t)$

Here, $k = \frac{2\pi}{\lambda}$, so $\lambda = \frac{2\pi}{k}$ is the wavelength

D

37. $y(x, t) = y_m \sin(kx - \omega t - \phi)$

Given: $y(0, 0) = 0 = y_m \sin(-\phi) \Rightarrow \sin \phi = 0 \Rightarrow$

$$\phi = 0 \text{ or } \phi = \pi$$

Given: $v_t = \left. \frac{\partial y}{\partial t} \right|_{x=0, t=0} > 0$ (transverse velocity)

But $\frac{\partial y}{\partial t} = y_m [\cos(kx - \omega t - \phi)] * (-\omega)$

$$\left. \frac{\partial y}{\partial t} \right|_{x=0, t=0} = y_m [\cos(-\phi)] * (-\omega)$$
$$= [y_m \cos \phi] * (-\omega)$$

D

Since we want this product to be positive, we must have $\cos \phi < 0 \Rightarrow \phi = \pi$ or 180° .

38. $v = f \lambda = (0.07 \text{ Hz})(300 \text{ m}) = \underline{21 \text{ m/s}}$

C

39. The speed of a wave on a stretched string with tension F_T and mass per unit length μ is $v = \sqrt{\frac{F_T}{\mu}}$. Also, $v = f \lambda$,

so $f = \frac{1}{\lambda} \sqrt{\frac{F_T}{\mu}} = \frac{1}{(0.2 \text{ m})} \sqrt{\frac{0.4 \text{ N}}{10^{-3} \text{ kg/m}}} = \frac{1}{(0.2 \text{ m})} \sqrt{400 \frac{\text{J}}{\text{kg}}}$

$$= \underline{100 \text{ Hz}}$$

C

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40. $y(x, t) = y_m \sin(kx - \omega t) \Rightarrow v_p = \omega/k$

$$v_t(x, t) = -\omega y_m \cos(kx - \omega t) \Rightarrow v_{t \max} = \omega y_m$$

Wave 1: $v_{p1} = \frac{6}{3} = 2 \text{ m/s}$, $v_{t \max 1} = 6 \frac{\text{rad}}{\text{s}} * 2 \text{ cm} = 12 \text{ cm/s}$

Wave 2: $v_{p2} = \frac{12}{4} = 3 \text{ m/s}$, $v_{t \max 2} = 12 \frac{\text{rad}}{\text{s}} * 3 \text{ cm} = 36 \text{ cm/s}$

Wave 3: $v_{p3} = \frac{11}{5} = 2.2 \text{ m/s}$, $v_{t \max 3} = 11 \frac{\text{rad}}{\text{s}} * 4 \text{ cm} = 44 \text{ cm/s}$

\therefore Wave 2 has the greatest speed of propagation, and wave 3 has the greatest max. transverse velocity.

D