WYSE – Academic Challenge
Physics Test (State) – 2016

1. **Correct Answer: E**

$$20.0\ \frac{\text{poof}}{\text{garp}} \times \frac{0.240\ \text{m}}{\text{poof}} \times \frac{\text{garp}}{4.20 \times 10^{-3}\text{s}} = 1143\ \text{m/s}$$

2. **Correct Answer: C**

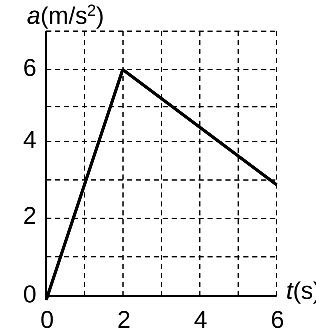
$$[F \cdot L] = [F][L] = \left(\frac{\text{M} \cdot \text{L}}{\text{T}^2}\right)(\text{L}) = \frac{\text{M} \cdot \text{L}^2}{\text{T}^2}$$

3. **Correct Answer: D**

$$\bar{v} = \frac{\text{path length}}{\text{travel time}} = \frac{d_1 + d_2 + d_3}{t_1 + t_2 + t_3} \quad \Longrightarrow \quad t_3 = \frac{d_1 + d_2 + d_3}{\bar{v}} - t_2 - t_3 \quad \Longrightarrow$$

$$v_3 = \frac{d_3}{t_3} = \frac{700.\,\text{m}}{\frac{1000.\,\text{m}}{6.00\ \text{m/s}} - 40.0\ \text{s} - 15.0\ \text{s}} = 6.27\ \text{m/s}$$

4. **Correct Answer: E**



The change in velocity is the area between the $a(t)$ curve and the *x*-axis.

$$v - v_o = \tfrac{1}{2}(2.0\ \text{s})(6.0\ \text{m/s}^2) + \tfrac{1}{2}(6.0\ \text{m/s}^2 + 3.0\ \text{m/s}^2)(4.0\ \text{s})$$

$$v = 6.0\ \text{m/s} + 18.0\ \text{m/s} = 24.0\ \text{m/s}$$

5. **Correct Answer: B**

The average is the area between the $a(t)$ curve and the x-axis divided by the length of the interval over which the averaging is performed.

$$\bar{a} = \frac{\tfrac{1}{2}(3.0\ \text{m/s}^2 + 6.0\ \text{m/s}^2)(1.0\ \text{s}) + \tfrac{1}{2}(6.0\ \text{m/s}^2 + 3.0\ \text{m/s}^2)(4.0\ \text{s})}{6.0\ \text{s} - 1.0\ \text{s}} = 4.5\,\text{m/s}^2$$

6. **Correct Answer: A**

Using a coordinate system with the x direction east and the y direction north,

$$\mathbf{A} + \mathbf{B} = (20.0)(\cos 30.0°\,\hat{\mathbf{i}} + \sin 30.0°\,\hat{\mathbf{j}}) + (30.0)(\sin 10.0°\,\hat{\mathbf{i}} + \cos 10.0°\,\hat{\mathbf{j}})$$

$$= 22.5\,\hat{\mathbf{i}} + 39.5\,\hat{\mathbf{j}}$$

$$|\mathbf{A} + \mathbf{B}| = \sqrt{22.5^2 + 39.5^2} = 45.5 \quad \text{and} \quad \theta_{\mathbf{A+B}} = \tan^{-1}\frac{39.5}{22.5} = 60.3°$$

7. **Correct Answer: B**

$$y = y_0 + v_{yo}t + \tfrac{1}{2}a_y t^2 \quad \Longrightarrow \quad t = \frac{-v_{yo} \pm \sqrt{v_{y0}^2 - 2a_y(y_0 - y)}}{a_y} =$$

$$\frac{-20.0\,\frac{\mathrm{m}}{\mathrm{s}} \pm \sqrt{\left(20.0\,\frac{\mathrm{m}}{\mathrm{s}}\right)^2 - 2(-9.80\ \mathrm{m/s^2})(2.00\ \mathrm{m} - 0.00\ \mathrm{m})}}{-9.80\ \mathrm{m/s^2}} = -0.0977\ \mathrm{s}\ \text{or}\ 4.18\ \mathrm{s}$$

The positive solution, 4.18 s, is the correct answer.

8. **Correct Answer: C**

At maximum height, the component of vertical velocity is zero,

$$v_y^2 - v_{y0}^2 = 2a_y(y - y_0) \quad \Longrightarrow$$

$$v_{y0} = \sqrt{v_y^2 - 2a_y(y - y_0)} = \sqrt{-2(-9.80\ \mathrm{m/s^2})(15.0\ \mathrm{m} - 2.00\ \mathrm{m})} = 15.96\ \mathrm{m/s}$$

Finding angle for which this is the y-component of the initial velocity,

$$v_{y0} = v_0 \sin\theta \quad \Longrightarrow \quad \theta = \sin^{-1}\frac{v_{y0}}{v_0} = \sin^{-1}\frac{15.96\,\frac{\mathrm{m}}{\mathrm{s}}}{20.0\,\frac{\mathrm{m}}{\mathrm{s}}} = 53.0°$$

9. **Correct Answer: A**

An application of Newton's third Law implies the sum of all the internal forces in a system is zero. Therefore the sum of the forces on object A and object B must be equal magnitude and opposite in direction to the force on object C.

10. **Correct Answer: D**

$$T - m_1 g = m_1 a \ \ \text{and} \ \ T - m_2 g = -m_2 a \quad \Longrightarrow \quad T = \frac{2m_1 m_2}{m_1 + m_2} g \quad \Longrightarrow$$

$$T = \frac{2(2.00\ \mathrm{kg})(3.00\ \mathrm{kg})}{(2.00\ \mathrm{kg}) + (3.00\ \mathrm{kg})}(9.80\ \mathrm{m/s^2}) = 23.5\ \mathrm{N}$$

11. **Correct Answer: B**

$$\Delta K = W \quad \Longrightarrow \quad \tfrac{1}{2}mv_f^2 - \tfrac{1}{2}mv_i^2 = W \quad \Longrightarrow$$

$$v_f = \sqrt{\frac{2W}{m} + v_i^2} = \sqrt{\frac{2(24.0\ \mathrm{J})}{(4.00\ \mathrm{kg})} + (2.00\ \mathrm{m/s})^2} = 4.00\ \mathrm{m/s}$$

12. **Correct Answer: B**

$$W = \mathbf{F} \cdot \mathbf{d} = Fd\cos\theta \quad \Longrightarrow \quad F\cos\theta = \frac{W}{d} = \frac{24.0\ \mathrm{J}}{9.00\ \mathrm{m}} = 2.67\ \mathrm{N}$$

13. **Correct Answer: A**

$$\mathbf{r}_{cm} = \frac{\sum m_i\,\mathbf{r}_i}{\sum m_i}$$
$$= \frac{(3.00\ \mathrm{kg})\left(1.0\ \mathrm{m}\hat{\mathbf{i}} + 3.0\ \mathrm{m}\hat{\mathbf{j}} - 2.0\ \mathrm{m}\hat{\mathbf{k}}\right) + (5.00\ \mathrm{kg})\left(-1.0\ \mathrm{m}\hat{\mathbf{i}} + 1.0\ \mathrm{m}\hat{\mathbf{j}} + 2.0\ \mathrm{m}\hat{\mathbf{k}}\right) + (10.0\ \mathrm{kg})\mathbf{r}_{\mathbf{10}}}{3.00\ \mathrm{kg} + 5.00\ \mathrm{kg} + 10.0\ \mathrm{kg}}$$

$$\Longrightarrow \quad \mathbf{r}_{\mathbf{10}} = 0.20\ \mathrm{m}\hat{\mathbf{i}} - 1.4\ \mathrm{m}\hat{\mathbf{j}} - 0.40\ \mathrm{m}\hat{\mathbf{k}}$$

14. **Correct Answer: D**

$$F_{average} = \frac{\Delta p}{\Delta t} = \frac{(m_1 v_{1f} + m_2 v_{2f}) - (m_1 v_{1i} + m_2 v_{2i})}{\Delta t}$$

Using a coordinate system with north positive and south negative,

$$F_{average} = \frac{\left((120.\ \mathrm{kg})(0) + (80.0\ \mathrm{kg})(0)\right) - \left((120.\ \mathrm{kg})(-8.00\ \mathrm{m/s}) + (80.0\ \mathrm{kg})(7.00\ \mathrm{m/s})\right)}{(0.500\ \mathrm{s})} = 800.\ \mathrm{N}$$

This the total external force on the players, so by Newton's 3rd Law, the force on the ground is 800. N south.

15. **Correct Answer: C**

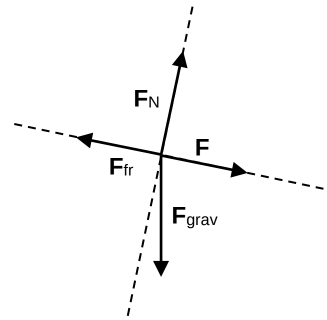
$$\text{nano} \quad \Longleftrightarrow \quad 10^{-9}$$

16. **Correct Answer: C**

$$\text{Impulse} = \Delta p = mv_f - mv_i \quad \Longrightarrow \quad m = \frac{\text{Impulse}}{v_f - v_i} = \frac{-100.\ \mathrm{N \cdot s}}{-12.0\,\frac{\mathrm{m}}{\mathrm{s}} - 20.0\,\frac{\mathrm{m}}{\mathrm{s}}} = 3.13\ \mathrm{kg}$$

17. **Correct Answer: B**

The free-body diagram for the situation is shown on the right along with *x* and *y* coordinate axes aligned and perpendicular to the plane, respectively. As the acceleration is in the *x* direction, the sum of the components of the forces in the *y* direction is zero,



$$F_y + F_{Ny} + F_{gravy} + F_{fry} = 0 \quad \Rightarrow$$
$$F_N = -(0 - mg\cos 10° + 0) = mg\cos 10°$$

In the *x* direction,

$$F_x + F_{Nx} + F_{gravx} + F_{frx} = ma_x$$

The maximum magnitude of the static friction force is $\mu_s F_N$,

$$F_x + 0 + mg\sin 10° - \mu_s F_N = F_x + 0 + mg\sin 10° - \mu_s mg\cos 10° = 0$$

$$F_x = \mu_s mg\cos 10° - mg\sin 10° \quad \Rightarrow$$

$$F_x = (0.400)(9.8\ \text{m/s}^2)(8.00\ \text{kg})(\cos 10°) - (9.8\ \text{m/s}^2)(8.00\ \text{kg})(\sin 10°) = 17.3\ \text{N}$$

18. **Correct Answer: D**

As the object is accelerating, the friction force will be kinetic friction with magnitude $\mu_k F_N$. As in the solution to problem 17, the magnitude of the normal force is again $mg\cos 10°$. Using the same coordinate system as the solution in problem 17,

$$F_x + F_{Nx} + F_{gravx} + F_{frx} = ma_x \quad \Rightarrow \quad a_x = \frac{F_x + F_{Nx} + F_{gravx} + F_{frx}}{m}$$

$$a_x = \frac{50.0\ \text{N} + 0 + mg\sin 10° - \mu_K mg\cos 10°}{m}$$

$$a_x = \frac{50.0\ \text{N}}{8.00\ \text{kg}} + (9.8\ \text{m/s}^2)\sin 10° - (0.300)(9.8\ \text{m/s}^2)\cos 10° = 5.06\ \text{m/s}^2$$

19. **Correct Answer: B**

The maximum mass without tipping results in a net zero net torque on the object. If the torque about the edge of the table is used,

$$+r_1 m_1 g - r_{cm\ block} m_{block} g = 0 \quad \Rightarrow$$
$$+(7.00\,\text{cm})m(9.80\,\text{m/s}^2) - (3.00\,\text{cm})(4.00\,\text{kg})(9.80\,\text{m/s}^2) = 0 \quad \Rightarrow$$
$$m = \frac{(3.00\,\text{cm})(4.00\,\text{kg})(9.80\,\text{m/s}^2)}{(7.00\,\text{cm})(9.80\,\text{m/s}^2)} = 1.71\text{kg}$$

20. **Correct Answer: A**

$$I_1\omega_1 = I_2\omega_2 \quad \Rightarrow \quad I_2 = \frac{I_1\omega_1}{\omega_2} = \frac{(30.0\,\text{kg}\cdot\text{m}^2)(3.00\,\text{rad/s})}{(5.00\,\text{rad/s})} = 18.0\ \text{kg}\cdot\text{m}^2$$

$$W = \Delta K = \tfrac{1}{2}I_2\omega_2^2 - \tfrac{1}{2}I_1\omega_1^2$$

$$= \tfrac{1}{2}(18.0\,\text{kg}\cdot\text{m}^2)(5.00\,\text{rad/s})^2 - \tfrac{1}{2}(30.0\,\text{kg}\cdot\text{m}^2)(3.00\,\text{rad/s})^2 = 90.0\,\text{J}$$

21. **Correct Answer: E**

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

$$GPE_i + KE_i + EPE_i = GPE_f + KE_f + EPE_f$$

$$m\cdot g\cdot(0.25\,\text{m} + \text{d}) + 0 + 0 = 0 + 0 + \frac{1}{2}(k)\,d^2$$

$$(2.00\,\text{kg})\cdot(9.80\,\text{m/s}^2)\cdot(0.25\,\text{m} + \text{d}) = \frac{1}{2}(400\ \text{N/m})\,d^2$$

$$d = 21.3\,\text{cm}$$

22. **Correct Answer: A**

$$T_{^\circ C} = mT_{new\ scale} + b \quad \Longrightarrow$$

$$m = \frac{T_{^\circ C_2} - T_{^\circ C_1}}{T_{new\ scale\ 2} - T_{new\ scale\ 1}} = \frac{100.\,^\circ\text{C} - 0.00^\circ\text{C}}{420.^\circ - 150.^\circ} = 0.3704\ ^\circ\text{C}/^\circ$$

$$b = T_{^\circ C_1} - mT_{new\ scale\ 1} = 0.00^\circ - (0.3704\ ^\circ\text{C}/^\circ)(150.^\circ) = -55.56\ ^\circ\text{C}$$

$$T_{^\circ C} = (0.3704\ ^\circ\text{C}/^\circ)(200.^\circ) - 55.56\ ^\circ\text{C} = 18.5\ ^\circ\text{C}$$

23. **Correct Answer: C**

$$\frac{P_1V_1}{N_1kT_1} = \frac{P_2V_2}{N_2kT_2} \quad \text{and} \quad P_1V_1^\gamma = P_2V_2^\gamma \quad \Longrightarrow$$

$$T_2 = \frac{P_2V_2}{P_1V_1}T_1 = \frac{V_2^{1-\gamma}}{V_1^{1-\gamma}}T_1 = \left(\frac{100.\,\text{liters}}{200.\,\text{liters}}\right)^{1-5/3}(300.+273.15)\text{K} = 909.8\ \text{K} = 637\ ^\circ\text{C}$$

24. **Correct Answer: E**

In a thermally isolated system, entropy never decreases. The only process for which the entropy can decrease is to exchange heat with the external environment, with the heat flowing out of the system.

25. **Correct Answer: B**

R_2 and R_3 are in parallel with each other and their parallel equivalent is in series with R_1:

$$R = R_1 + \left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = 400.\,\Omega + \left(\frac{1}{300.\,\Omega} + \frac{1}{600.\,\Omega}\right)^{-1} = 600.\,\Omega$$

26. **Correct Answer: B**

$$Z = \sqrt{R^2 + X_C^2} = \sqrt{(3.00\ \Omega)^2 + (4.00\ \Omega)^2} = 5.00\ \Omega$$

27. **Correct Answer: D**

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \quad \Longrightarrow \quad n_2 = \frac{n_1 \sin\theta_1}{\sin\theta_2} = \frac{(1.40)\sin 30.0°}{\sin 20.0°} = 2.05$$

28. **Correct Answer: C**

$$m\lambda = \frac{dy}{L} \quad \Longrightarrow \quad \lambda = \frac{d}{L}\frac{y_2 - y_1}{m_2 - m_1} = \frac{(3.00 \times 10^{-4}\ \text{m})}{2.00\ \text{m}}\frac{7.20 \times 10^{-3}\ \text{m}}{2} = 540\ \text{nm}$$

29. **Correct Answer: B**

$$\frac{1}{f_1} = \frac{1}{s_{01}} + \frac{1}{s_{i1}} \quad \Longrightarrow \quad s_{i1} = \frac{f_1 s_{01}}{s_{01} - f_1} = \frac{(20.0\ \text{cm})(30.0\ \text{cm})}{(30.0\ \text{cm}) - (20.0\ \text{cm})} = 60.0\ \text{cm}$$

$$s_{o2} = d - s_{i1} = 80.0\ \text{cm} - 60.0\ \text{cm} = 20.0\ \text{cm}$$

$$\frac{1}{f_2} = \frac{1}{s_{02}} + \frac{1}{s_{i2}} \quad \Longrightarrow \quad f_2 = \frac{s_{02} s_{i2}}{s_{02} + s_{i2}} = \frac{(20.0\ \text{cm})(30.0\ \text{cm})}{(30.0\ \text{cm}) + (20.0\ \text{cm})} = 12.0\ \text{cm}$$

30. **Correct Answer: B**

Chromatic aberration only occurs for lenses, as it is the result of the varying refractive index of the lens material for different wavelengths of light.

31. **Correct Answer: A**

General form of sinusoidal wave:

$$y(x,t) = A\cos\{kx + \omega t\} \quad \Longrightarrow \quad c = \frac{\omega}{k} = \frac{3.00\ \text{s}^{-1}}{5.00\ \text{cm}^{-1}} = 0.600\ \text{cm/s}$$

32. **Correct Answer: E**

$$E_n = (-13.6\ \text{eV})\frac{Z^2}{n^2} \quad \Longrightarrow \quad \frac{E_2}{E_1} = \frac{Z_2^2}{Z_1^2} \quad \Longrightarrow \quad E_2 = \frac{Z_2^2}{Z_1^2}E_1 = \frac{4^2}{1^2}(-13.6\ \text{eV}) = -218\ \text{eV}$$

The enenergy level is -218 eV and to ionize the atom will take 218 eV to free the electron.

33. **Correct Answer: A**

$${}^{128}_{53}\text{I} \quad \longrightarrow \quad {}^{128}_{54}\text{Xe} + {}^{0}_{-1}e + {}^{0}_{0}\bar{\nu}$$

34. **Correct Answer: B**

$$K = (\gamma - 1)E_0 \quad \Longrightarrow \quad \gamma = \frac{K + E_0}{E_0} = \frac{5E_0 + E_0}{E_0} = 6$$

$$\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \Longrightarrow \quad v = \sqrt{1 - \frac{1}{\gamma^2}}\ c = \sqrt{1 - \frac{1}{6^2}}\ c = 0.986\ c$$

35. **Correct Answer: D**

$$A(t) = A_0 e^{-\lambda t} \quad \Longrightarrow$$

$$A(t_1) = A(t_2)e^{\lambda(t_2 - t_1)} = 400\ \text{s}^{-1} e^{(0.300\ s^{-1})(120.\ \text{s} - 60.0\ \text{s})} = 2.63 \times 10^{10}\ \text{s}^{-1}$$