Units?
Units?

Name________________________

Class Time: 10am 11am 1pm

Nov. 6, 2003

Phys 2010 — Fall 2003
Exam #2

1.	______	(6)
2.	______	(14)
3.	______	(13)
4.	______	(13)
5.	______	(14)
6.	______	(20)
MC.	______	(20)
Total	______	(100)

You must show all your work and include the right units with your answers!

$$1\,\text{in} = 2.54\,\text{cm} \qquad 1\,\text{m} = 3.281\,\text{ft} \qquad 1\,\text{mi} = 5280\,\text{ft} \qquad 1\,\text{yd} = 36\,\text{in}$$

$$g_{\text{earth}} = 9.80\,\frac{\text{m}}{\text{s}^2} \qquad G = 6.67\times10^{-11}\,\frac{\text{N}\cdot\text{m}^2}{\text{kg}^2} \qquad M_{\text{earth}} = 5.98\times10^{24}\,\text{kg}$$

$$A_x = A\cos\theta \qquad A_y = A\sin\theta \qquad A = \sqrt{A_x^2 + A_y^2} \qquad \tan\theta = (A_y/A_x)$$

$$v_x = v_{0x} + a_x t \qquad x = v_{0x}t + \tfrac{1}{2}a_x t^2 \qquad v_x^2 = v_{0x}^2 + 2a_x x \qquad x = \tfrac{1}{2}(v_{0x} + v_x)t$$

$$v_y = v_{0y} + a_y t \qquad y = v_{0y}t + \tfrac{1}{2}a_y t^2 \qquad v_y^2 = v_{0y}^2 + 2a_y y \qquad y = \tfrac{1}{2}(v_{0y} + v_y)t$$

$$\mathbf{F} = m\mathbf{a} \qquad f_k = \mu_k F_N \qquad f_s^{\text{MAX}} = \mu_s F_N \qquad F = G\frac{m_1 m_2}{r^2} \qquad g = G\frac{M}{R^2}$$

$$a_c = \frac{v^2}{r} \qquad F_c = \frac{mv^2}{r} \qquad C = 2\pi r$$

$$W = Fs\cos\theta \qquad \text{KE} = \tfrac{1}{2}mv^2 \qquad W_{\text{tot}} = \Delta\text{KE} \qquad \text{PE}_{\text{grav}} = mgy \qquad \text{PE}_{\text{spr}} = \tfrac{1}{2}kx^2$$

$$P = \frac{W}{t} \qquad P = Fv \qquad \mathbf{p} = m\mathbf{v} \qquad \overline{\mathbf{F}} = \frac{\Delta\mathbf{p}}{\Delta t}$$

$$s = \theta r \qquad \omega = \omega_0 + \alpha t \qquad \theta = \omega_0 t + \tfrac{1}{2}\alpha t^2 \qquad \omega^2 = \omega_0^2 + 2\alpha\theta \qquad \theta = \tfrac{1}{2}(\omega_0 + \omega)t$$

$$\omega = \frac{2\pi}{T} = 2\pi f \qquad v = \omega r \qquad a_T = \alpha r \qquad a_c = \omega^2 r \qquad \tau = I\alpha \qquad \tau = Fr\sin\phi$$

$$I_{\text{cyl}} = \tfrac{1}{2}MR^2 \qquad I_{\text{sphere}} = \tfrac{2}{5}MR^2 \qquad I_{\text{rod, mid}} = \tfrac{1}{12}ML^2 \qquad I_{\text{rod, end}} = \tfrac{1}{3}ML^2$$

$$\text{KE}_{\text{rot}} = \tfrac{1}{2}I\omega^2 \qquad W = \tau\theta \qquad L = I\omega$$

$$v_{\text{cm}} = \omega R \qquad a_{\text{cm}} = \alpha R \qquad \text{KE}_{\text{roll}} = \tfrac{1}{2}mv_{\text{cm}}^2 + \tfrac{1}{2}I\omega^2 \qquad E = \tfrac{1}{2}mv_{\text{cm}}^2 + \tfrac{1}{2}I\omega^2 + mgh$$

Multiple Choice

Choose (with a circle around the letter) the best answer from among the four.

1. A joule is equal to

a) $1\ \frac{\mathrm{kg \cdot m^2}}{\mathrm{s^2}}$

b) $1\ \frac{\mathrm{kg \cdot m}}{\mathrm{s}}$

c) $1\ \frac{\mathrm{kg \cdot m^2}}{\mathrm{s^3}}$

d) $1\ \frac{\mathrm{kg^2 \cdot m}}{\mathrm{s^2}}$

2. A golf ball approaches a stationary bowling ball with momentum of $5.0\ \frac{\mathrm{kg \cdot m}}{\mathrm{s}}$. The golf ball hits the bowling ball head-on and bounces back with momentum of $4.0\ \frac{\mathrm{kg \cdot m}}{\mathrm{s}}$. What is the magnitude of the bowling ball's momentum change?

a) 0

b) $1.0\ \frac{\mathrm{kg \cdot m}}{\mathrm{s}}$

c) $4.0\ \frac{\mathrm{kg \cdot m}}{\mathrm{s}}$

d) $9.0\ \frac{\mathrm{kg \cdot m}}{\mathrm{s}}$

3. When a mass slides on a rough surface, the work done by friction

a) Is always negative.

b) Is always zero.

c) Is always positive.

d) Can be negative, positive or zero.

4. Springs A and B have the same force constant but spring B is compressed by twice the distance of spring A. The potential energy stored in spring B is

a) The same as that of spring A.

b) Twice that of spring A.

c) Four times that of spring A.

d) None of the above.

5. If we convert $78 \frac{\mathrm{rev}}{\mathrm{min}}$ to $\frac{\mathrm{rad}}{\mathrm{s}}$, the answer is closest to

a) $8.0\ \frac{\mathrm{rad}}{\mathrm{s}}$

b) $80\ \frac{\mathrm{rad}}{\mathrm{s}}$

c) $800\ \frac{\mathrm{rad}}{\mathrm{s}}$

d) $8000\ \frac{\mathrm{rad}}{\mathrm{s}}$

6. The angular momentum of a rotating system will be conserved when

a) There is no net external torque on the system.

b) There is no net external force on the system.

c) The moment of inertia of the system stays constant.

d) There are no friction forces operating within the system.

7. A uniform cylinder of mass M and radius R rolls without slipping on a horizontal surface. If the center of mass has speed v, the *rotational* part of the kinetic energy is

a) $\frac{1}{4}Mv^2$

b) $\frac{1}{2}Mv^2$

c) Mv^2

d) $2Mv^2$

8. The kinetic energy of a rotating object can be written in terms of its angular momentum and moment of inertia as:

a) $\frac{1}{2}LI^2$
b) $\frac{L}{I^2}$
c) $\frac{L^2}{2I}$
~~**d)**~~ $\cancel{\frac{1}{2}LI^2}$

9. A spinning ice skater pulls in her outstretched arms. Neglecting friction from the ice, what happens to her angular momentum?

a) It does not change.
b) It increases.
c) It decreases.
d) It changes, but it is impossible to tell how.

10. A spinning ice skater pulls in her outstretched arms. Neglecting friction, what happens to her rotational kinetic energy?

a) It does not change.
b) It increases.
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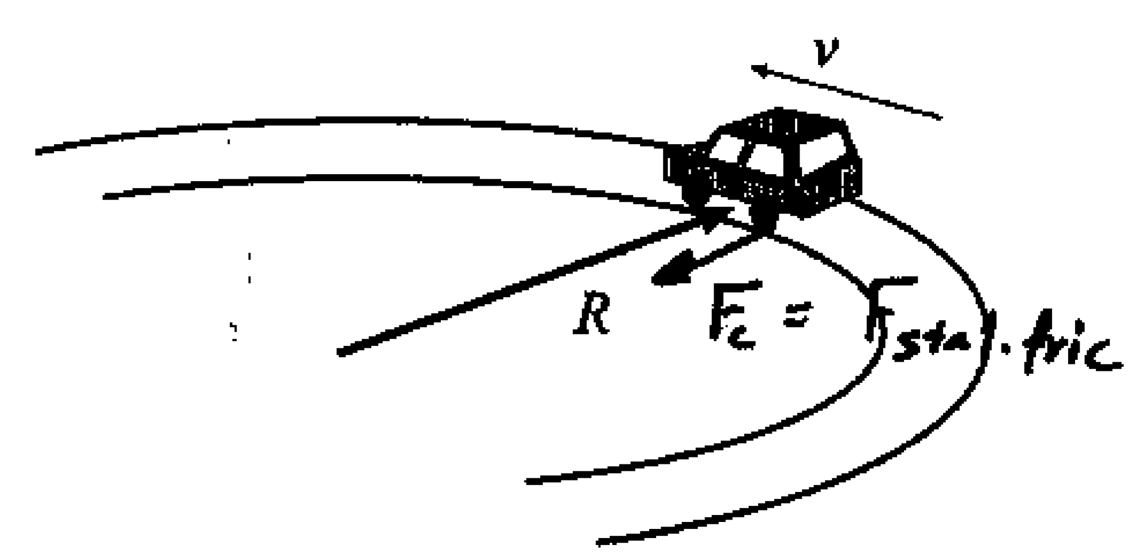
Problems

1. A 2000 kg car moves without skidding around a flat curve of radius 50.0 m at a speed of 22.0 $\frac{\mathrm{m}}{\mathrm{s}}$. It can do so because of the force of static friction from the road.

What is the magnitude *and direction* of the force of static friction on this car? (6)

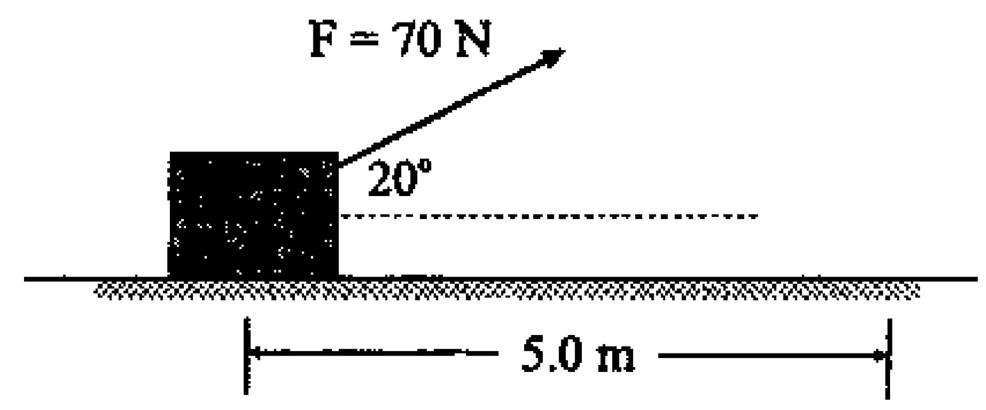


Magnitude of the force of static friction equals the centripetal force on the car,

$$F_c = \frac{mv^2}{r} = \frac{(2000\ \mathrm{kg})(22.0\ \frac{\mathrm{m}}{\mathrm{s}})^2}{(50\ \mathrm{m})} = \boxed{1.94 \times 10^4\ N}$$

and the direction of this force is $\boxed{\text{toward the center}}$ of the circle (of curvature).

2. A 15.0 kg block is dragged across a rough horizontal surface by a constant force of 70.0 N acting at an angle of 20.0° above the horizontal. The block is displaced 5.0 m. The coefficient of kinetic friction between the block and the surface is $\mu_k = 0.10$.

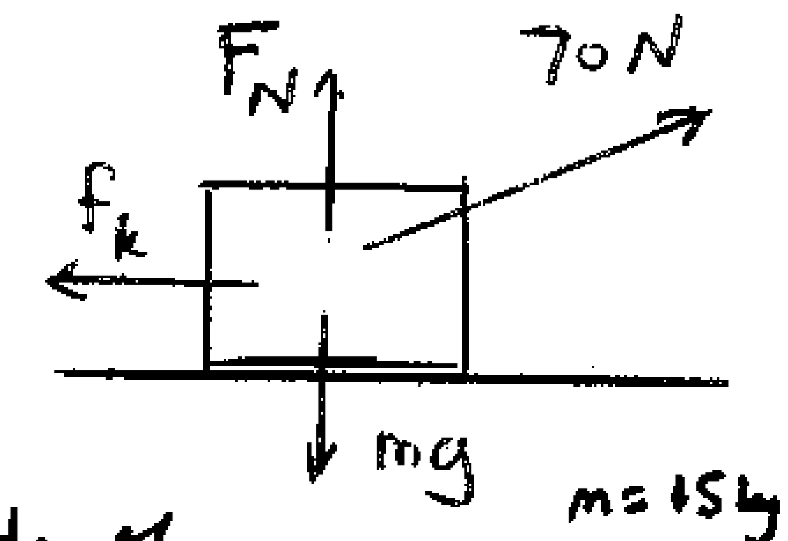


a) Find the work done by the 70.0 N force. (3)

The 70 N force pulls at 20° from the direction of motion so the work done is

$$W = Fs\cos\theta = (70.0\,N)(5.0\,m)\cos 20° = \boxed{329\,J}$$

b) Find the work done by the frictional force. (3)



First find normal force from the surface. Sum of vertical forces is zero:

$$F_N + (70\,N)\sin 20° - (15\,kg)(9.8\,\tfrac{m}{s^2}) = 0$$

Solving for F_N gives $F_N = 123\,N$. Then the magnitude of the friction force is $f_k = \mu_k F_N = (0.10)(123\,N) = 12.3\,N$

Friction points opposite the motion so the work done is

$$W = Fs\cos(180°) = (12.3\,N)(5.0\,m)(-1) = \boxed{-61.5\,J}$$

c) Find the net work done on the block. (3)

Note, the forces of gravity & the normal force but they are perp to the displacement & do no work. So the net work is the sum of (a) and (b),

$$W_{net} = 329\,J - 61.5\,J = \boxed{268\,J}$$

d) Find the velocity of the block after it moved 5.0 m. (5)

Since the block starts from rest,

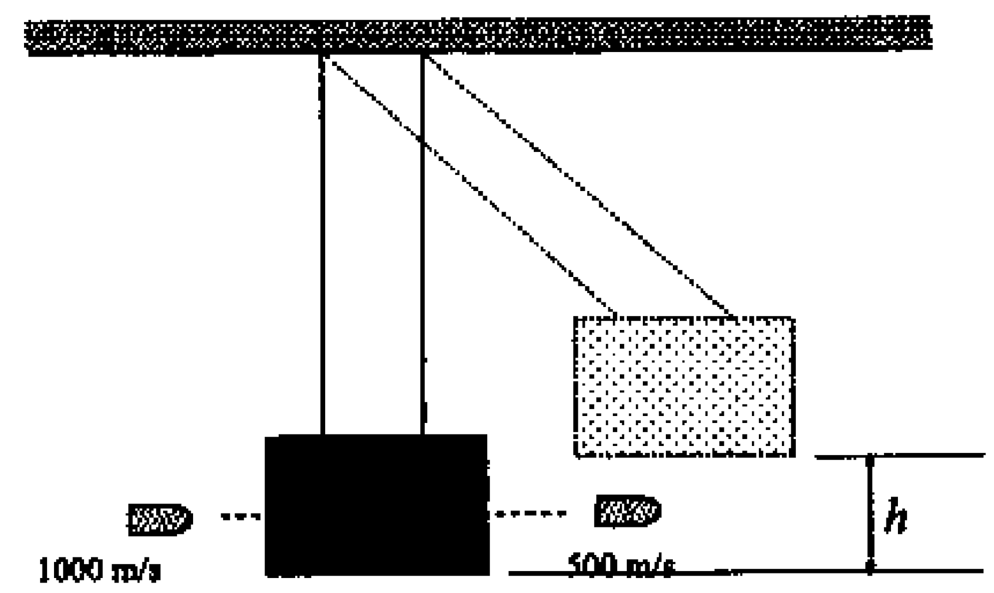
$$W_{net} = \Delta KE = KE_f - KE_o = KE_f = \tfrac{1}{2} m v_f^2$$

Solve for v_f:

$$v_f^2 = \frac{2(\Delta KE)}{m} = \frac{2(268\,J)}{(15\,kg)} = 35.7\,\tfrac{m^2}{s^2}$$

$$v_f = \boxed{5.97\,\tfrac{m}{s}}$$

3. A 0.025 kg bullet traveling at $1000\,\frac{\text{m}}{\text{s}}$ hits a 1.60 kg block which is at rest and passes through it, leaving the block with a speed of $500\,\frac{\text{m}}{\text{s}}$.



a) Using conservation of momentum, find the speed of the block immediately after the bullet hits it. (7)

Let V be speed of block just after collision (when bullet has passed thru). This gives:

$$(0.025\,\text{kg})(1000\,\tfrac{\text{m}}{\text{s}}) = (0.025\,\text{kg})(500\,\tfrac{\text{m}}{\text{s}}) + (1.60\,\text{kg})\,V$$

Solve for V, get:

$$V = \boxed{7.81\,\tfrac{\text{m}}{\text{s}}}$$

b) The block swings upward, coming to rest at a height h above its original position. What is the value of h ? (6)

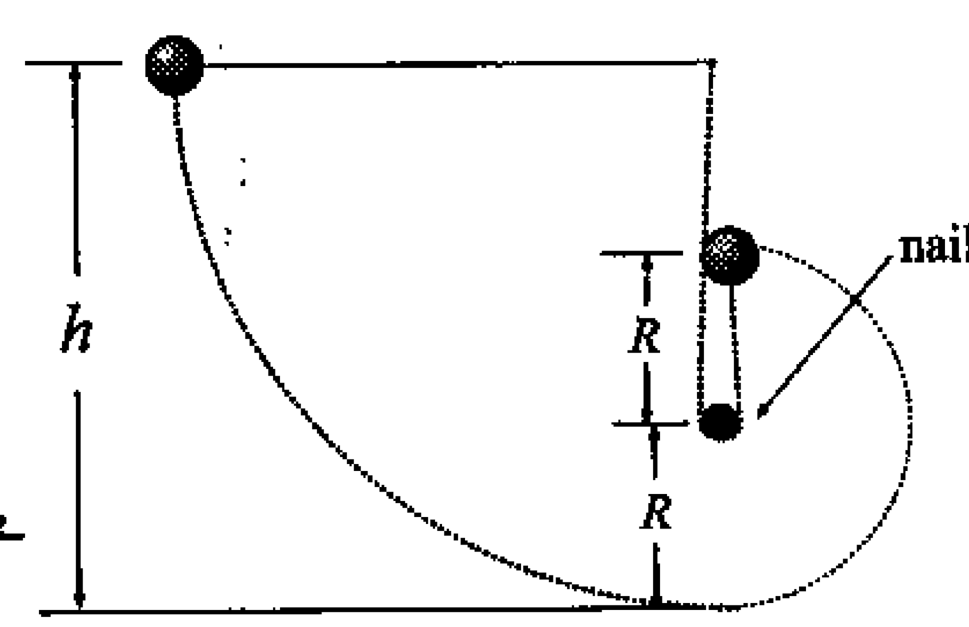
Energy is conserved while the block is swinging up. Then $E_0 = E_f$ gives us:

$$\tfrac{1}{2}(1.60\,\text{kg})V^2 = (1.60)\,g\,h$$

Cancel (1.60 kg) and solve for h:

$$h = \frac{V^2}{2g} = \frac{(7.81\,\frac{\text{m}}{\text{s}})^2}{2(9.8\,\frac{\text{m}}{\text{s}^2})} = \boxed{3.11\text{ m}} \qquad (!)$$

4. A ball is attached to a string and released from rest at a height of 0.82 m. The string hits a nail which causes the ball to swing in a circle of radius $R = 0.24$ m.



a) Find the speed of the ball as it swings around at the top of the circle. (As shown). (7)

Energy is conserved between the two positions shown; if v is the speed at the second position we get:

$$mgh = mg(2R) + \tfrac{1}{2}mv^2$$

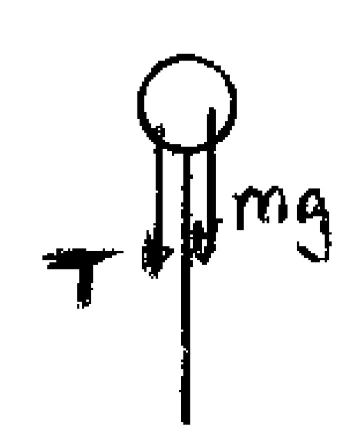
we can cancel m here. Solve for v:

$$\tfrac{1}{2}v^2 = gh - 2gR = g(h-2R) = (9.8\,\tfrac{\text{m}}{\text{s}^2})\big(0.82\text{m} - 2(0.24\text{m})\big) = 3.33\,\tfrac{\text{m}^2}{\text{s}^2}$$

$$\rightarrow \quad v^2 = 6.66\,\tfrac{\text{m}^2}{\text{s}^2} \qquad v = \boxed{2.58\,\tfrac{\text{m}}{\text{s}}}$$

b) What is the minimum speed the ball would need at the highest point to keep the string tight? (6)

Generally at the highest point the centripetal force is from gravity and the string tension:



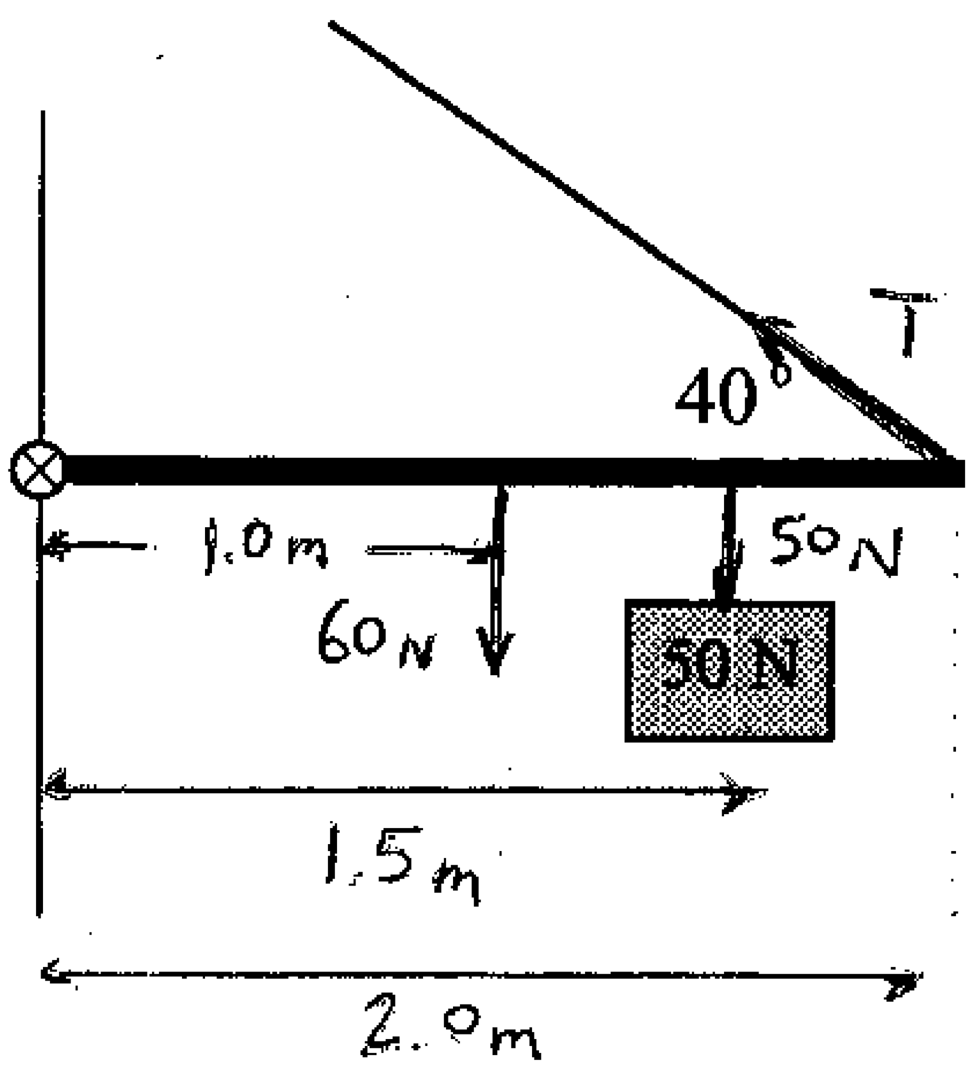
$$F_c = \frac{mv^2}{R} = mg + T$$

but at the value of v where the string is "barely" tight, $T = 0$ and so

$$\frac{mv^2}{R} = mg \quad \rightarrow \quad \frac{v^2}{R} = g \quad \rightarrow \quad v = \sqrt{Rg}$$

So $$v = \sqrt{(0.24\text{m})(9.8\,\tfrac{\text{m}}{\text{s}^2})} = \sqrt{2.35\,\tfrac{\text{m}^2}{\text{s}^2}} = \boxed{1.53\,\tfrac{\text{m}}{\text{s}}}$$

5. A 60.0 N beam of length 2.00 m is pivoted at one end and is supported at the other by a cable which makes an angle of 40.0° with the horizontal. A 50.0 N weight hangs from the beam at a distance of 1.50 m from the pivot.



a) What is the tension in the cable? (8)

Forces on the rod and appl points are as shown. Total torque on beam is zero. This gives:

$$-(60\,N)(1.0m) - (50N)(1.50m) + T\,(2.0m)\sin 40^\circ = 0$$

Solve for T.

Get: $T\,(2.0m)\sin 40^\circ = 135\ N\cdot m$

$\rightarrow \quad T = \boxed{105\ N}$

b) If the cable breaks when its tension exceeds 120 N, what is the largest weight we could hang in place of the 50.0 N weight (at the same place)? (6)

So now set $T = 120\ N$ (breaking point) and let hanging mass have unknown weight W. Now the condition of zero torque gives:

$$-(60N)(1.0m) - W(1.50m) + (120N)(2.0m)\sin 40^\circ = 0$$

Solve for W: $\quad W(1.50m) = 94.3\ N\cdot m \quad \rightarrow \quad W = \boxed{62.8\ N}$

6. A ceiling fan is turned on and a net torque of $20.0\,N\cdot m$ is applied to the blades. It starts from rest and in 2.00 s is turning at a rate of $25.0\,\frac{rad}{s}$.

a) What is the angular acceleration of the fan? (4)

Use $\alpha = \frac{\omega - \omega_0}{t}$. Get:

$$\alpha = \frac{(25.0\,\frac{rad}{s} - 0)}{(2.00s)} = \boxed{12.5\ rad/s^2}$$

b) What is the moment of inertia of the fan? (5)

Use $\tau = I\alpha$. Then:

$$I = \tau/\alpha = \frac{20.0\ N\cdot m}{12.5\ rad/s^2} = \boxed{1.60\ kg\cdot m^2}$$

c) How many revolutions did the fan make in the 2.00 s? (6)

Use $\theta = \frac{1}{2}(\omega_0 + \omega)\,t$. Then:

$$\theta = \tfrac{1}{2}(0 + 25.0\,\tfrac{rad}{s})(2.00s) = 25.0\ rad$$

Convert to revs:

$$(25.0\ rad)\left(\frac{1\ rev}{2\pi\ rad}\right) = \boxed{3.98\ rev}$$

d) What is the final kinetic energy of the fan? (5)

Use $KE = \frac{1}{2}I\omega^2$. Then:

$$KE_f = \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}(1.60\ kg\cdot m^2)(25.0\,\tfrac{rad}{s})^2 = \boxed{500\ J}$$