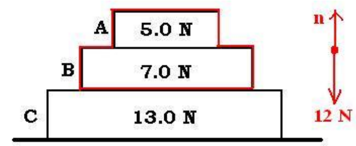
2010 Physics Bowl Solutions

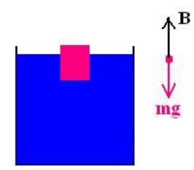
#	Ans	#	Ans	#	Ans	#	Ans	#	Ans
1	D	11	B	21	D	31	A	41	C
2	D	12	E	22	C	32	B	42	B
3	C	13	C	23	C	33	E	43	E
4	B	14	D	24	D	34	C	44	C
5	C	15	D	25	A	35	D	45	D
6	B	16	C	26	E	36	E	46	B
7	A	17	A	27	A	37	E	47	A
8	D	18	E	28	A	38	B	48	C
9	A	19	C	29	B	39	A	49	A
10	E	20	B	30	E	40	B	50	D

1. **D…** Converting units… $\frac{25\,yr}{1}\times\frac{365\,dy}{1\,yr}\times\frac{24\,hr}{1\,dy}\times\frac{60\,\text{min}}{1\,hr}\times\frac{60\,s}{1\,\text{min}} = 7.88\times10^{8}\,s\ \sim 10^{9}\,s$
2. **D…** Energy is a scalar quantity. Linear momentum is mass multiplied by *velocity* (which is a vector and hence, so is average *velocity)*. Force and acceleration are related by Newton's Second Law by mass… force and acceleration are both vectors.
3. **C…** Addition rules of sig. figs means that the calculation stops at the "last column" for which each number is known. Hence, since L_3 is known only to the tenths place, the sum must be recorded to the tenths. Hence, 117.7623 m is rounded to 117.8 m
4. **B…** Let's change all quantities to $^{m}/_{s}$. Changing units leads to
   $v_1 = 1.25\times10^{-4}\frac{cm}{\mu s}\times\frac{1m}{100\,cm}\times\frac{1\mu s}{1\times10^{-6}s} = 1.25\,\frac{m}{s}$;
   $v_2 = 0.076\frac{Mm}{wk}\times\frac{1\times10^{6}m}{1\,Mm}\times\frac{1wk}{7\,dy}\times\frac{1\,dy}{24\,hr}\times\frac{1hr}{60\,min}\times\frac{1\,min}{60\,s} = 0.126\,\frac{m}{s}$
   $v_3 = 9.50\frac{km}{dy}\times\frac{1000\,m}{1\,km}\times\frac{1dy}{24\,hr}\times\frac{1\,hr}{60\,min}\times\frac{1\,min}{60\,s} = 0.110\,\frac{m}{s}$
   Hence, $v_3 < v_2 < v_1$
5. **C…** Looking up these quantities on the constants page, we make the calculation
$$\frac{R}{k_B} = \frac{8.31\frac{J}{mol\cdot K}}{1.38\times10^{-23}\frac{J}{K}} = 6.02\times10^{23}\,\frac{1}{mol} = N_A$$
6. **B…** The idea of "action-reaction" pair forces is a statement of Newton's Third Law. Answer (C) is related to Newton's First Law; Answer (D) is Newton's Second Law; Answer (E) is a statement of the Second Law of Thermodynamics; Answer (A) means that there is gravity! ☺
7. **A…** Using constant acceleration kinematics, we have $v^2 = v_0^2 + 2a\Delta x = (-12)^2 + 2(-9.8)(-10) = 340\frac{m^2}{s^2}$. Taking the square root gives the speed as $v = \sqrt{340}\frac{m}{s} = 18.4\frac{m}{s}$
8. **D…** From the graph, the period is the time it takes the wave to repeat… one region to consider is for the first 8 seconds of the motion.
9. **A…** Amplitude is the size of the motion as measured from equilibrium. The mass is moving 1.0 meter on either side of the equilibrium position of 4.0 meters above the ground.
10. **E…** Displacement (a vector) is the change in position. For an object completing one trip around a circle, it ends at the same location at which it begins meaning that there is NO change in position.
11. **B…** Acceleration is related to the slope of the velocity vs. time graph. To find where the acceleration is zero, we need to find a place on the velocity graph which has a tangent line that is locally horizontal. This occurs only at time $t = 5.0\,s$.

12. **E…** By Newton's Third Law, the force of the proton on the nucleus is equal and opposite to the force on the helium nucleus by the proton. By Newton's Second Law ($F = ma$), since the force is the same on each object, the object with less mass (the proton) has a larger magnitude of acceleration.
13. **C…** The LHC is located along the border of France and Switzerland at CERN near Geneva.
14. **D…** Kelvin temperature is not the same as Celsius temperature (($T_K = T_C + 273$) gives a values expression)… but the *change* in temperature has the same magnitude on both scales.
15. **D…** Considering the blocks A+B to be a system, they have a 12.0 N gravitational force. Consequently, from the free body diagram of the A+B system, there is a contact force of $n = 12.0\ N$ directed upward to keep the system from accelerating. By Newton's Third Law, this 12.0 N force exerted on the surface of block B by block C is the same in magnitude of the force provided onto block C from the surface of block B.



16. **C…** Using that the net torque on the plank+masses system is zero ($\tau_{\text{mass 1}} + \tau_{\text{mass 2}} = 0$) and measuring torques from the center of the plank with the M_1's torque assumed "negative" to indicate clockwise, we have $-r_{\text{mass 1}}(M_1 g) + r_{\text{mass 2}}(M_2 g) = 0$. Hence, $-(3.0\text{ m})(40\text{ kg})(g) + X(80\text{ kg})(g) = 0 \rightarrow X = \frac{120}{80} = 1.50\ m$
17. **A…** The frequency for the n[th] harmonic of a tube is equal to n times the fundamental frequency f_1. This means that we have (regardless of whether the tube was open at both ends or not) that $f_n = nf_1 \rightarrow f_1 = \frac{f_n}{n} = \frac{120\ Hz}{5} = 24\ Hz$.
18. **E…** rapidly rotating neutron stars emitting radiation are most closely associated with pulsars… if we had asked the question including a large magnetic field, "magnetar" would have been a better answer.
19. **C…** All electromagnetic waves traveling through vacuum do so at the speed of light $3.0 \times 10^8 \frac{m}{s}$.
20. **B…** Using the ideal gas equation with $R = 0.0821\ \frac{L\cdot atm}{mol\cdot K}$ and remembering to convert Celsius to Kelvin, we find $n = \frac{PV}{RT} = \frac{(2.50\ atm)(25\ L)}{\left(.0821\frac{L\cdot atm}{mol\cdot K}\right)(373\ K)} = 2.04\ mol$. So, the number of molecules can be computed with $N = nN_A = 2.04 * 6.02 \times 10^{23} = 1.23 \times 10^{24}$. Alternatively, one can use the ideal gas equation in the form $PV = Nk_BT$ and solve for the number of molecules directly, although unit conversions for P and V are needed.
21. **D…** To change the phase of a material, the quantity most associated with this is called the latent heat. Specific heat refers to the energy associated with the change in temperature of a material per unit mass.

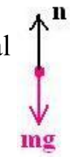


22. **C…** The free body diagram of the floating mass has two forces acting… a gravitational force acting downward and a buoyant force acting upward. By Newton's Second Law, we have $F_{net} = ma \rightarrow B + (-mg) = 0 \ \rightarrow\ B = mg = (10)(10) = 100\ N$. The fact that the container is large and the object is small means that the object is not touching the bottom of the container and thus, there is no normal force of contact with the container. Knowing that 75 % of the object is submerged lets us determine that the density of the object is 75% the density of water.
23. **C…** The period of a simple pendulum depends only on the string length and the acceleration due to gravity $T = 2\pi\sqrt{L/g}$… not the mass connected to the end of the pendulum.
24. **D…** The area under the acceleration vs. time graph gives the *change* in velocity.
25. **A…** Assuming that object 1 has speed v, we find from use of mechanical energy conservation that $\Delta KE + \Delta PE = 0 \ \rightarrow \left(0 - \frac{1}{2}mv^2\right) + mgH = 0 \ \rightarrow H = \frac{v^2}{2g}$. Now, object 2 has the same linear momentum, but twice the mass… meaning that since $p = mv$, by having twice the mass, object 2 has **one-half** the initial speed of object 1. That is $p_1 = p_2 \rightarrow mv = (2m)(\frac{v}{2})$. Using our relation previously derived for height in terms of speed, we have that the maximum height attained by

object 2 is $H_2 = \frac{v_2^2}{2g} = \frac{\left(v/_2\right)^2}{2g} = \frac{1}{4}\frac{v^2}{2g} = \frac{1}{4}H$.

26. **E… METHOD 1:** using the right-hand rule… right fingers point in the direction of the electron's velocity and the fingers are curled into the direction of the magnetic field. Here, that results in the right thumb pointing into the plane of the page. However, since the electron is negatively charged, one must flip the hand over to find the final direction of the force. This means that the force when entering the field region points directly out of the plane of the page.
METHOD 2: Only motion perpendicular to a magnetic field results in a magnetic force on a charged particle. For this scenario, only the motion of the electron directed up the page gives rise to a magnetic force (the component of velocity directed to the right is parallel to the magnetic field and produces no force). Therefore, using the right-hand rule, the right fingers are pointed upward, the fingers are curled to the right, leaving the right thumb pointing into the plane of the page. Since the charge in question is negative, the hand is flipped over to find the direction of the magnetic force (out of the plane of the page).
27. **A…** When the total resistance of the circuit increases, this decreases the current for the circuit. With a decreased current, the terminal voltage increases since it is found as $V_{bat} - Ir$ and the current, I, has decreased with both the emf and the internal resistance remaining unchanged. Since the terminal voltage increases, so too does the voltage across the rheostat (Kirchhoff's Loop Rule) . The power associated with the internal resistance also decreases from $P = I^2 r$ (I decreased).
28. **A…** If one places a converging lens at a distance between the focal length and twice the focal length, the resulting image will be real (inverted) and it would be larger. If the lens is placed at a distance equal to twice the focal length, the image is the same size as the object… placing the object outside of twice the focal length results in a smaller inverted image. The diverging lens always produces a smaller virtual image and by placing the object inside the focal length of the converging lens produces a larger but virtual image.
29. **B…** Using constant acceleration kinematics, we compute the time for the first distance to be
$\Delta x = v_0 \Delta t + \frac{1}{2}a(\Delta t)^2 \;\; \rightarrow \;\; \frac{-h}{2} = 0 - \frac{1}{2}gt^2 \;\; \rightarrow \;\; t_1 = \sqrt{\frac{h}{g}} = t.$
Now, to travel the entire distance, we use the same logic to find
$\Delta x = v_0 \Delta t + \frac{1}{2}a(\Delta t)^2 \;\; \rightarrow \;\; -h = 0 - \frac{1}{2}gt^2 \;\; \rightarrow \;\; t_{Total} = \sqrt{\frac{2h}{g}}.$
This means that the time for the second half-distance, one must subtract the time from the first half-distance from the total time. This gives $t_2 = t_{Total} - t_1 = \sqrt{\frac{2h}{g}} - \sqrt{\frac{h}{g}} = \left(\sqrt{2} - 1\right)\sqrt{\frac{h}{g}} = (0.41\,)t.$
30. **E…** Chromatic aberration is a phenomenon that results when light shines through a lens and different colors focus at different places because the wavelengths of light experience different indices of refraction. This is called dispersion.
31. **A…** We can write an expression for energy as $\Delta KE + \Delta PE + \Delta E_{Thermal} = W$ where the thermal energy term is generated by friction and the work done is by the external force. The system is the block+incline+earth. For each case, there is the same change in both the kinetic energy and the potential energy. So, to determine for which case the applied force does more work, we only need to consider for which case there is a larger friction force since the total displacement is the same for both boxes and the thermal energy generated between the incline and box is found as $\Delta E_{Thermal} = \left|f_{fric} d\right|$. Since the external force in Case 1 is partly directed into the incline, there is a corresponding increase in the normal force acting on the box from the incline which therefore increases the friction force from $f_k = \mu_k n$. Hence, $f_{k\ Case\ 1} > f_{k\ Case\ 2} \;\rightarrow W_{Case\ 1} > W_{Case\ 2}$
32. **B…** The definition of average acceleration is the change in velocity divided by the time. Using this gives $\langle a \rangle = \frac{\Delta v}{\Delta t} = \frac{0.60-(-0.90)}{.25} = 6.0\ \frac{m}{s^2}$. One must note that velocity is a vector and so if the object

moves upward with velocity $0.60\ \frac{m}{s}$ after collision, then it moved with velocity $-0.90\ \frac{m}{s}$ before the collision with the minus sign indicating downwardness.



33. E… From the Free Body Diagram, two forces act on the mass during the collision… the gravitational force (mg) and the contact force from the surface (n). Writing Newton's Second Law, we have $F_{net} = ma \ \rightarrow n - mg = ma \ \rightarrow n = mg + ma = (2\ kg)\left(10\ \frac{m}{s^2}\right) + (2\ kg)\left(6.0\ \frac{m}{s^2}\right) = 32.0\ N.$

34. C… The impulse is equal to the change of momentum. For the 2.0-kg piece that moves along the y-axis after explosion, we compute $\Delta\vec{p} = \left(\vec{p}_f - \vec{p}_i\right) = \left(m(-8.0\ \hat{y})\right) - \left(m(10\ \hat{x})\right) = -20\ \hat{x} - 16\hat{y}$ in MKS units. The size of the impulse is the magnitude of this vector found from the Pythagorean Theorem to be $|\vec{J}| = \sqrt{20^2 + 16^2} = 25.6\ \ N \cdot s$

35. D… Equating the tangential acceleration $(a_t = r\alpha)$ and radial acceleration $\left(a_r = \frac{v^2}{r} = r\omega^2\right)$ with the result from constant angular acceleration kinematics: $\omega = \omega_0 + \alpha T \ \ \rightarrow \omega = \alpha T$, we have $r\alpha = r(\alpha T)^2 \ \ \rightarrow \ \ T = \frac{1}{\sqrt{\alpha}} = \frac{1}{\sqrt{5}} = 0.447\ s.$

36. E… METHOD #1: From the expression for the capacitance of the parallel plate, $C = \varepsilon_0 \frac{A}{d}$ and using the Constants page for ε_0, we have (where F stands for Farad – the unit of capacitance and C is for Coulomb) $F \rightarrow \frac{C^2}{Nm^2}\frac{m^2}{m} = \frac{(As)^2}{\frac{kg\,m}{s^2}m^2}\frac{m}{1} = \frac{A^2s^4}{kg\,m^2}.$

ALTERNATIVE (one of many): In a similar way, one can use $C = \frac{Q}{V}$ and write the units (with volts v = Joules per Coulomb) as $\frac{C}{J/_C} = \frac{C^2}{J} = \frac{(As)^2}{Nm} = \frac{A^2s^2}{\frac{kg\,m}{s^2}m} = \frac{A^2s^4}{kg\,m^2}$

37. E… Electric field points toward decreasing potential which means that for the situation presented, the field points to the *left*. -4.0 volts is less than -2.0 volts and so the field points from -2.0 volts toward –4.0 volts. As for the work done by the external agent… since the electric force from this field is directed to the left from $\vec{F} = q\vec{E}$, the external agent must exert a force to the right in order to move the charge. Since the force and motion are to the right, the work done is positive by the force.
ALTERNATIVE: From $\Delta KE + \Delta PE = W$, since the kinetic energy is constant, the work done by an external agent goes into the potential energy change. The potential energy change here is $\Delta U = q\Delta V = (e)\left((-2) - (-4)\right) = 2\ eV$. Since the potential energy change is positive, so was the work done by the external agent. As the force pushes the object to the right, the applied force must be to the right, meaning that the electric force (and therefore field) in this region of space is to the LEFT to resist the applied force (from $\vec{F} = q\vec{E}$).

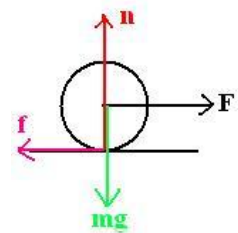
38. B… METHOD #1: Try a concrete example… choose $v_1 = 2\frac{m}{s};\ v_2 = 1\frac{m}{s};\ \ a_1 = 1\frac{m}{s^2};\ a_2 = 2\frac{m}{s^2}$
Equating velocity expressions $(v_f = v_i + aT)$ for the two objects gives
$v_{1f} = v_{2f} \ \ \rightarrow \ \ 2 + 1T = 1 + 2T \ \ \rightarrow T = 1s$. So, we can then write the changes in position as
$\Delta x_1 = v_1T + \frac{1}{2}a_1T^2 = 2 \cdot 1 + \frac{1}{2}1 \cdot 1^2 = \frac{5}{2}m$ and $\Delta x_2 = v_2T + \frac{1}{2}a_2T^2 = 1 \cdot 1 + \frac{1}{2}2 \cdot 1^2 = 2m$.
So, the ratio of distance traveled is $\frac{\Delta x_2}{\Delta x_1} = \frac{2}{5/_2} = \frac{4}{5}$

METHOD #2: For object 1, we will write expression for constant acceleration kinematics as $\Delta x_1 = v_1T + \frac{1}{2}a_1T^2$ and $v_{1f} = v_1 + a_1T$. We write corresponding expressions for Object 2: $\Delta x_2 = v_2T + \frac{1}{2}a_2T^2$ and $v_{2f} = v_2 + a_2T$. Using the information about the speed and acceleration allows us to write $v_{1f} = 2v_2 + \frac{1}{2}a_2T$ and since $v_{1f} = v_{2f}$, we equate our expressions to yield $v_{1f} = v_{2f} \ \ \rightarrow 2v_2 + \frac{1}{2}a_2T = v_2 + a_2T \ \rightarrow v_2 = \frac{1}{2}a_2T$. We now take the ratio of the required expressions to yield $\frac{\Delta x_2}{\Delta x_1} = \frac{v_2T + \frac{1}{2}a_2T^2}{v_1T + \frac{1}{2}a_1T^2} = \frac{\frac{1}{2}a_2T^2 + \frac{1}{2}a_2T^2}{2v_2T + \frac{1}{2}\left(\frac{1}{2}a_2\right)T^2} = \frac{a_2T^2}{a_2T^2 + \frac{1}{4}a_2T^2} = \frac{1}{5/_4} = \frac{4}{5}$

39. **A…** The induced current in the solenoid wraps from behind the solenoid to in front of the solenoid. This means that the induced magnetic field (from the right hand rule) is directed to the right in the solenoid (the right end of the solenoid is modeled with a N pole). This field fights the change in field from the motion of the bar magnet… which is increasing in strength. This means that a North directed field must be nearing the solenoid… The ?? is a North Pole. Since the North end of the magnet is now approaching the North end of the solenoid… the two poles repel producing a force on the solenoid from the magnet directed to the right.

40. **B…** Drawing the FBD of the cylinder gives 4 forces (applied, gravitational, normal, friction). As for the direction of the friction force… as viewed from your (the reader's) point of view from the center of the cylinder, the cylinder will rotate in a clockwise manner. This means that from the center of the cylinder, the friction must point to the left in order to produce a torque to rotate the cylinder.

METHOD #1: So, by writing expressions for both force and torque from the center, we have $F_{net} = ma \;\rightarrow\; F - f = Ma$ and $\tau_{net} = I\alpha \;\rightarrow fR = \left(\frac{1}{2}MR^2\right)\alpha$. Since the object is rolling without slipping here, we can equate $a = R\alpha$. Substituting this in the torque expression gives $fR = \frac{1}{2}MRa \;\rightarrow f = \frac{1}{2}Ma \;\rightarrow a = \frac{2f}{M}$. Substituting this in for the force equation, we have $F - f = Ma \;\rightarrow F - f = 2f \;\rightarrow F = 3f \;\rightarrow f = \frac{F}{3}$.



METHOD #2: We write the torque from the instantaneous axis of rotation on the ground yielding $\tau_{net} = I\alpha \;\rightarrow FR = \left(\frac{3}{2}MR^2\right)\alpha \rightarrow F = \frac{3}{2}Ma \;\rightarrow a = \frac{2F}{3M}$ where the parallel axis theorem was employed to determine the moment of inertia of the cylinder as $I = I_{cm} + MR^2 = \frac{3}{2}MR^2$. Now, into Newton's Second Law, we obtain $F - f = Ma \;\rightarrow F - f = \frac{2F}{3} \;\rightarrow f = \frac{F}{3}$.

41. **C…** The rate at which energy is radiated from a sample is given by the expression $P = \sigma AeT^4$ where the surface area is given as A. Since the diameter increases, and the surface area is proportional to the diameter squared, the radiation rate increases by a factor of $2^2 = 4$.

42. **B…** The angular momentum of the system is constant since there is no net external torque (since there are no net external forces acting on the comet-sun system). As the comet comes closer to the sun, its speed will increase (increasing the kinetic energy) which means from mechanical energy conservation that the potential energy of the system will correspondingly decrease.

43. **E…** Writing Newton's Second Law for this scenario, we have $F_{net} = ma = m\frac{v^2}{r} = qvB \rightarrow mv = qBr$. From this analysis, we see immediately that $p = mv$ is the same for the charges since q,B, and r were all given as identical. This means neither the mass nor the speed have to be the same as long as the product of these quantities is the same. This leads to the conclusions that the other choices are not *necessarily* the same for the ions.

44. **C…** Radioactive decay obeys $\mathrm{N} = \mathrm{N_0 e^{-\lambda t}}$ leading to $\frac{N_0}{2} = \mathrm{N_0 e^{-\lambda(100)}} \;\rightarrow -\lambda(100) = \ln\frac{1}{2} \;\rightarrow \lambda = \frac{\ln 2}{100}$. Hence, $\mathrm{N} = (10000)\mathrm{e}^{-\frac{\ln 2}{100}(250)} = 1767.8$ which is approximately 1770 molecules.

45. **D… METHOD #1:** The rate at which energy is stored is the power which is calculated as $P = I\,\Delta V$. When the current in the circuit is 0.40A, this makes the voltage across the resistor $\Delta V = IR = 4.0\ v$. From Kirchhoff's Loop Rule, the voltage across the inductor is 8.0 volts. Hence, the power associated with the inductor is therefore $P = I\,\Delta V = (0.40)(8.0) = 3.2\ W$.

METHOD #2: The power associated with the battery at the instant in question is $P = I\,\Delta V = (0.40A)(12\ v) = 4.8\ W$. The power associated with the resistor is given as $P = I^2R = (0.40\ A)^2(10\ \Omega) = 1.6\ W$. From energy conservation, the leftover power is being stored in the inductor giving $P_{inductor} = P_{Bat} - P_R = 4.8W - 1.6\ W = 3.2\ W$

46. **B…** Balancing the values in the reaction, there are 22 nucleons on both sides (the electron neutrino has no nucleons), so X has no nucleons. The lower number in the reaction starts as 11 on the left side and decreases by 1 to 10 on the right side. Hence, we write X as ${}_{-1}^{0}X = {}_{-1}^{0}e$ which is an electron. This reaction would be an example of electron capture.

47. A… We start with kinematics to determine the flow speed out of the hole. From the information given, we compute the time of flight of the fluid from the vertical motion (noting the initial vertical component of velocity is zero) to be $\Delta y = v_{oy}t + \frac{1}{2}a_y t^2 \to t = \sqrt{\frac{2\Delta y}{-g}} = \sqrt{\frac{2H}{g}}$. Now using the horizontal component of kinematics (with no acceleration) we have $\Delta x = v_{ox}t + \frac{1}{2}a_x t^2 \to H = v_{0x}\sqrt{\frac{2H}{g}} \to v_{0x} = \sqrt{\frac{gH}{2}}$. Now, using Bernoulli's Equation at the top of the container and at the opening, and noting that 1) since everything is open to the atmosphere that the pressure at both places is (approximately) the same and that 2) the area of the top opening is very large compared to the small opening, then the speed at which the fluid moves at the top of the container is negligible, we have $\rho g y_{Top} = \rho g y_{Bottom} + \frac{1}{2}\rho v^2 \to (y_{Top} - y_{Bottom}) = L = \frac{v^2}{2g} = \frac{1}{2g}\frac{gH}{2} = \frac{H}{4}$.

48. C… Incoming photons having enough energy to produce photoelectrons must have at least as much energy as the work function. Hence, by writing the work function to be less than or equal to the photon energy, we find a condition on the wavelength as $\phi \le hf = \frac{hc}{\lambda} \to \lambda \le \frac{hc}{\phi} = \frac{(4.14 \times 10^{-15} eV \cdot s)(3.0 \times 10^8 m/s)}{4.80\ eV} = 2.59 \times 10^{-7} m = 259\ nm$. This means that photoelectrons will have increasing kinetic energy as the wavelength becomes smaller. Of the choices provided, answer (C) is the largest wavelength that will still produce photoelectrons, meaning that these photoelectrons have the least kinetic energy.

49. A… The efficiency of the engine is computed as $e = \left|\frac{W}{Q_h}\right|$. The work done is related to the area the curve which is given as $(2P_0 - P_0)\left(\frac{3}{2}V_0 - V_0\right) = \frac{1}{2}P_0V_0 = \frac{1}{2}nRT_0$. The heat that enters the engine comes during stages $A \to B$ and $B \to C$. To determine the heat for each process, we use $Q_{AB} = nc_v\Delta T$ and $Q_{BC} = nc_p\Delta T$. From the ideal gas equation, the temperature doubles from A to B because the pressure doubles at constant volume. By the same logic, the temperature increases by 3/2 from B to C since the pressure is constant with an increasing volume. We then write $Q_{AB} = nc_v\Delta T = n\left(\frac{3}{2}R\right)(2T_0 - T_0) = \frac{3}{2}nRT_0$. Likewise, $Q_{BC} = nc_p\Delta T = n\left(\frac{5}{2}R\right)(3T_0 - 2T_0) = \frac{5}{2}nRT_0$. This makes the total heat added equal to $Q_h = \frac{5}{2}nRT_0 + \frac{3}{2}nRT_0 = 4nRT_0$. Hence, the efficiency is $e = \left|\frac{W}{Q_h}\right| = \frac{1/2\, nRT_0}{4nRT_0} = \frac{1}{8}$.

50. D… One must conserve linear momentum and total energy… except that the speed $2.4 \times 10^8\ m/s = (0.8\ c)$ involved requires special relativity. So we note that the rest mass of the conglomerate object after collision is *not* 2m… Let's call it M. We start by computing the Lorentz Factor (with $\beta = v/c$) as $\gamma = \frac{1}{\sqrt{1-\beta^2}} = \frac{1}{\sqrt{1-(0.8)^2}} = \frac{5}{3}$ and then use Conservation of Linear Momentum to give $\gamma mv = \gamma' Mv_f \to \gamma m(0.8c) = \gamma' Mv_f \Rightarrow \frac{5}{3}m(\frac{4}{5}c) = \frac{4}{3}mc = \gamma' Mv_f$

From here, we now write the Conservation of Energy to obtain

$$E_i = E_{moving\ m} + E_{non-moving\ m} = \gamma mc^2 + mc^2 = \left(\frac{8}{3}\right)mc^2 = E_f = \gamma' Mc^2 \Rightarrow \quad \gamma' M = \frac{8}{3}m$$

Substitution of these expressions yields

$$\frac{4}{3}mc = \gamma' Mv_f = \left(\frac{8}{3}m\right)v_f \Rightarrow v_f = \frac{4}{8}c = 1.50 \times 10^8\ \frac{m}{s}$$