WYSE Academic Challenge
2012 Regional Physics Exam
SOLUTION SET

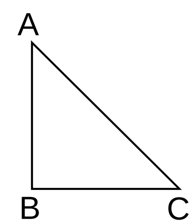
1. **Correct answer: B**

Definition: The average speed of an object is calculated by dividing the distance traveled by the object by the time it takes for the object to travel this distance.

2. **Correct answer: A**

The SI unit of mass is the kilogram.

3. **Correct answer: E**



For a conservative force, the amount of work done by this force depends upon the end points of the path, but not upon the path itself. Thus if the work done by the force along the direct path from A to B is W, then the work done by this conservative force along the path from A to C to B will also be W since the end points of both paths (A to B and A to C to B) are the same end points (A and B).

4. **Correct answer: B**

From an inertial frame of reference an object that is not interacting with other objects would always be seen to have zero acceleration.

To say that the object is not interacting with other objects is to say that no forces act on the object. Viewed from a non-accelerating (inertial) frame of reference, if the net force acting on an object is zero, the acceleration of the object is zero.

5. **Correct answer: D**

The impulse acting upon an object divided by the time the impulse acts is equal to the average net force acting on the object.

$$\vec{I} \equiv \int \vec{F}\, dt$$

$$\frac{\vec{I}}{T} \equiv \frac{\int \vec{F} dt}{T} \equiv \text{average net force}$$

Or,

Impulse = change in momentum

$$\sum \vec{F} \delta t = m\Delta\vec{v}$$

$$\frac{\sum \vec{F}\delta t}{\mathrm{T}} = m\frac{\Delta\vec{v}}{\mathrm{T}} = \mathrm{m}\vec{\mathrm{a}}_{\mathrm{ave}} = \vec{\mathrm{F}}_{\mathrm{ave,net}}$$

6. **Correct answer: C**

Using conservation of momentum since no external forces act upon the two object system:

$(m_{3500} + m_{2500}) \times (V_{\text{initial}}) = (m_{3500}) \times (V_{3500}) + (m_{2500}) \times (V_{2500})$

$(3.50\times10^3 \text{ kg} + 2.50\times10^3 \text{ kg}) \times (5.00 \text{ km/s}) = (3.50\times10^3 \text{ kg}) \times (V_{3500}) + (2.50\times10^3 \text{ kg}) \times (V_{2500})$

$(3.50\times10^3 \text{ kg} + 2.50\times10^3 \text{ kg}) \times (5.00 \text{ km/s}) = (3.50\times10^3 \text{ kg}) \times (V_{2500} + 200.\,\text{m/s}) + (2.50\times10^3 \text{ kg}) \times (V_{2500})$

$V_{2500} = 4.88 \text{ km/s}$

7. **Correct answer: E**

$V(t_f) = V(t_i) + a \times (t_f - t_i)$ (*)

$V(4.00\ s) = V(0.00\ s) + a_1 \times (4.00\ s - 0.00\ s)$

$V(4.00\ s) = 0 + (2.50\ m/s^2)(4.00\ s - 0.00\ s) = 10.0\ m/s$

Using (*) again with new initial and final values and the new acceleration:

$V(6.00\ s) = V(4.00\ s) + a_2 \times (6.00\ s - 4.00\ s)$

$V(6.00\ s) = V(4.00\ s) + (3.00\ m/s^2)(6.00\ s - 4.00\ s)$

$V(6.00\ s) = 10.0\frac{m}{s} + \left(3.00\frac{m}{s^2}\right)(6.00\ s - 4.00\ s) = 16.0\ m/s$

8. **Correct answer: A**

$x(t_f) = x(t_i) + V(t_i) \times (t_f - t_i) + \frac{1}{2}\, a \times (t_f - t_i)^2$ (**)

$x(4.00\ s) = x(0.00\ s) + V(0.00\ s) \times (4.00\ s - 0.00\ s) + \frac{1}{2}\,(2.50\ m/s^2) \times (4.00\ s - 0.00\ s)^2$

$x(4.00\ s) = (0.00\ m) + (0.00\ m/s) \times (4.00\ s) + \frac{1}{2}\,(2.50\ m/s^2) \times (4.00\ s - 0.00\ s)^2 = 20.0\ m$

Using (**) again with new initial and final values and the new acceleration:

$x(6.00\ s) = x(4.00\ s) + V(4.00\ s) \times (6.00\ s - 4.00\ s) + \frac{1}{2}\,(3.00\ m/s^2) \times (6.00\ s - 4.00\ s)^2$

$x(6.00\ s) = (20.0\ m) + (10.0\ m/s) \times (2.00\ s) + \frac{1}{2}\,(3.00\ m/s^2) \times (6.00\ s - 4.00\ s)^2 = 46.0\ m$

9. **Correct answer: A**

The mass on the spring has zero speed when the spring reaches its maximum extension or compression. That is, when $x = \pm A$. This yields the largest value of spring force, kA, and thus the largest value of acceleration. Using Newton's 2nd Law:

$$|a_{max}| = \frac{kA}{m} = \frac{(125.0\ N/m)(0.360\ m)}{5.00\ kg} = 9.00\ m/s^2$$

10. **Correct answer: D**

Using conservation of energy:

$$\frac{1}{2}kx^2 + \frac{1}{2}mv^2 = constant = \frac{1}{2}kA^2 + \frac{1}{2}m0^2$$

$$\frac{1}{2}(125.0\ N/m)x^2 + \frac{1}{2}(5.00\ kg)(1.20\ m/s)^2 = constant = \frac{1}{2}(125.0\ N/m)(0.360\ m)^2$$

$$x = 0.268\ m$$

11. **Correct answer: B**

$$F = G\frac{Mm_o}{R^2}$$

$$\frac{F}{m_o} = G\frac{M}{R^2} = g \quad \Rightarrow \quad M = \frac{gR^2}{G}$$

$$Density = \frac{mass}{volume} = \frac{\frac{gR^2}{G}}{\frac{4\pi R^3}{3}} = \frac{3g}{4\pi RG}$$

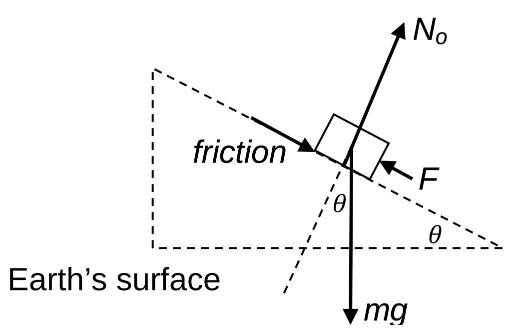
12. **Correct answer: E**

$$\left|\overrightarrow{\mathbf{Impulse}}\right| = \left|M\Delta\vec{\mathbf{V}}\right| = 1500\ kg\ \times 1.52\frac{m}{s} = 2.28\ kNs$$

13. **Correct answer: C**

$$Work = \Delta KE = \frac{1}{2}MV_f^2 - \frac{1}{2}MV_i^2 = \frac{1}{2}M\left(V_f^2 - V_i^2\right) = \frac{1}{2}(1500.kg)((1.52\ m/s)^2 - 0^2) = 1.73\ kJ$$

14. **Correct answer: C**



$\theta = 30.0^o$

Since the block moves with constant velocity, the sum of forces acting on the block is zero.

Along the incline plane:

$$F - friction - mg\sin(\theta) = 0$$

$$F = 47.0\ N + 128\ kg\ \times 9.80\frac{m}{s^2}\sin(30.0^o) = 674\ \mathrm{N}$$

15. **Correct answer: A**

$$N_o = mg\cos(\theta) = 128\text{ kg} \times 9.80\frac{\text{m}}{\text{s}^2} \times \cos(30.0^o) = 1086\,N$$

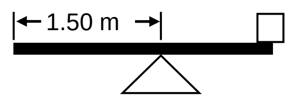
$$\mu = \frac{friction}{N_o} = \frac{47.0\,N}{1086\,N} = 0.0433$$

16. **Correct answer: D**

$$eff = \frac{\Delta PE}{Work} \times 100\% = \frac{mg\,d\sin(\theta)}{Fd\cos(0^o)} = \frac{mg\sin(\theta)}{F} = \frac{128\,kg \times 9.80\frac{m}{s^2} \times \sin(30.0^o)}{674\,N} = 93.0\%$$

$d = distance\ block\ is\ moved\ across\ the\ plane$

17. **Correct answer: D**

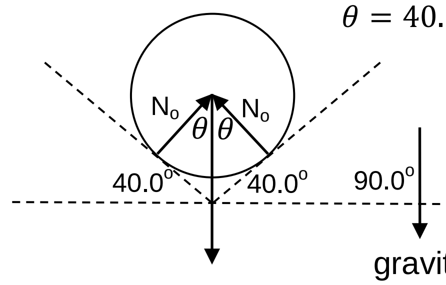


$$\sum Torques = 0 = (5.00\,kg)(\cancel{9.80\,m/s^2})(L - 1.50\,m)CW + (20.0\,kg)(\cancel{9.80\,m/s^2})\left(1.50\,m - \frac{L}{2}\right)CCW$$

$L = 2.50\,m$

$\theta = 40.0^o$

18. **Correct answer: E**



$\sum F = 0$

$2N_o\cos(\theta) = 148\,N$

$N_o = 96.6\,N$

19. **Correct answer: C**

$x_{speeder}(t_{to\ catch}) = x_{speeder,i} + (V_{speeder,i})(t_{to\ catch})$

$x_{speeder}(t_{to\ catch}) = 45.6\,m + (19.0\,m/s)(t_{to\ catch})$

$x_{police\ car}(t_{to\ catch}) = x_{police\ car,i} + (V_{police\ car,i})(t_{to\ catch}) + \frac{1}{2}a_{police\ car}t^2_{to\ catch}$

$x_{police\ car}(t_{to\ catch}) = 0.00\,m + (0.00\,m/s)(t_{to\ catch}) + \frac{1}{2}(3.80\,m/s^2)t^2_{to\ catch}$

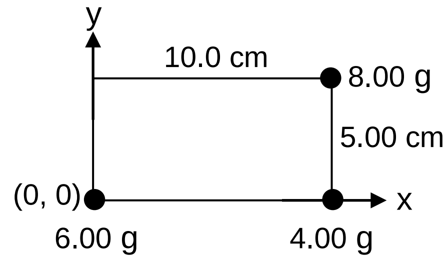
$x_{police\ car}(t_{to\ catch}) = x_{speeder}(t_{to\ catch})$

$\frac{1}{2}(3.80\,m/s^2)t^2_{to\ catch} = 45.6\,m + (19.0\,m/s)(t_{to\ catch})$

$1.90\,t^2_{to\ catch} - (19.0\,s)(t_{to\ catch}) - 45.6\,s^2 = 0$

$t_{to\ catch} = 12.0\,s$

20. **Correct answer: A**

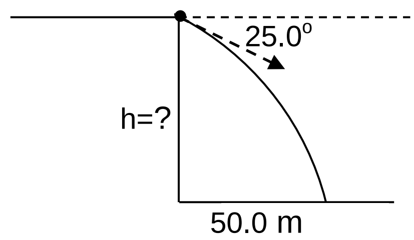


$x_{cm} =$

$$\frac{(18.0\ g)(5.00\ cm)+(6.00\ g)(0.00\ cm)+(4.00\ g)(10.0\ cm)+(8.00\ g)(10.0\ cm)}{(18.0\ g + 6.00\ g + 4.00\ g + 8.00\ g)}$$

$x_{cm} = 5.83\ cm$

21. **Correct answer: B**



$x(t_f) = x(t_i) + V_x(t_f - t_i)$

$50.0\ m = 0 + 40.0\frac{m}{s} \times \cos(25.0^\circ) \times (t_f - 0.00\ s)$

$t_f = 1.379\ s$

$y(t_f) = y(t_i) + V_{y,i}(t_f - t_i) + \frac{1}{2}a_y(t_f - t_i)^2$

Choosing the origin at the black dot with positive y axis downward:

$h = 0 + 40\frac{m}{s} \times \sin(25.0^\circ) \times (1.379\ s) + \frac{1}{2}\left(9.8\frac{m}{s^2}\right) \times (1.379\ s)^2$

$h = 32.6\ m$

22. **Correct answer: A**

$\vec{F} = m\,\vec{a} = 2.34\ kg \times (4.00\,\hat{\imath} + 5.00\,\hat{\jmath})\frac{m}{s^2} = (9.36\,\hat{\imath} + 11.7\,\hat{\jmath})\ kg \cdot \frac{m}{s^2} = (9.36\,\hat{\imath} + 11.7\,\hat{\jmath})\ N$

$|\vec{F}| = |m\,\vec{a}| = |(9.36\,\hat{\imath} + 11.7\,\hat{\jmath})\ N| = \sqrt{9.36^2 + 11.7^2}\ N = 15.0\ N$

23. **Correct answer: D**

Letting up be positive: $N - mg = ma$, where N is the normal force on the physics book, m is the mass of the book, g is the **magnitude** of the acceleration due to gravity, and a is the acceleration of the elevator (or book).

If the elevator moves with constant speed, up or down, a = 0

If the elevator accelerates upward, a>0; if downward, a<0.

Thus,

$N = m(a + g)$

$F = \mu N = \mu m(a + g)$

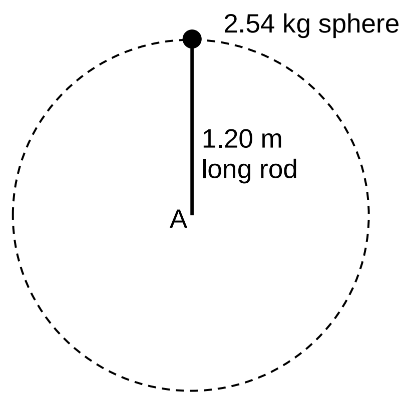
The required force, F, is greatest for a>0.

24. **Correct answer: B**

$$\vec{F}_{on\ ball} = m\vec{a} = m\left(\frac{\Delta\vec{\mathrm{v}}}{\mathrm{t_{contact}}}\right) = \mathrm{m}\left(\frac{\vec{\mathrm{v}}_\mathrm{f}-\vec{\mathrm{v}}_\mathrm{i}}{\mathrm{t_{contact}}}\right) = (0.150\ \mathrm{kg})\left(\frac{3.80(\mathrm{away})-3.80(\mathrm{toward})}{0.0120}\right)(\mathrm{m/s^2})$$

$$= (0.150)\left(\frac{3.8(\mathrm{away})+3.80(\mathrm{away})}{0.0120}\right)(\mathrm{kg\cdot m/s^2}) = (0.150)\left(\frac{7.6(\mathrm{away})}{0.0120}\right)(\mathrm{N}) = 95.0\ \mathrm{N\ away\ from\ wall}$$

25. **Correct answer: E**



$$a_{trans} = \sqrt{a_{tangential}^2 + a_{centripetal}^2}$$

$$a_{trans} = \sqrt{(R\alpha)^2 + \left(\frac{V^2}{R}\right)^2} = \sqrt{(1.20 \times 4.50)^2 + \left(\frac{3.00^2}{1.20}\right)^2}\ (m/s^2) =$$

$$a_{trans} = 9.24\ m/s^2$$

26. **Correct answer: C**

$$\theta = \bar{\omega}t = \left(\frac{4.2+13.2}{2}\right)(3.00)\ rad = 26.1\ rad$$

27. **Correct answer: B**

$$distance\ masses\ move = (2.00\ rev)\left(\frac{2\pi\ rad}{rev}\right)(0.150\ m) = 1.885\ m$$

The work done by the frictional torque equals the change in energy of the pulley-block-earth system:

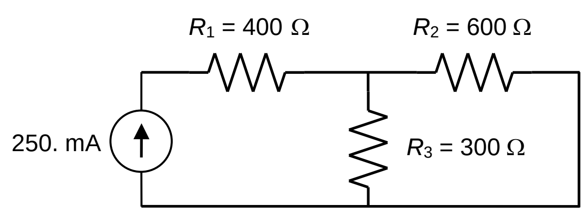
$$Work = \tau\Delta\theta\cos(180^o) = -(2.40\ Nm)(4\pi) = -30.15\ J$$

$$Work = \Delta GPE_{12} + \Delta GPE_{21} + \Delta KE_{12} + \Delta KE_{21} + \Delta KE_{pulley}$$

$$-30.15\ J = (12)(9.8\ )(1.885)J - (21)(9.8)(1.885)J + \frac{1}{2}(12)(.15\omega)^2 J + \frac{1}{2}(21)(.15\omega)^2 J + \frac{1}{2}(1.74)(\omega)^2 J$$

$$\omega = 10.5\ rad/s$$

28. **Correct answer: B**



The equivalent resistance connected to the terminals of the current source is:

$$R_{eq} = R_1 + (R_2||R_3) = 400\ \Omega + \frac{(600\ \Omega)(300\ \Omega)}{600\ \Omega + 300\ \Omega} = 600\ \Omega$$

$$V_{cs} = IR_{eq} = (0.250\ A)(600\ \Omega) = 150\ V$$

29. **Correct answer: E**

The node locations occur where $sin\left(\frac{2\pi\ \text{rad}}{\text{meter}}x\right) = 0$

When x = 0.00 m, $\sin\left(\frac{2\pi\ \text{rad}}{\text{meter}}x\right) = 0$. (one fixed end of the string) $\frac{2\pi\ \text{rad}}{\text{meter}}x = 0$

When x = 2.50 m, $\sin\left(\frac{2\pi\ \text{rad}}{\text{meter}}x\right) = 0$. (the other fixed end of the string) $\frac{2\pi\ \text{rad}}{\text{meter}}x = 5\pi\ \text{rad}$

The other nodes occur at $\frac{2\pi\ \text{rad}}{\text{meter}}x = \pi, 2\pi, 3\pi, 4\pi\ (\text{rad})$.

The 1st lobe is located between $\frac{2\pi\ \text{rad}}{\text{meter}}x = 0$ and $\frac{2\pi\ \text{rad}}{\text{meter}}x = \pi$.

The 2nd lobe is located between $\frac{2\pi\ \text{rad}}{\text{meter}}x = \pi$ and $\frac{2\pi\ \text{rad}}{\text{meter}}x = 2\pi$.

The 3rd lobe is located between $\frac{2\pi\ \text{rad}}{\text{meter}}x = 2\pi$ and $\frac{2\pi\ \text{rad}}{\text{meter}}x = 3\pi$.

The 4th lobe is located between $\frac{2\pi\ \text{rad}}{\text{meter}}x = 3\pi$ and $\frac{2\pi\ \text{rad}}{\text{meter}}x = 4\pi$.

The 5th lobe is located between $\frac{2\pi\ \text{rad}}{\text{meter}}x = 4\pi$ and $\frac{2\pi\ \text{rad}}{\text{meter}}x = 5\pi$.

30. **Correct answer: C**

$$V_{new} = V_o + \beta V_o \Delta T = V_o(1 + 3 \times 6.07 \times 10^{-5}/\ ^oC \times 190.00\ ^oC) = 1.0346\ V_o$$

$$\rho_{new} = \frac{m}{V} = \frac{m}{1.0346\ V_o} = \frac{13.6\ \text{kg/m}^3}{1.0346} = 13.1\ \text{kg/m}^3$$

31. **Correct answer: D**

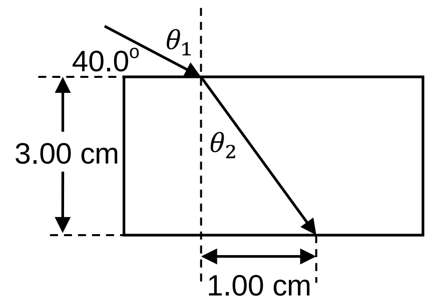
$$\Delta T = \frac{Q}{mC} = \frac{I^2 R \Delta t}{mC} = \frac{(0.750\ A)^2(440.\ \Omega)(120.\ \text{s})}{(0.385\ kg)(4186\ \text{J/(kg}\ ^\text{o}\text{C))}} = 18.4\ ^\text{o}\text{C}$$

32. **Correct answer: A**

$$n_2 \sin(\theta_2) = n_1 \sin(\theta_1)$$

$$n_2 \frac{1.00}{\sqrt{1.00^2 + 3.00^2}} = 1.00 \sin(50.0^o)$$

$$n_2 = 2.42$$



33. **Correct answer: D**

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

$$\frac{1}{12\ cm} = \frac{1}{d_i} + \frac{1}{35.0\ cm}$$

$$d_i = 18.3\ cm$$

$$M = -\frac{d_i}{d_o} = -\frac{18.3\ cm}{35.0\ cm} = \frac{h_i}{h_o} = \frac{h_i}{2.50\ cm}$$

$$h_i = -1.30\ cm = 1.30\ cm\ inverted$$

34. **Correct answer: E**

$$d\sin(\theta) = \lambda = \frac{c}{f}$$

$$d = \frac{c}{f\sin(\theta)} = \frac{2.9979\times 10^8\ \frac{m}{s}}{\frac{4.738\times 10^{14}}{s}\sin(25.7^o)} = 1.46\ \mu m$$

35. **Correct answer: D**

$$KE = E - E_o = mc^2 - m_oc^2 = \frac{m_oc^2}{\sqrt{1-\left(\frac{v}{c}\right)^2}} - m_oc^2 = m_oc^2\left(\frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} - 1\right)$$

$$KE = m_oc^2\left(\frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} - 1\right) = (1.6726\times 10^{-27} kg)\left(2.9979\times 10^8\ \frac{m}{s}\right)^2\left(\frac{1}{\sqrt{1-(0.925)^2}} - 1\right) = 0.245\ nJ$$