# ANSWER KEY PHYSICS 1 TEST 1

| | | | |
|---|---|---|---|
| 1. | D | 26. | D |
| 2. | D | 27. | B |
| 3. | B | 28. | A |
| 4. | A | 29. | B |
| 5. | B | 30. | A |
| 6. | C | 31. | C |
| 7. | C | 32. | D |
| 8. | C | 33. | D |
| 9. | D | 34. | D |
| 10. | A | 35. | D |
| 11. | D | 36. | D |
| 12. | A | 37. | C |
| 13. | B | 38. | A |
| 14. | C | 39. | C |
| 15. | B | 40. | A |
| 16. | D | 41. | A |
| 17. | B | 42. | D |
| 18. | C | 43. | B |
| 19. | D | 44. | B |
| 20. | C | 45. | C |
| 21. | A | 46. | A, C |
| 22. | C | 47. | C, D |
| 23. | D | 48. | B, C |
| 24. | A | 49. | A, C |
| 25. | D | 50. | A, D |

## SECTION II

1. (a) At its maximum height, the pellet-block system has only potential energy so the total energy can be calculated to be:

$$U = mgh = (m_{\text{pellet}} + m_{\text{block}})gh = (2\text{ kg} + 18\text{ kg}) \cdot 10\text{ m/s}^2 \cdot 0.2\text{ m} = 40\text{ J}$$

(b) After the pellet collides with the block, the pellet-block system has only kinetic energy. This kinetic energy is completely converted to potential energy when the block swings up to a height of 0.2 m. As the block had a total potential energy of 40 J when it swung up to its maximum height, the pellet-block system has a total kinetic energy of 40 J just after the collision. This allows the speed of the pellet-block system just after the collision to be calculated as:

$$K = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2K}{m}} = \sqrt{\frac{2 \cdot 40\text{ J}}{2\text{ kg} + 18\text{ kg}}} = \sqrt{\frac{80\text{ J}}{20\text{ kg}}} = \text{m/s}^2$$

(c) As the pellet becomes embedded in the block, the collision between the pellet and block is perfectly inelastic so the initial speed of the block can be calculated by using conservation of momentum:

$$m_{\text{pellet}}v_{\text{pellet}} + m_{\text{block}}v_{\text{block}} = (m_{\text{pellet}} + m_{\text{block}})\, v_{\text{final}}$$

$$2\text{ kg} \cdot v_{\text{pellet}} + 18\text{ kg} \cdot 0\text{ m/s} = (2\text{ kg} + 18\text{ kg}) \cdot 2\text{ m/s}$$

$$2\text{ kg} \cdot v_{\text{pellet}} + 0 = (2\text{ kg} + 18\text{ kg}) \cdot 2\text{ m/s}$$

$$2\text{ kg} \cdot v_{\text{pellet}} = 20\text{ kg} \cdot 2\text{ m/s}$$

$$2 \cdot v_{\text{pellet}} = 20 \cdot 2\text{ m/s}$$

$$v_{\text{pellet}} = 20\text{ m/s}$$

2. (a) The elastic potential energy of the spring turns into kinetic energy of the ball, which then becomes gravitational potential energy of the ball. Let the zero for gravitational potential energy be the initial position of the ball on the compressed spring (that is, 8 cm below ground level). Then

$$K_i + U_i = K_f + U$$

$$0 + (0 + \frac{1}{2}kx^2) = 0 + [mg(h + 0.08\text{ m}) + 0]$$

$$h = \frac{\frac{1}{2}kx^2}{mg} - 0.08\text{ m}$$

$$= \frac{\frac{1}{2}(500\text{ N/m})(0.08\text{ m})^2}{(0.15\text{ kg})(10\text{ N/kg})} - 0.08\text{ m}$$

$$= 0.99\text{ m}$$

(b) (i) Use the impulse–momentum theorem (Newton's Second Law):

$$\begin{aligned} J &= \Delta p \\ F_{avg}\Delta t &= m\Delta v \\ F_{avg} &= m\frac{\Delta v}{\Delta t} \\ &= (0.15\text{ kg})\frac{30\text{ m/s}}{0.004\text{ s}} \\ &= 1{,}100\text{ N} \end{aligned}$$

(ii) The ball is in flight until its vertical displacement is $-h$ (calling *up* the positive direction). Therefore,

$$\Delta y = v_{0y}t - \frac{1}{2}gt^2 = -\frac{1}{2}gt^2 \quad \Rightarrow \quad t = \sqrt{\frac{-2\Delta y}{g}} = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2(1.0\text{ m})}{10\text{ m/s}^2}} = 0.45\text{ s}$$

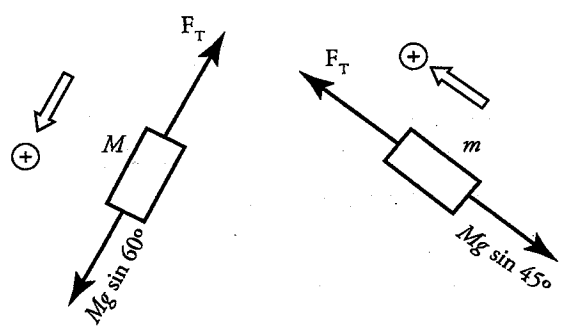
(iii) The ball's horizontal displacement is $v_{0x}t$, where $t$ is the time calculated in part (b) (ii):

$$\Delta x = v_{0x}t = \left(30\frac{\text{m}}{\text{s}}\right)(0.45\text{ s}) = 13.5\text{ m}$$

(c) The frequency of this simple harmonic oscillator is

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\pi}\sqrt{\frac{500\text{ N/m}}{0.15\text{ kg}}} = 9.2\text{ Hz}$$

3. (a) First draw a free-body diagram for the blocks:




Now, apply Newton's Second Law:

$$Mg\sin 60° - F_T = Ma$$

add equations

$$F_T - mg\sin 45° = ma$$

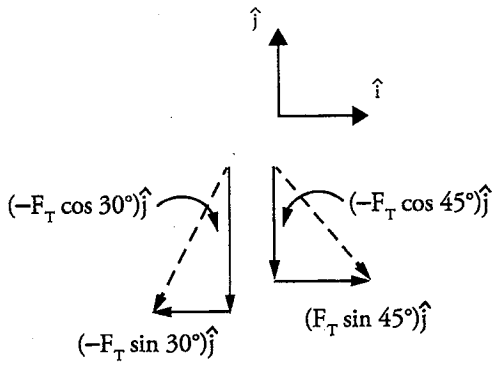
$$Mg\sin 60° - mg\sin 45° = Ma + ma$$

$$\begin{aligned} a &= \frac{M\sin 60° - m\sin 45°}{M + m}g \\ &= \frac{(8\text{ kg})\sin 60° - (2\text{ kg})\sin 45°}{8\text{ kg} + 2\text{ kg}}(10\text{ m/s}^2) \\ &= 5.5\text{ m/s}^2 \end{aligned}$$

(b) Using the value for $a$ determined above, find $F_T$; we can use either of the two original equations from part (a):

$$\begin{aligned} F_T &= mg\sin 45° + ma \\ &= (2\text{ kg})(10\text{ m/s}^2)\sin 45° + (2\text{ kg})(5.5\text{ m/s}^2) \\ &= 25.1\text{ N} \end{aligned}$$

From the following diagram,



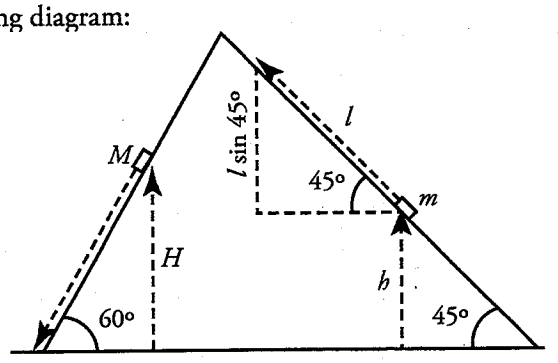

We see that the total force exerted by the cord on the peg is

$$\begin{aligned} \mathbf{F} &= [(-F_T\sin 30°)\hat{\mathbf{i}} + (F_T\sin 45°)\hat{\mathbf{i}}] + [(-F_T\cos 30°)\hat{\mathbf{j}} + (-FT\cos 45°)\hat{\mathbf{j}}] \\ &= F_T[(-\sin 30° + \sin 45°)\hat{\mathbf{i}} + (-\cos 30° - \cos 45°)\hat{\mathbf{i}}] \end{aligned}$$

So

$$\begin{aligned} F &= F_T\sqrt{(-\sin 30° + \sin 45°)^2 + (-\cos 30° - \cos 45°)^2} \\ &= (25.1\text{ N})\sqrt{2.518} \\ &= 40\text{ N} \end{aligned}$$

(c) Refer to the following diagram:




We have the constant acceleration of 5.5 m/s² from part (a), so we may use $v^2 = v_0^2 - 2a(x - x_0)$. We know that $v_0 = 0$ because it starts from rest. The distance $M$ moves is given by: $(x - x_0) = \dfrac{H}{\sin 60°}$.

$$M = \frac{1.5\text{ m}}{\left(\dfrac{\sqrt{3}}{2}\right)} = \frac{3}{\sqrt{3}}\text{ m}$$

Now we have $a$, $v_0$, and $d$, so we can solve for $v_f$ using a kinematics equation: $v_f^2 = v_0^2 + 2ad$.

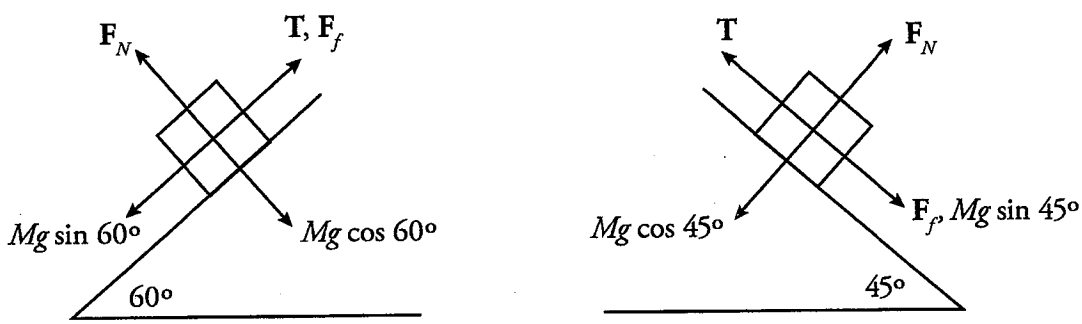
$$v_f = \sqrt{v_0^2 + 2ad}$$

$$= \sqrt{(0\ \text{m/s}^2) + 2(5.5\ \text{m/s}^2)(\sqrt{3}/3\text{m})}$$

$$= \sqrt{\frac{33}{\sqrt{3}}\ \text{m}^2/\text{s}^2}$$

$$\approx 4.4\ \text{m/s}$$

(d) Let's break the slide into two parts.




The right hand drawing is the one to focus on first. On that block, we have five forces: tension going up the ramp, friction AND a portion of the gravitational force ($mg \sin \theta$) going down the ramp, normal force directly out of the ramp, and the other portion of gravity ($mg \cos \theta$) directly into the ramp. We know that the normal force and the $mg \cos \theta$ force must be equal because the block is obviously not falling through the ramp or lifting up off it. Plugging in the numbers for that, you get that the normal force is $10\sqrt{2}$ N. Using that, we can solve for the friction force, which is the normal force times the coefficient of friction. The coefficient is given as 0.2, so:

$$0.2 \times 10\sqrt{2}\ \text{N} = 2\sqrt{2}\ \text{N}.$$

The tension on the string is the next thing we need. Well, the tension is just how hard the little block on the right pulls back on the big block on the left. So it will be equal to the sum of the "down the ramp" forces, which are friction and the $mg \sin \theta$ portion of gravity. Adding those, you get:

$$2\sqrt{2}\ \text{N} + 10\sqrt{2}\ \text{N} = 12\sqrt{2}\ \text{N}.$$

Now that we have the value of tension, we can carry this over to the block on the left. This block also has five forces. The only difference is that friction is now up the ramp rather than down because friction always opposes movement. Going through similar processes as before, we get that normal force = 40 N and friction = 8 N. Now we can get the net force, which will be:

$$mg \sin \theta - (\text{Tension} + \text{Friction Force}) = 40\sqrt{3}\ \text{N} - (12\sqrt{2}\ \text{N} + 8\ \text{N}) = 43.2\ \text{N}.$$

Finally, to solve for the acceleration, we need to use Newton's Second Law, which states $F_{net} = ma$. The trick is to remember is that our mass here is actually both blocks, so plugging in the numbers gives

$$43.2 \text{ N} = (8 \text{ kg} + 2 \text{ kg})a.$$

Rearranging, we get:

$$a = 43.2 \text{ N}/(8 \text{ kg} + 2 \text{ kg}) = 43.2 \text{ N}/(10 \text{ kg}) = 4.32 \text{ m/s}^2.$$

4. (a) The diagram given with the question shows that after the clay balls collide, they move in the $-y$ direction, which means that the horizontal components of their linear momentum cancel. In other words, $\mathbf{p}_{1x} + \mathbf{p}_{2x} = 0$:

$$m_1\mathbf{v}_{1x} + m_2\mathbf{v}_{2x} = 0$$

$$(m_1 v_1 \sin 45°)\hat{\mathbf{i}} + (m_2 v_2 \sin 60°)(-\hat{\mathbf{i}}) = 0$$

$$v_2 = \frac{m_1 v_1 \sin 45°}{m_2 \sin 60°}$$

$$= \frac{(200 \text{ g})(6.0 \text{ m/s}) \sin 45°}{(100 \text{ g}) \sin 60°}$$

$$= 9.8 \text{ m/s}$$

(b) Apply Conservation of Linear Momentum in the $y$ direction:

$$m_1\mathbf{v}_{1y} + m_2\mathbf{v}_{2y} = (m_1 + m_2)\mathbf{v}'_y$$

$$(m_1 v_1 \cos 45°)(-\hat{\mathbf{j}}) + (m_2 v_2 \cos 60°)(-\hat{\mathbf{j}}) = (m_1 + m_2)\mathbf{v}'_y$$

$$v'_y = \frac{m_1 v_1 \cos 45° + m_2 v_2 \cos 60°}{m_1 + m_2}$$

$$= \frac{(200 \text{ g})(6.0 \text{ m/s}) \cos 45° + (100 \text{ g})(9.8 \text{ m/s}) \cos 60°}{200 \text{ g} + 100 \text{ g}}$$

$$= 4.5 \text{ m/s}$$

(c) The total kinetic energy before the collision is

$$K_{i\,total} = K_1 + K_2$$

$$= \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2$$

$$= \frac{1}{2}(0.2 \text{ kg})(6.0 \text{ m/s})^2 + \frac{1}{2}(0.1 \text{ kg})(9.8 \text{ m/s})^2$$

$$= 8.4 \text{ J}$$

The total kinetic energy after the collisions is

$$K_{f\,total} = \frac{1}{2}(m_1 + m_2)v_3^2$$

In part (b) we solved the final velocity $v' = 4.5$ m/s, so

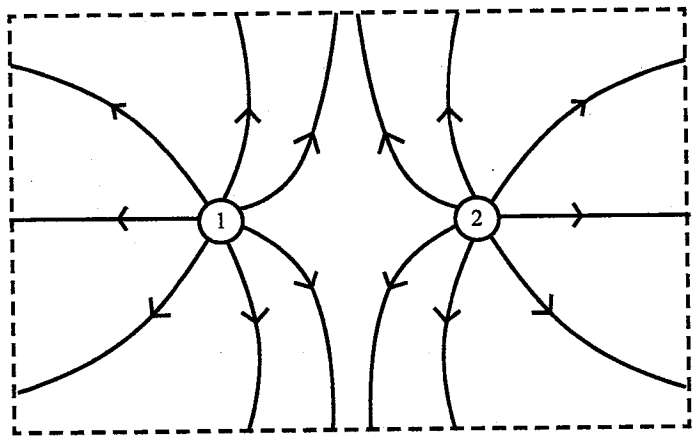
$$K_{f\,total} = \frac{1}{2}(0.2\text{ kg} + 0.1\text{ kg})(4.5)^2$$

$$= 3.0\text{ J}$$

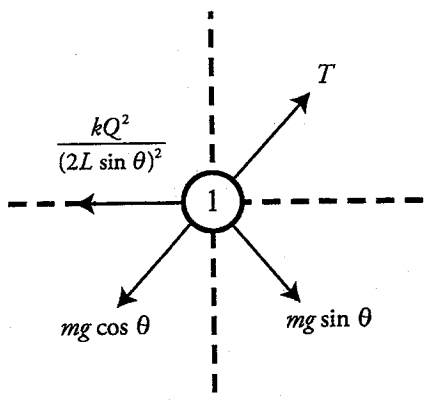
The loss in kinetic energy is calculated by subtracting the initial kinetic energy from the final kinetic energy.

$$K_{i\,total} - K_{f\,total} = 8.4\text{ J} - 3.0\text{ J} = 5.4\text{ J}$$

5. (a)




(b)




(c) Break apart the tension into its $x$- and $y$-components. For our $x$-component,

$$T_x - F_E = 0 \;=\; T\sin\theta = F_E$$

$$T\sin\theta = \frac{kQ^2}{4L^2\sin^2\theta}$$

$$T = \frac{kQ^2}{4L^2\sin^3\theta}$$