WYSE Academic Challenge
2013 Regional Physics Exam
SOLUTION SET

1. **Correct answer: D**

The statement, "no two electrons in an atom can have the same set of values for all four quantum numbers" is associated with Pauli. It is known as the Pauli Exclusion Principle.

2. **Correct answer: B**

$$V_f^2 = V_i^2 + 2a\left(x_f - x_i\right)$$
$$V_f^2 = (3.00\ \text{m/s})^2 + 2(-0.0156\ \text{m/s})(235\ \text{m} - 0\ \text{m})$$
$$V_f = 1.29\ \text{m/s}$$

3. **Correct answer: E**

$$Energy_i = Energy_f$$
$$GPE_i + KE_i = GPE_f + KE_f$$
$$45.0\ \text{J} + 83.0\ \text{J} = GPE_f + 34.0\ \text{J}$$
$$GPE_f = 94.0\ \text{J}$$

4. **Correct answer: A**

$$KE_f = \frac{1}{2} m v_f^2$$
$$m = \frac{2KE_f}{v_f^2} = \frac{2(34.0\ \text{J})}{(6.50\ \text{m/s})^2} = 1.61\frac{\text{Nm}}{\text{m}^2/\text{s}^2} = 1.61\frac{\left(\text{kg}\cdot\text{m/s}^2\right)\text{m}}{\text{m}^2/\text{s}^2} = 1.61\,\text{kg}$$

5. **Correct answer: C**

The principle known as conservation of charge is credited to Benjamin Franklin.

6. **Correct answer: B**

The electron is a member of the family known as lepton.

7. **Correct answer: B**

$$P(\text{diopters}) = \frac{1}{f\,(\text{m})}$$
$$f\,(\text{m}) = \frac{1}{P(\text{diopters})} = \frac{1}{4\ \text{diopters}} = 0.25\ \text{m} = 25.0\ \text{cm}$$

8. **Correct answer: E**

$$[I] = \frac{[P]}{[A]} = \frac{\text{W}}{\text{m}^2} = \frac{\text{J}}{\text{s}\cdot\text{m}^2} = \frac{\text{N}\cdot\text{m}}{\text{s}\cdot\text{m}^2} = \frac{\text{N}}{\text{s}\cdot\text{m}} = \frac{\text{kg}\cdot\text{m/s}^2}{\text{s}\cdot\text{m}} = \frac{\text{kg}}{\text{s}^3}$$

9. **Correct answer: D**

$$\left[\frac{R \cdot u}{M}\right] = \frac{(kg/s)(m/s)}{kg} = m/s^2$$

10. **Correct answer: A**

Let system = woman and cart.

Impulse on system in the horizontal direction = change of momentum of the system in the horizontal dirction.

$$I_{\text{system,x}} = p_{\text{f,system,x}} - p_{\text{i,system,x}}$$
$$0 = p_{\text{f,system,x}} - p_{\text{i,system,x}}$$
$$p_{\text{f,system,x}} = p_{\text{i,system,x}}$$
$$m_{\text{woman}} v_{\text{woman,f}} + m_{\text{cart}} v_{\text{cart,f}} = m_{\text{woman}} v_{\text{woman,i}} + m_{\text{cart}} v_{\text{cart,i}}$$
$$m_{\text{cart}}\left(v_{\text{cart,f}} - v_{\text{cart,i}}\right) = m_{\text{woman}}\left(v_{\text{woman,i}} - v_{\text{woman,f}}\right)$$
$$\left(v_{\text{cart,f}} - v_{\text{cart,i}}\right) = \left(m_{\text{woman}} / m_{\text{cart}}\right)\left(v_{\text{woman,i}} - v_{\text{woman,f}}\right) = (65.0\text{ kg}/29.0\text{ kg})(3.40\text{ m/s} - 0) = 7.62\text{ m/s}$$

11. **Correct answer: E**

$$\left|F_{\text{woman on cart}}\right| = \left|-F_{\text{cart on woman}}\right| =$$
$$\left|\frac{-\Delta p_{\text{woman}}}{\Delta t}\right| = \left|\frac{m_{\text{woman}}\left(v_{\text{woman,i}} - v_{\text{woman,f}}\right)}{\Delta t}\right| = \left|\frac{65.0\text{ kg}(3.40\text{ m/s} - 0)}{0.890\text{ s}}\right| = 248\text{ N}$$

12. **Correct answer: C**

$$|\tau| = rF\sin\left(\theta_{\text{r, F}}\right) = (5.40\text{ m})(0.400\text{ kg})\left(9.80\text{ m/s}^2\right)\sin\left(90.0^{\circ}\right) = 21.2\text{ Nm}$$

13. **Correct answer: D**

$$v_f^2 = v_o^2 + 2a\left(y_f - y_i\right)$$
$$v_f^2 = 0^2 + 2\left(-9.80\text{ m/s}^2\right)(0 - 11.0\text{ m})$$
$$v_f = -14.68\text{ m/s} \text{ (just before hitting ground)}$$
$$I_{\text{ground on ball}} = \Delta \boldsymbol{p}_{\text{ball}} = m_{\text{ball}}\left(v_{\text{ball,f}} - v_{\text{ball,i}}\right)$$
$$I_{\text{ground on ball}} = (0.400\text{ kg})(14.68\text{ m/s (up)} - 14.68\text{ m/s (down)})$$
$$I_{\text{ground on ball}} = (0.400\text{ kg})(29.36\text{ m/s (up)})$$
$$\left|I_{\text{ground on ball}}\right| = |11.7\text{ Ns (up)}| = 11.7\text{ Ns}$$

14. **Correct answer: E**

Using conservation of energy, with origin, y=0, at the position of maximum compression:

$$GPE_i + KE_i + EPE_i = GPE_f + KE_f + EPE_f$$
$$m \cdot g \cdot (0.35\text{ m} + \text{d}) + 0 + 0 = 0 + 0 + \frac{1}{2}(k)\,d^2$$
$$(2.5\text{ kg}) \cdot (9.80\text{ m/s}^2) \cdot (0.35\text{ m} + \text{d}) = \frac{1}{2}(1840\text{ N/m})\,d^2$$
$$d = 11.1\text{cm}$$

15. **Correct answer: C**

The time from maximum compression to equilibrium position is ¼ of the period of oscillation.

$$T = \frac{1}{4}(2\pi)\sqrt{\frac{m}{k}} = \frac{\pi}{2}\sqrt{\frac{2.5\text{ kg}}{1840\text{ N/m}}} = 0.0579\text{ s} = 57.9\text{ ms}$$

16. **Correct answer: A**

$$F = \mu_{static} N = \mu_{static} mg = (0.448)(34.5\text{kg})(9.80\text{m/s}^2) = 151\text{N}$$

17. **Correct answer: A**

$$x = -6.00t^2 + 8.00t - 4.00 = \frac{1}{2}a_x t^2 + v_{ox}t + x_o$$
$$\frac{1}{2}a_x = -6.00$$
$$a_x = -12.0$$
$$y = 4.00t^2 - 12.0t = \frac{1}{2}a_y t^2 + v_{oy}t + y_o$$
$$\frac{1}{2}a_y = 4.00$$
$$a_y = 8.00$$
$$\text{a} = \text{-}12.0\text{i} + 8.00\text{j}$$

18. **Correct answer: D**

$$x = -6.00t^2 + 8.00t - 4.00$$
$$x(0) = -6.00(0)^2 + 8.00(0) - 4.00 = -4.00$$

$$y = 4.00t^2 - 12.0t$$
$$y(0) = 4.00(0)^2 - 12.0(0) = 0.00$$

$$x(0.500) = -6.00(0.500)^2 + 8.00(0.500) - 4.00 = -1.5\text{ m}$$
$$y(0.500) = 4.00(0.500)^2 - 12.0(0.500) = -5.00\text{ m}$$

$$\Delta x = [(-1.5\text{ m}) - (-4.00\text{ m})] = 2.50\text{ m}$$
$$\Delta y = [(-5.00\text{ m}) - (0.00\text{ m})] = -5.00\text{ m}$$
$$|\text{displacement}| = \sqrt{(\Delta x)^2 + (\Delta y)^2} = 5.59\text{ m}$$

19. **Correct answer: B**

$$x_o = 45.0\text{ gal}$$
$$v_o = -0.750\text{ gal/s}$$
$$a = -0.128\text{ gal/s}^2$$
$$x = x_o + v_o t + \frac{1}{2}at^2 =$$
$$x = 45.0\text{ gal} + (-0.750\text{ gal/s})(14.0\text{ s}) + \frac{1}{2}(-0.128\text{ gal/s}^2)(14.0\text{ s})^2$$
$$x = 22.0\text{ gal}$$

20. **Correct answer: A**

Note: mass = weight / (acceleration due to gravity)
m=W/g
g cancels from the equations below, so use weight in place of mass.

$$KE_{\text{sys,f}} = 0.700 \cdot KE_{\text{sys,i}}$$
$$\frac{1}{2}\left(\frac{30.0\text{ ton} + W_{\text{flatcar}}}{g}\right)v_f^2 = 0.700 \cdot \frac{1}{2}\left(\frac{30.0\text{ ton}}{g}\right)v_i^2$$
$$\frac{(30.0\text{ ton} + W_{\text{flatcar}})}{21.0\text{ ton}} = \frac{v_i^2}{v_f^2} \quad **$$

(*continued*)

$$p_{\text{sys,f}} = p_{\text{sys,i}}$$

$$\left(\frac{30.0\text{ ton} + W_{\text{flatcar}}}{g}\right)v_f = \left(\frac{30.0\text{ ton}}{g}\right)v_i$$

$$\frac{(30.0\text{ ton} + W_{\text{flatcar}})}{(30.0\text{ ton})} = \frac{v_i}{v_f}$$

$$\frac{(30.0\text{ ton} + W_{\text{flatcar}})^2}{(30.0\text{ ton})^2} = \left(\frac{v_i}{v_f}\right)^2 = \quad **$$

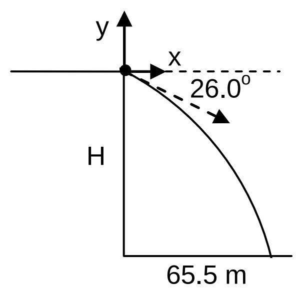
$$\frac{(30.0\text{ ton} + W_{\text{flatcar}})^2}{(30.0\text{ ton})^2} = \frac{(30.0\text{ ton} + W_{\text{flatcar}})}{21.0\text{ ton}}$$

$$900\text{ ton}^2 + 60\text{ ton}\cdot W_{\text{flatcar}} + W_{\text{flatcar}}^2 = 1286\text{ ton}^2 + 42.86\text{ ton}\cdot W_{\text{flatcar}}$$

$$-386\text{ ton}^2 + 17.14\text{ ton}\cdot W_{\text{flatcar}} + W_{\text{flatcar}}^2 = 0$$

$$W_{\text{flatcar}} = \frac{-17.14 \pm \sqrt{17.14^2 - 4\cdot 1\cdot(-386)}}{2\cdot 1}\text{ ton} = \underline{\underline{12.9\text{ ton}}},\text{ or } -30.0\text{ ton (not physical)}$$

21. **Correct answer: C**



$$x(t) = x_o + v_{ox}t + \frac{1}{2}a_x t^2$$

$$65.5\text{ m} = 0 + (38.0\text{ m/s})\cos(26.0^o)t + 0$$

$$t = 1.918\text{ s}$$

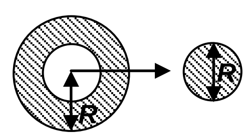
$$y(t) = y_o + v_{oy}t + \frac{1}{2}a_y t^2$$

$$-H = 0 - (38.0\text{ m/s})\sin(26.0^o)t - (4.90\text{ m/s}^2)t^2$$

$$H = (38.0\text{ m/s})\sin(26.0^o)(1.918\text{ s}) + (4.90\text{ m/s}^2)(1.918\text{ s})^2$$

$$H = 50.0\text{ m}$$

22. **Correct answer: B**



Using the conept of density:

$$\text{density} = \frac{\text{mass}}{\text{area}} = \text{constant} \qquad \text{(since uniform)}$$

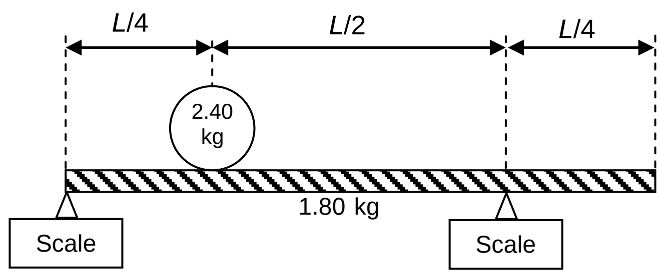
$$\rho = \frac{M}{A} = \left(\frac{M}{\pi R^2}\right) = \frac{M_{\text{cut out}}}{A_{\text{cut out}}} = \frac{M_{\text{cut out}}}{\pi\left(\frac{R}{2}\right)^2}$$

$$M_{\text{cut out}} = \left(\frac{M}{\pi R^2}\right)\pi\left(\frac{R}{2}\right)^2 = \frac{M}{4}$$

23. **Correct answer: E**

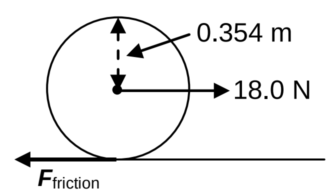
$$\sum \mathbf{F} = m \cdot \mathbf{a}$$
$$25.0\text{ N East} + \mathbf{F}_2 = (13.5\text{ kg}) \cdot (3.00\text{ m/s}^2\text{ East})$$
$$\mathbf{F}_2 = 40.5\text{ N East} - 25.0\text{ N East}$$
$$\mathbf{F}_2 = 15.5\text{ N East}$$

24. **Correct answer: D**



$$\sum \tau_{\text{left end}} = 0$$
$$(2.40\text{ kg})(9.8\text{ m/s}^2)\left(\frac{L}{4}\right)\mathbf{CW} + (1.80\text{kg})(9.8\text{ m/s}^2)\left(\frac{L}{4} + \frac{L}{4}\right)\mathbf{CW} + (F_{\text{right scale}})\left(\frac{L}{4} + \frac{L}{2}\right)\mathbf{CCW} = 0$$
$$(5.88\text{ N})(L)\mathbf{CW} + (8.82\text{ N})(L)\mathbf{CW} - (F_{\text{right scale}})(0.750L)\mathbf{CW} = 0$$
$$F_{\text{right scale}} = 19.6\text{ N}$$

25. **Correct answer: C**



$$\sum \mathbf{F} = m \cdot \mathbf{a}$$
$$18.0\text{ N }\mathbf{Right} + F_{\text{friction}}\ \mathbf{Left} = (15.0\text{ kg}) \cdot (0.564\text{ m/s}^2\ \mathbf{Right})$$
$$18.0\text{ N }\mathbf{Right} - F_{\text{friction}}\ \mathbf{Right} = (15.0\text{ kg}) \cdot (0.564\text{ m/s}^2\ \mathbf{Right})$$
$$F_{\text{friction}} = 9.54\text{ N}$$

26. **Correct answer: E**

$$v_f = v_i + at$$
$$v_f = 0 + (0.564\text{ m/s}^2)(4.50\text{ s}) = 2.54\text{ m}$$

27. **Correct answer: E**

$$\sum \mathbf{F} = m\mathbf{a}$$
$$(4.00\text{ kg})(9.80\text{ m/s}^2) - (3.00\text{ kg})(9.80\text{ m/s}^2) = (7.00\text{ kg})(a)$$
$$a = 1.40\text{ m/s}^2$$

$$\sum \mathbf{F} = m\mathbf{a}$$
$$(4.00\text{ kg})(9.80\text{ m/s}^2) - T = (4.00\text{ kg})(a)$$
$$(4.00\text{ kg})(9.80\text{ m/s}^2) - T = (4.00\text{ kg})(1.40\text{ m/s}^2)$$
$$T = 33.6\text{ N}$$

28. **Correct answer: B**

Using conservation of angular momentum:

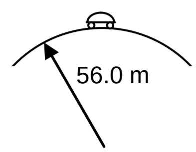
$$I_{\text{merry-go-round}}\,\omega_i = \left(I_{\text{merry-go-round}} + I_{\text{child}}\right)\omega_f$$
$$I_{\text{merry-go-round}}\,\omega_i = \left(I_{\text{merry-go-round}} + m_{\text{child}}R^2\right)\omega_f$$
$$\left(260.\text{ kg}\cdot\text{m}^2\right)\left(3.20\text{ rad/s}\right) = \left[260.\text{ kg}\cdot\text{m}^2 + (45.0\text{ kg})(1.60\text{ m})^2\right]\omega_f$$
$$2.22\text{ rad/s}$$

29. **Correct answer: A**

Using energy concepts:

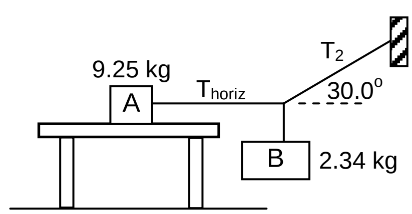
$$Work_{\text{ext}} = \Delta E_{\text{sys}}$$
$$fd\cos(\theta) = E_{\text{f, sys}} - E_{\text{i, sys}} = \left(KE_{\text{f}} + GPE_{\text{f}}\right) - \left(KE_{\text{i}} + GPE_{\text{i}}\right)$$
$$\mu Nd\cos\left(180^o\right) = (0+0) - (0 + mgh)$$
$$\mu mgd(-1) = -mgh$$
$$\mu d = h$$
$$d = \frac{(5.00\text{ m})\sin\left(30.0^o\right)}{(0.450)} = 5.56\text{ m}$$

30. **Correct answer: D**



$$\sum \mathbf{F} = m\mathbf{a}$$
$$F_{\text{car on man}}(\mathbf{up}) + Weight_{\text{man}}(\mathbf{down}) = m_{\text{man}}a_{\text{man}}(\mathbf{down})$$
$$F_{\text{car on man}}(\mathbf{up}) - m_{\text{man}}g(\mathbf{up}) = m_{\text{man}}a_{\text{man}}(-\mathbf{up})$$
$$F_{\text{car on man}} - m_{\text{man}}g = -m_{\text{man}}a_{\text{man}}$$
$$F_{\text{car on man}} = m_{\text{man}}\left(-a_{\text{man}} + g\right) = m_{\text{man}}\left(-\frac{v_{\text{man}}^2}{\text{R}} + g\right)$$
$$F_{\text{car on man}} = (64.0\text{ kg})\left(-\frac{(14.0\text{ m/s})^2}{56.0\text{ m}} + 9.8\text{ m/s}^2\right) = 403\text{ N}$$

31. **Correct answer: B**



$$T_2\sin\left(30.0^o\right) = (2.34\text{ kg})\left(9.80\text{ m/s}^2\right)$$
$$T_2 = 45.86\text{ N}$$
$$T_{\text{horiz}} = T_2\cos\left(30.0^o\right) = (45.86\text{ N})\cos\left(30.0^o\right) = 39.7\text{ N}$$

Note: The maximum frictional force between A and the table top would be:

$$f_{\text{max static}} = \mu N = \mu m_{\text{A}}g = (0.460)(9.25\text{ kg})\left(9.80\text{ m/s}^2\right) = 41.7\text{ N},$$

which is greater than T_{horiz}, so the actual frictional force on A from the table will be 39.7 N.

32. **Correct answer: A**

The frictional force on A remains the same. Doubling the mass of the block would double the maximum possible frictional force, but the actual frictional force required is still 39.7 N, the tension in the horizontal cord.

33. **Correct answer: C**

$$\omega_f^2 = \omega_i^2 + 2\alpha(\theta_f - \theta_i)$$

$$\alpha = \frac{\omega_f^2 - \omega_i^2}{2\cdot(\theta_f - \theta_i)} = \frac{0-(7.00\text{ rad/s})^2}{2\cdot(14.0\text{ rev})} = \frac{-49.0\text{ rad}^2/\text{s}^2}{28.0\text{ rev}}$$

$$\alpha = \frac{-49.0\text{ rad}^2/\text{s}^2}{(28.0\text{ rev})\left(\frac{2\pi\text{ rad}}{\text{rev}}\right)} = -0.279\text{ rad/s}^2$$

$$|\alpha| = 0.279\text{ rad/s}^2$$

34. **Correct answer: D**

$$\Delta Q = mc\Delta T$$

$$R = \frac{\Delta Q}{\Delta t} = m_\text{w} c_\text{w} \frac{\Delta T_\text{w}}{\Delta t} = (180.\text{ g})\left(1.00\,\frac{\text{cal}}{\text{g}\cdot\text{C}^\text{o}}\right)\left(\frac{17.0^\text{o}\text{C}}{180.\text{ s}}\right) = 17.0\text{ cal/s}$$

$$R = 17.0\text{ cal/s} = m_\text{x} c_\text{x} \frac{\Delta T_\text{x}}{\Delta t} = (300.\text{ g})(c_x)\left(\frac{95.7^\text{o}\text{C}}{360.\text{ s}}\right)$$

$$c_x = 0.213\text{ cal/(g}\cdot\text{C}^\text{o})$$

35. **Correct answer: C**

$$F = qE$$

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

$$v_f^2 = v_i^2 + 2a(x_f - x_i)$$

$$v_f^2 = 0 + 2\cdot\frac{qE}{m}\cdot d$$

$$v_f = \sqrt{2\cdot\frac{qE}{m}\cdot d} = \sqrt{2\cdot\frac{(1.602\times10^{-19}\text{ C})(7.45\times10^4\text{ N/C})}{1.6726\times10^{-27}\text{ kg}}\cdot(0.0600\text{ m})}$$

$$v_f = 9.25\times10^5\text{ m/s}$$