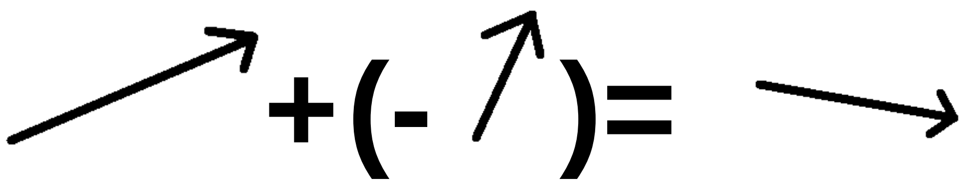
WYSE – Academic Challenge
Physics Solutions (Sectional) – 2019

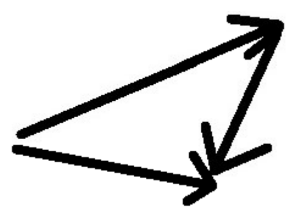
1. **Correct Response: E**

$$\mathbf{31}\boldsymbol{days} \times \frac{\mathbf{24}\boldsymbol{hr}}{\mathbf{1}\boldsymbol{day}} \times \frac{\mathbf{60}\boldsymbol{min}}{\mathbf{1}\boldsymbol{hr}} \times \frac{\mathbf{60}\boldsymbol{s}}{\mathbf{1}\boldsymbol{min}} \times \frac{\mathbf{1000}\boldsymbol{ms}}{\mathbf{1}\boldsymbol{s}} = \mathbf{2.68} \times \mathbf{10^9}\boldsymbol{ms}$$

2. **Correct Response: A**



OR



3. **Correct Response: B**

$$y = h - \frac{1}{2}gt^2$$

$$t = \sqrt{\frac{2h}{g}} = 3.44s$$

4. **Correct Response: D**

$$y = h - \frac{1}{2}gt^2$$

$$2.45m = 58.2m - \frac{1}{2}gt^2$$

$$t = 3.37s$$

$$v = v_o - gt = 0.00 - 9.81 \times 3.37 = -33.1m/s$$

Speed is the magnitude of the velocity so 33.1m/s

5. **Correct Response: E**

$$t_s = \frac{d_s}{v_s} = \frac{5.25m}{2.78m/s} = 1.8885s$$

$$v_D = \frac{x_D}{t} = \frac{9.68m}{1.8885s} = 5.13m/s$$

6. **Correct Response: D**

   The wheels are not sliding on the surface of the road so the coefficient of static friction is used. The normal force is just the weight of the vehicle. This creates a frictional force that causes the vehicle to travel in a circular path of radius 45.2m.

$$\frac{mv^2}{R} = \mu_s mg$$

$$v = \sqrt{\mu_s gR} = 19.2m/s$$

7. **Correct Response: D**

$$KE = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$$

For a cylinder the moment of inertia is $I = \frac{1}{2}mr^2$ and we know that to roll without slipping means that $\omega = \frac{v}{r}$ so plugging in we get:

$$KE = \frac{1}{2}mv^2 + \frac{1}{2}\frac{1}{2}mr^2\left(\frac{v}{r}\right)^2 = \frac{1}{2}mv^2 + \frac{1}{4}mv^2 = \frac{3}{4}mv^2 = 8.56J$$

8. **Correct Response: D**

$$PE_o + KE_o = PE_f + KE_f$$

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

   The total height that the jumper dropped was 75.0-11.2=63.8m and that goes in as mgh but the stretching doesn't start until the jumper reaches the end of the 25 m bungee cord. Thus x=(63.8m-25m) Solving for k gives $k = \frac{2\times 62.1kg \times 9.8\frac{m}{s^2}\times 63.8m}{(38.8m)^2} = 51.6\frac{N}{m}$.

9. **Correct Response: C**

   Kinematic equation: $x = x_0 + v_{0x}t + (1/2)a_x t^2$
   Position vs. time: $x = (1.00\text{ m}) + (3.00\text{ m/s})t - (2.00\text{ m/s}^2)t^2$

   By comparing the above two equations, one can see that
   $(1/2)a_x = -2.00\text{ m/s}^2$, $a_x = -4.00\text{ m/s}^2$.

   Also, one can see that $v_{0x} = 3.00$ m/s.

10. Correct Response: A

Kinematic equation: $v_x = v_{0x} + a_x t$

At t = 1.00 s, v_x = (3.00 m/s) + (– 4.00 m/s^2)(1.00 s) = – 1.00 m/s.

11. Correct Response: C

The energy released in the jump is equal to the kinetic energy of the grasshopper after launch.

$$E = \frac{1}{2}mv^2 = 0.00375J$$

Since the force is constant the acceleration must also be constant and we can find the acceleration from the initial velocity, the final velocity, and the distance of the acceleration.

$$v = \sqrt{{v_o}^2 + 2ax}$$

$$a = \frac{v^2}{2x} = 268\frac{m}{s^2}$$

And from this we get the time $v = v_o + at$ which can be solved for t to get

$$t = \frac{v}{a} = \frac{2.66}{268} = 0.00993s$$

And power is simply the energy divided by the time:

$$P = \frac{E}{t} = \frac{0.00375J}{0.00993s} = 0.378W$$

12. Correct Response: D

Kepler's third law gives us:

$$T = \left(\frac{4\pi^2}{GM}\right)^{1/2} R^{3/2} = \left[\frac{4\pi^2}{6.67 \times 10^{-11} \times 7.36 \times 10^{22}}\right]^{1/2} (1.74 \times 10^6 + 60000)^{3/2} = 6848s$$

And 6848 s converts to 1 hr 54 min.

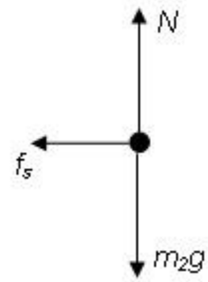
13. Correct Response: A

The two blocks are at rest relative to each other (even though they are on the verge of sliding relative to each other) and thus have the same acceleration. Since the surface is frictionless, the net force acting on the two-block system has a magnitude *F* and is directed to the left. Apply Newton's Second Law in the horizontal direction:

$F = (m_1 + m_2)a \Rightarrow a = F/(m_1 + m_2)$ = 10.0 N/(3.00 kg + 2.00 kg) = 2.00 m/s^2

14. Correct Response: B

Free-body diagram for block m_2 at the top:



In the horizontal direction, let's choose the positive direction to be directed to the left. Apply Newton's Second Law in the horizontal direction:

$f_s = m_2a$

Since the two blocks are on the verge of sliding relative to each other, $f_s = f_{s,\,max} = \mu_s N$. In the vertical direction, the block does not have any acceleration, and thus, $N = m_2g$.

So, $\mu_s m_2 g = m_2 a$ ➔ $\mu_s = a/g = (2.00\ m/s^2)/(9.80\ m/s^2) = 0.204$

15. Correct Response: C

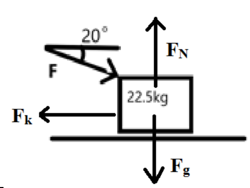
The acceleration can be found from the equation:

$$v = \sqrt{{v_o}^2 + 2ax}$$

$$a = \frac{v^2 - {v_o}^2}{2x} = -1.122$$

Force is just mass (950kg) times acceleration or -1066N rounds to -1070N.

16. Correct Response: A



We start with the force diagram for the system**.**

From the force diagram we can write: $F_N - F_g - Fsin20 = 0$ so that $F_N = F_g + Fsin20$

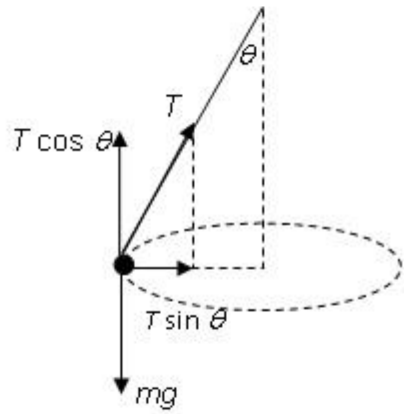
We can also see from the force diagram that $Fcos20 - F_K = ma$ We know that kinetic friction depends on the normal force through $F_K = \mu_K F_N$ Finally with the mass known so that $F_g = mg$ we can substitute and see that:

$$Fcos20 - \mu_K mg - \mu_K Fsin20 = ma$$

Which we can solve for the acceleration because we are given F, m, and μ_K. After plugging in we get $a = 0.444 \frac{m}{s^2}$.

17. Correct Response: E

Free-body diagram:



First, resolve tension T onto the radial direction and the vertical direction perpendicular to the horizontal plane. In the vertical direction, the object does not have any acceleration, and thus $T \cos \theta = mg \Rightarrow T = mg/\cos \theta$.

Apply Newton's Second Law in the radial direction:

$T \sin \theta = mv^2/r \Rightarrow (mg/\cos \theta) \sin \theta = mv^2/r$, where $r = L \sin \theta$

Solving for v, we have $v = (Lg \sin \theta \tan \theta)^{1/2}$

18. Correct Response: A

$C = FA/v$, where $[F] = [M][L][T]^{-2}$, $[A] = [L]^2$, and $[v] = [L][T]^{-1}$.

So, $[C] = [M][L]^2[T]^{-1}$.

19. Correct Response: D

$W_f = \Delta K + \Delta U$
$= (1/2)(1.00 \text{ kg})(5.00 \text{ m/s})^2 + (1.00 \text{ kg})(9.80 \text{ m/s}^2)(1.00 \text{ m} - 5.00 \text{ m})$
$= -26.7 \text{ J}$

20. Correct Response: C

Apply Conservation of Momentum in the horizontal direction:
$mv = (M + m)v' \Rightarrow v' = mv/(M + m)$

21. Correct Response: B

The collision between the bullet and the block is completely inelastic. Apply Conservation of Momentum to find the speed v' of the block and bullet after the collision: $mv = (M + m)v' \Rightarrow v' = mv/(M + m) = (0.200\text{ kg})(5.00\text{ m/s})/(0.500\text{ kg} + 0.200\text{ kg}) = 1.43$ m/s.

Suppose the block (with the bullet inside) moves a distance d before coming to a stop. Apply Work-Energy Theorem: $W_{\text{total}} = \Delta K$

$-f_k d = 0 - (1/2)(M + m)v'^2$, where $f_k = \mu_k N = \mu_k(M + m)g$

$-\mu_k(M + m)gd = -(1/2)(M + m)v'^2$

$d = v'^2/(2\mu_k g) = (1.43\text{ m/s})^2/[2(0.400)(9.80\text{ m/s}^2)] = 0.261$ m

22. Correct Response: A

Definition of the magnitude of torque: $\tau = Fr_\perp$, where $r_\perp$ is the level arm and $r_\perp = R \sin\theta$. So, $\tau = FR \sin\theta$.

23. Correct Response: B

Conditions for static equilibrium: Both the total force and total torque acting on the object must be zero.

24. Correct Response: C

According to Archimedes' Principle, the buoyant force F_b is given by $F_b = \rho g V$, where ρ is the density of the fluid and V is the volume of the fluid displaced by the object.

25. Correct Response: E

Choose the lower left end of the board as the axis of rotation. Apply one of the conditions for static equilibrium: $\sum\tau = 0$

$T(1.50\text{ m}) \sin 60.0° - (250\text{ N})(1.00\text{ m}) \cos 60.0° = 0 \Rightarrow T = 96.2$ N

26. Correct Response: C

The torque is given by $\tau = RT = I\alpha$

A force diagram for the weight shows $mg - T = ma$

Plugging these two together and realizing the definitions $\alpha = \frac{a}{R}$ and $I = \frac{1}{2}MR^2$ for a disk we get

$$mg - \frac{1}{2}mR^2\frac{a}{R^2} = ma$$

Solving for a gives $a = \frac{2}{3}g$

27. Correct Response: C

For uniform circular motion we have $a = \frac{v^2}{r}$ so that $v = \sqrt{ar} = \sqrt{\left(6.0 \times 10^5 \frac{m}{s^2}\right) 0.2m} = 346.4\frac{m}{s}$

Now we can calculate the angular velocity from this $\omega = \frac{v}{r} = \frac{346.4\frac{m}{s}}{0.2m} = 1732\frac{rad}{s}$

28. Correct Response: A

Apply $PV = nRT$:

Here, V and n are constant. So, $P_1/P_2 = T_1/T_2$ ➔ $P_2 = P_1(T_2/T_1)$ = (1.63 atm)(873 K/523 K) = 2.72 atm.

29. Correct Response: C

According to the First Law of Thermodynamics, $\Delta U = Q - W$.
Here, $W = P\Delta V$.
$Q = \Delta U + W = 8.00 \times 10^5$ J + $(3.00 \times 10^5$ Pa$)(5.00$ m$^3 - 3.00$ m$^3) = 14.00 \times 10^5$ J

30. Correct Response: B

For a pipe with both ends open, the resonant frequencies are:
$f_n = nv/(2L)$, $n = 1, 2, 3, \ldots$

For the lowest resonant frequency, $n = 1$, and f_1 = (344 m/s)[2(1.00 m)] = 172 Hz.

31. Correct Response: B

$|\psi|^2$ represents the probability density of finding the particle at any given point in space.

32. Correct Response: C

Minima from a single slit occur at $asin\theta = m\lambda$ here the wavelength, λ, is 5.14×10^{-7}m, the order, m, is 3, and the sine is 0.0275/1.34 or 0.020522. Solving for a above gives us 7.51×10^{-5}m which is 75.1μm.

33. Correct Response: B

The mass is converted to energy via the equation: $E = mc^2$ but we must note that .667 mg is the equivalent of .667 micro kilograms. So the mass converted to energy is 6.67×10^{-7}kg. This yields a total of 6.00×10^{10}J of energy. When 1000kg of TNT is exploded we get 4.00×10^{9}J of energy released so when 1kg of TNT is exploded we would get 4.00×10^{6}J. Dividing the number of joules of nuclear energy by the number of joules per kilogram of TNT explosion we get 1.5×10^{4}kg or 15,000kg of TNT.

34. Correct Response: B

Alessandro Volta is credited with being the first person to make a voltaic pile by layering zinc, copper, and parchment.

35. Correct Response: A

In an RC circuit the charge on a capacitor is given by the equation $Q = CV\left(1 - e^{-t/_{RC}}\right)$

When we realize that the two resistors are in series and thus their resistances just add for this circuit we know everything on the right hand side of the equation above.

$$Q = 0.00351F2.5V\left(1 - e^{-0.158s/_{185\Omega 0.00351F}}\right) = 0.00190Coulombs = 1.90mC$$