Second sample final exam answer key

1. A sealed can is cooled from 273 K to 77 K. What happens to the pressure in the can if the process is isochoric (also called isovolumetric)?

a) it doubles b) it increases by some factor other than 2 c) it is halved

d)* it decreases by some factor other than 2 e) it is unchanged

The ideal gas law $PV = nRT$ implies that at constant volume the pressure P and the temperature T are linearly related. The pressure *decreases* by a factor $273/77 \approx 3.5$.

2. How much heat in kilocalories is needed to convert 1 kg of ice at 0 degrees C into 1 kg of steam at 100 degrees C? ($L_{ice} = 80$ cal/gr, $L_{steam} = 540$ cal/gr)

a) 640 b) 180 c)* 720 d) 360 e) 620

One must first melt the ice into water (80 kilocalories), raise that amount of water by 100 Centigrade degrees (100 kc), and then turn that amount of water into steam (540 kc).

3. Five moles of an ideal gas expands isothermally at 100 degrees C to five times its initial volume. How much heat (in Joules) flows into the system?

a) 2.5×10^4 b)* 1.1×10^4 c) 6.7×10^3 d) 2.9×10^3 e) 7.0×10^2

The gas does work ($W = nRT \log V_2/V_1$) in a the isothermal expansion. By the first law of thermodynamics ($Q = W + \Delta E$), the work must be equal to the heat which flows in since the internal energy stays constant for isothermal processes. $Q = 5 \times 8.31 \times 373 \times \log 2 = 1.1 \times 10^4$ J.

4. A refrigerator is set in the middle of an insulated room on a hot day. The door of the refrigerator is left open in an effort to cool down the room. What actually happens to the room temperature?

a) Nothing b) It decreases c)* It increases d) Impossible to say

e) It first increases and then it decreases later.

The refrigerator motor is attempting to remove heat from the inside of the refrigerator. It then transfers that amount of heat plus the work required to the "outside". In this case the "outside" is still the insulated room, so the temperature must go up.

5. A device that partially converts thermal energy into useful work is called

a) a perpetual motion machine b) a violation of thermodynamics c)* a heat engine

d) a refrigerator e) a heat pump

Note the word *partially* here since by the Second Law of Thermodynamics a given amount of heat can never be completely transformed into useful work.

6. A Carnot engine has a 0.35 efficiency factor and an exhaust temperature of 270 K. What is the high temperature operating point of this engine, in Kelvin?

a)* 420 b) 390 c) 430 d) 380 e) 440

The Carnot efficiency is $\epsilon = (T_H - T_C)/T_H \Longrightarrow T_H = T_C/(1-\epsilon) = 270/.65 = 415$ K.

Second sample final exam answer key

7. A which point on this velocity-time graph is the acceleration 0?

a) A b) B c)* C d) D e) E

This is the only flat portion of the curve meaning that the speed is constant which is the same as zero acceleration in one dimension.

8. At t = 1.8 s a particle moving with constant velocity is at $x = 5.2$ m. At $t = 3.2$ s the particle is at $x = 8.1$ m. What is its speed in m/s?

a) 1.4 b) 1.5 c)* 2.1 d) 3.2 e) 4.2

The speed $v = \Delta x/\Delta t = (8.1 - 5.2)/(3.2 - 1.8) = 2.1$ m/s.

9. A 2 kg car collides elastically with an 8 kg cart. Which cart experiences the greater average force during the collision?

a) the 2 kg car b) the 8 kg cart c) the average force is 0 d) it is impossible to say
e)* the forces are equal in magnitude and opposite in direction

Answer is by Newton's Third Law for Action-Reaction force pairs. Note that you cannot add up the forces to get 0 since they act on different bodies.

10. Stars originate as large bodies of slowly rotating gas which collapses because of gravitational attraction. The angular velocity of the star is greater than that of the rotating gas. Why?

a) no one knows for sure b) conservation of linear momentum c) conservation of energy
d)* conservation of angular momentum e) the Bohr model

For the same reason all the planets in the solar system travel in the same plane in the same direction so that their angular momentum vector is in the same direction. Pluto is the one slight exception.

11. Two observers are traveling towards each other at a speed of $.49c$ each. Observer A sends a pulse of light towards observer B. Observer B will measure the light speed as

a) $0.49c$ b) $0.98c$ c)* c d) 0 e) $1.98c$

The Second Special Relativity Postulate says that all observers measure the same value for c independent of their motion or the motion of the light source.

12. A planet has the same mass as the Earth but its radius is one-third that of the Earth. The acceleration due to gravity at this planet's surface will be

a) $g/9$ b) $g/3$ c) g d) $3g$ e)* $9g$

From Newton's Law of Universal Gravity $F_G = GMm/r^2$, if one drops the radius by one-third, the denominator drops by one-ninth resulting in nine times the weight force at the planet's surface.

Second sample final exam answer key

13. A fish which weighs 10.0 N is placed in an elevator accelerating upward at 2.6 m/s^2. What would its apparent weight be in this moving elevator (answer in N)?

a) 7.35 b) 10.7 c) 11.7 d)* 12.7 e) 13.7

The upward acceleration of the elevator, 2.6 m/s^2, effectively adds to the normal g value of 9.8 m/s^2. So the apparent weight becomes $w' = (12.4/9.8)10 = 12.7$ N.

14. A 15 kg block is resting on a rough horizontal surface. A minimum of 25 N must be exerted to get the block moving. What is the coefficient of static friction between the block and the surface?

a) 0.12 b) 0.15 c)* 0.17 d) 0.19 e) 0.21

The 25 N is the force necessary to overcome the maximum static friction force

$$f_s^{max} = 25 = \mu_s N = \mu_s w = \mu_s(15)(9.8) \Longrightarrow \mu_s = \frac{25}{(15 \times 9.8)} = 0.17$$

15. Tarzan is located 12 m above the Earth's surface. He swings down on a vine but brushes by some branches on the way down such that his speed at the lowest point is 5 m/s less than it would normally be. How far up (in meters) will he swing on the other side?

a) 7.32 b)* 5.45 c) 5.93 d) 4.84 e) 4.57

Without any friction (brushing the branches) Tarzan's speed at the bottom of his swing would be $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 12} = 15.3$ m/s. That is decreased to 10.3 m/s according to the problem, so he will reach a height $h = v^2/(2g) = (10.3)^2/(19.6) = 5.45$ m.

16. Vector $\vec{A}$ is $-2\,\hat{\mathbf{j}}$ and vector $\vec{B}$ is $-3\,\hat{\mathbf{i}}$ What is the direction of $\vec{B} \times \vec{A}$?

a) $\hat{\mathbf{j}}$ b) $\hat{\mathbf{i}}$ c)* $\hat{\mathbf{k}}$ d) $-\hat{\mathbf{k}}$ e) $-\hat{\mathbf{i}}$

$$\vec{B} \times \vec{A} = -3\,\hat{\mathbf{i}} \times -2\,\hat{\mathbf{j}} = 6\,\hat{\mathbf{k}}$$

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17. A 16 N suitcase and a 64 N suitcase fall off a loading cart. What is their ratio of accelerations due to gravity?

a)* 1:1 b) 1:4 c) 1:8 d) 1:16 e) 1:32

The acceleration due to gravity is the same for all masses.

18. A 5.0 kg mass moves in a circle of radius 0.70 m. If the maxium centripetal force which can be endured by the sample is 120 N, what is the maximum speed the object can have? (in m/s)

a) 14.2 b) 14.8 c) 15.2 d)* 16.8 e) 4.1

$$F_c = \frac{mv^2}{r} \Longrightarrow v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{120 \times 0.70}{5.0}} = 16.8 \text{ N}$$

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Second sample final exam answer key

1. A train is moving along a straight, horizontal track at a constant speed of 20 m/s. From a flatcar on the train a small cannon fires a projectile at an elevation angle of 60 degrees above the horizontal. The exit speed of the projectile, relative to the cannon, is 15 m/s. (Use Classical Mechanics, not Special Relativity, in this problem.)

a) What is the **velocity** of the projectile relative to the tracks? (5 points)

Since **velocity** is a vector, we need to given a magnitude and a direction, or the horizontal and vertical components with respect to the tracks. The vertical component v_y is given by

$$v_y = v_0 \sin \theta_0 = 15 \times \sin 60 = 13.0 \text{ m/s}$$

where v_0 is the speed relative to the cannon.

The horizontal component is the speed relative to the cannon in the horizontal direction plus the speed of the cannon relative to the tracks:

$$v_x = v_0 \cos \theta_0 + 20 = 15 \times \cos 60 + 20 = 27.5 \text{ m/s}$$

Specifying v_x and v_y in this manner is sufficient to determine the velocity. One could also get the magntitude and direction

$$v = \sqrt{v_x^2 + v_y^2} = \sqrt{(13.0)^2 + (27.5)^2} = 30.4 \text{ m/s}$$

$$\theta = \tan^{-1}(13/27.5) = 25^{\text{O}}$$

b) How much time will it take the projectile to reach its highest point in its trajectory (5 points)?

Compute the time it takes for the vertical speed to go to 0 from its initial value of 13.0 m/s:

$$v_y(t) = 0 = v_{0y} - gt = 13.0 - 9.8t \Longrightarrow t = 13.0/9.8 = 1.33 \text{ seconds}$$

c) How far away, in the horizontal direction, will the projectile land with respect to the horizontal position at which it was fired (ignore any height difference between the cannon and the tracks; 5 points)?

The total time in flight is twice the time in part b) = 2.65 s. Multiply that time by the constant horizontal speed, 27.5 m/s, to get the total horizontal distance travelled

$$x(t = 2.65) = v_{0x}t = 27.5 \times 2.65 = 72.9 \text{ m}$$

Second sample final exam answer key

2. A 0.5 kg mass hangs from a light string which is wound around the rim of a wheel with an 0.18 m radius. The wheel rotates on a frictionless horizontal axle through its center. The 0.5 kg mass is released from rest and is observed to fall a distance of 4.0 m in 2.0 seconds.

a) From what is stated directly in the problem, compute the constant linear acceleration a of the mass (2 points).

The particle falls a distance of 4.0 m in 2.0 seconds at constant acceleration:

$$y(t) = 4.0 = \frac{1}{2}at^2 \Longrightarrow a = \frac{8}{4} = 2 \text{ m/s}^2$$

b) In terms of the weight of the mass m and the tension T in the string write Newton's Second Law for the constant linear acceleration a of the mass (4 points).

There are two forces, w and T acting in opposite directions on m. Newton's second law then becomes

$$F = w - T = ma$$

From this answer and the previous answer you can get T right away as

$$T = w - ma = 5.0 \times 9.8 - 5.0 \times 2 = 39.0 \text{ N}$$

c) In terms of the tension T in the string, the radius R of the wheel, and the unknown moment of inertia I of the wheel, write Newton's Second Law for the constant angular acceleration α of the wheel (4 points).

The tension T is exerting a torque $\tau = TR$ on the wheel. The Newton's Second Law for rotation says that the torque is equal to the momentum of inertia times the angular acceleration:

$$\tau = TR = I\alpha$$

d) What is the relationship between the linear acceleration a of the mass and the angular acceleration α of the wheel, assuming that there is no slipping of the string (2 points)?

For no slipping we have

$$a = R\alpha$$

From what we are given for R and what we have determined for a we can get the value of α

$$\alpha = \frac{a}{R} = \frac{2}{0.18} = 11.1 \text{ rad/s}$$

e) Using all the previous answers, compute I the value the moment of inertia of the wheel (3 points).

From part c)

$$I = \frac{TR}{\alpha} = \frac{39.0 \times 0.18}{11.1} = 0.63 \text{ kg-m}^2$$

3. Two moles of an ideal gas are put through a closed cycle represented by points A, B, and C in a two dimensional P vs. V diagram. From A to B there is an isothermal expansion from a volume of 2.0 m^3 to a volume 12.0 m^3. From B to C there is a contraction at constant pressure from 12.0 m^3 back to 2.0 m^3. And from point C back to the original starting point A there is an increase in pressure back to the original pressure which was 3×10^5 Pa.

a) What is the absolute temperature at points A and B (4 points)?

We are given P_A and V_A at point A, so we can use the ideal gas law to determine the absolute temperature T_A

$$PV = nRT \Longrightarrow T_A = \frac{P_A V_A}{nR} = \frac{3 \times 10^5 \times 2}{2 \times 8.31} = 36,101 \text{ K}$$

Since point B is on the same isothermal curve as point A, then $T_B = T_A$

b) What is the pressure at points B and C (4 points)

Knowing the temperature T_B and the volume V_B, we can compute the pressure P_B from the ideal gas law:

$$P_B = \frac{nRT_B}{V_B} = \frac{2 \times 8.31 \times 36101}{12} = 50,000 \text{ Pa}$$

The process point B to point C is isobaric, so $P_C = P_A$.

c) How much work was done by the gas in going from point A to point B (4 points)?

Use the formula for work done in an isothermal expansion

$$W_{AB} = nRT \ln \frac{V_B}{V_A} = 2 \times 8.31 \times 36101 \times ln6 = 1.07 \times 10^6 \text{ J}$$

d) What was the net total work in this cycle (3 points)?

In compressing from point B to point C, work is done *on* the gas meaning negative work. Since this is done at constant pressure, it is easy enough to calculate

$$W_{BC} = \int P\,dV = \text{ (for constant pressure) } W = P\Delta V = 50,000 \times (-10) = -5.0 \times 10^5 \text{ J}$$

So the total work done is

$$W_{total} = W_{AB} + W_{BC} = 1.07 \times 10^6 - 5.0 \times 10^5 = 5.7 \times 10^5 \text{ J}$$

4. A projectile of mass m is moving with a constant speed v_0 in the $+x$ direction. Suddenly it ejects a particle with a mass $0.1m$ leaving it with $0.9m$ remaining. A student observes that the ejected mass is traveling in the $+y$ direction with a speed of $3v_0$.

a) What is the x velocity component of the $0.9m$ mass after the ejection occurs (5 points)?

LInear momentum is conserved in this problem in both the x and the y directions. The initial momentum is all in the x direction:

$$p_x = mv_x = m \times v_0$$

Since the $0.1m$ is moving only in the y direction, all the x momentum component must be in the $0.9m$

$$0.9mv'_x = mv_0 \Longrightarrow v'_x = \frac{v_0}{0.9} = 1.1v_0$$

b) What is the y velocity component of the $0.9m$ mass after the ejection occurs (5 points)?

Since there was no y component of momentum in the beginning, the total y component of momentum must be zero at the end. This means that the $0.9m$ has a y component of momentum equal and opposite to the y component of momentum of the $0.1m$

$$0.9mv'_y = 0.1m3v_0 \Longrightarrow v'_y = .33v_0$$

c) Does this process conserve translational kinetic energy, and if not by how much is the kinetic energy changed (5 points)?

The kinetic energy in the beginning is

$$K_1 = \frac{1}{2}mv_0^2 = 0.5mv_0^2$$

The kinetic energy at the end is

$$K_2 = \frac{1}{2}(0.9m)((1.1v_0)^2 + (0.33v_0)^2) + \frac{1}{2}(0.1m)(3.0v_0)^2 = 1.05mv_0^2$$

So kinetic energy is *not* conserved in this process, and the kinetic energy just about doubles.

5. In a TV set an electron $m_e = 9.1 \times 10^{-31}$ kg is accelerated from rest to a speed of 4.0×10^7 m/s in a time of 0.5 nanoseconds.

(Note: most of you realized that there was a negative sign left off the exponent in the electron's mass. The correct mass value was also given on the cover page of the exam. If you did not notice the error, no points are deducted but your answers will be 62 orders of magnitude higher.)

a) How much work was done on the electron to give it this speed (use Classical Mechanics; 4 points)?

$$\Delta W = \Delta K.E. = \frac{1}{2}mv^2 = \frac{1}{2}9.1 \times 10^{-31} \times (4.0 \times 10^7)2 = 1.82 \times 10^{-23} \text{ J}$$

b) What was the average power expended during the acceleration process (4 points)?

$$\overline{P} = \frac{\Delta W}{\Delta t} = \frac{1.82 \times 10^{-23}}{0.5 \times 10^{-9}} = 3.64 \times 10^{-14} \text{ W}$$

c) Compare the Classical Mechanics and the Special Relativity values of the linear momentum of the electron after the acceleration process (4 points)?

$$\text{Classical Mechanics:} \quad p = mv = 9.1 \times 10^{-31} \times 4.0 \times 10^7 = 3.72 \times 10^{-23} \text{ kg-m/s}$$

(*Note: Physics 116a students in 2008 do not have to know relativity in the first semester.*)

$$\text{Special Relativity:} \quad p = \gamma mv = \frac{1}{\sqrt{1 - v^2/c^2}}mv$$

For this case

$$\gamma = \frac{1}{\sqrt{1 - (4 \times 10^7)^2/(3 \times 10^8)^2}} = 1.009$$

So the relativistic momentum value is about 1% higher than the classical value.

(*Note: Physics 116a students in 2008 do not have to know relativity in the first semester.*)

d) Compare the average force on the electron using Classical Mechanics and Special Relativity (*HINT: Use the same Δt in both cases;* 3 points)

The alternate from of Newton's Second Law is Force equals the time rate of change of momentum. For the Classical Mechanics value we have

$$F = \frac{dp}{dt} \Longrightarrow \overline{F} = \frac{\Delta p}{\Delta t} = \frac{3.72 \times 10^{-23}}{0.5 \times 10^{-9}} = 7.44 \times 10^{-14} \text{ N}$$

The Special Relativity Force value will again be the Lorentz factor γ times the Classical Mechanics value, meaning here about 1% higher.