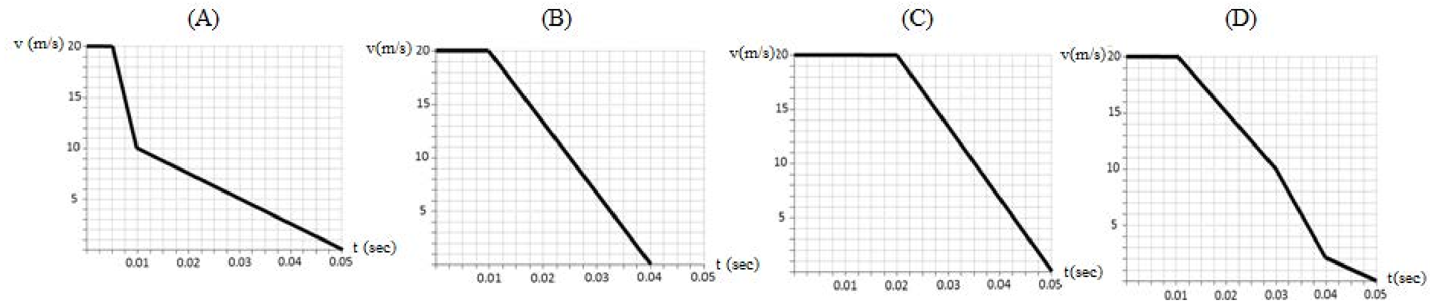
PHYSICS I Salmon Exam

JANUARY 12, 2017

Directions: For each question or statement fill in the appropriate space on the answer sheet. Use the letter preceding the word, phrase, or quantity which best completes or answers the question. Each of the 25 questions is worth 4 points.

Use: g = -10 m/s*^{2} *and the vertically upward direction is positive unless specifically stated otherwise.
Ignore air resistance unless specifically stated otherwise. ***Corrections***

Use the following information for Questions #1 - #3. In light of the Takata™ airbag debacle during this past year where more than 100 million defective airbags have been recalled, the NHTSA (*National Highway Transportation Safety Administration*) tested several other airbags to replace the recalled Takata™ ones. Following are four graphs indicating the velocity of identical crash test dummies (sensors placed on the dummy forehead) in identical cars under identical parameters as a function of time after the test vehicle crashes into a brick wall. The initial speed of the car/crash test dummy head in each case is 20 m/s and time ***t*** = 0 represents the instant of impact.



1. Which of the four airbags shown provided the **smallest average deceleration** for the test dummy after contact with the airbag?
(A) A (B) B (C) C (D) D

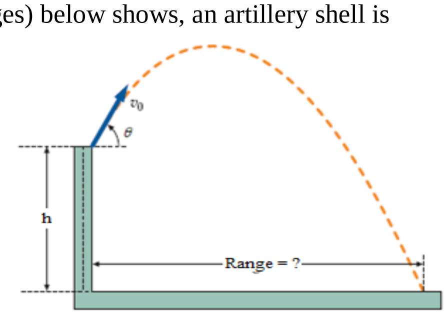
2. Which of the four airbags shown provided the **largest magnitude of displacement** for the test dummy's head from ***t*** = 0 to ***v*** = 0?
(A) A (B) B (C) C (D) D

3. Note that in all four cases the velocity of the dummy's head does not decrease at the instant of the collision, ***t*** = 0 seconds. What is a good physics reason for this?
(A) The sensors for the airbag are programmed to inflate in that amount of time.
(B) Due to Newton's First Law of Motion, the airbag needs time to stop moving forward first before it can inflate.
(C) Due to Newton's First Law of Motion, the crash test dummy's head continued forward at the initial speed until making contact with the airbag.
(D) Due to Newton's Third Law of Motion, the crash test dummy's head continued forward at the initial speed until making contact with the airbag.

4. During the recent classic duel between the Chicago Cubs and the Cleveland Indians in the 2016 baseball World Series, Cubs relief pitcher Aroldis Chapman threw a fastball at exactly 100 miles per hour (161 km / hr). The batter, Indians' rookie Francisco Lindor, hit the ball directly back toward the pitcher at a speed of 120 miles per hour (193 km / hr). What was the average acceleration of the ball during the hit given that the ball and bat were in physical contact for exactly 0.7 milli-seconds? *Use the direction from the pitcher to the batter as the positive direction.*

(A) $1.4x10^2 \; {}^{m}/_{s^2}$ (B) $-1.4x10^2 \; {}^{m}/_{s^2}$ (C) $1.4x10^5 \; {}^{m}/_{s^2}$ (D) $-1.4x10^5 \; {}^{m}/_{s^2}$

Use the following information for Questions #5 - #7. As the image (stolen from Google® images) below shows, an artillery shell is fired from a vertical cliff, from a height ***h***,140 meters above a canyon floor. The initial speed of the shell upon leaving the barrel $\boldsymbol{v_o}$ is 100 m/s and the barrel is aimed at an angle $\boldsymbol{\theta}$, 37^o above the horizontal. NOTE: Use $\sin 37^o = 0.6$ and $\cos 37^o = 0.8$.



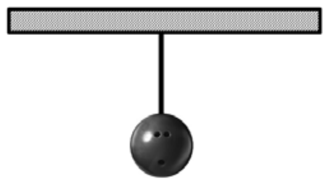
5. How long is the shell in the air between leaving the end of the barrel and striking the ground below?
(A) 2 seconds (B) 5.3 seconds (C) 14 seconds (D) 17.6 seconds

6. What is the horizontal distance (Range) the shell travels?
(A) 840 m (B) 1120 m (C) 1400 m (D) 2800 m

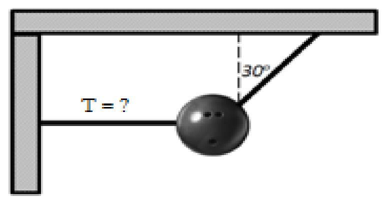
7. With what final *vertical* velocity does the shell strike the ground?
(A) -60 m/s (B) -70 m/s (C) -80 m/s (D) -90 m/s

8. Two identical massive objects are falling from the top of the Leaning Tower of Pizza after John Galileo drops them in an experiment. After falling exactly halfway down to the level ground, someone leans out a window and nudges one of the objects horizontally thus imparting it with a horizontal velocity. The other object continues its true vertical path to the ground. Which statement below is **correct** concerning the "**nudged**" object?
(A) It strikes the ground after the unencumbered object. (B) It strikes the ground at the same time as the unencumbered object.
(C) It follows a straight line path at an angle to the ground. (D) It strikes the ground before the unencumbered object.

9. A bowling ball is suspended by a thick string from a ceiling as shown below. If the "action" force is gravity from the Earth pulling the ball downward, the "reaction" force is
(A) the string pulling upward on the ball. (B) the ball pulling down on the string.
(C) the ceiling pulling upward on the string (D) the ball pulling upward on the Earth

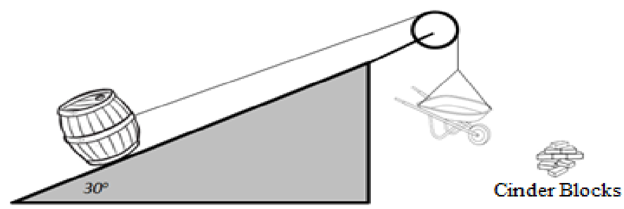


10. The same 4-kg bowling ball pictured in #9 above is now suspended by two strings as depicted below. What is the tension, ***T***, in the horizontal string?
(A) 12 N (B) 23 N
(C) 40 N (D) 80 N



Use the following information for Questions #11 & #12. A non-physics trained worker named Bobo is tasked with raising a heavy water barrel and devises the system shown below. The water barrel has a total mass of 300-kg. (Don't ask why he doesn't raise the *empty* container first then fill it…) Over the right side of the constructed ramp he attaches a large wheelbarrow into which Bobo plans to place cinder blocks until the water barrel is pulled up to the top of the ramp. Each cinder block has a mass of 10-kg and the wheel barrow also has a mass of 10-kg. The coefficients of static and kinetic friction are 0.7 and 0.4 respectively.

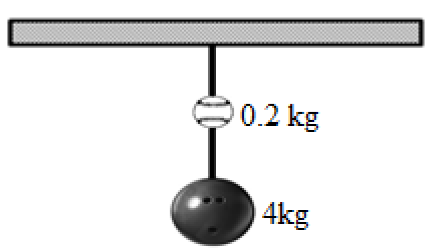
11. What is the **maximum number** of cinder blocks Bobo can place in the wheel barrow without causing the water container to move upward?
(A) 30 (B) 32
(C) 33 (D) 40



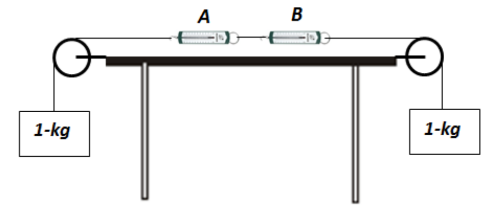
12. Bobo places just one more cinder block in the wheelbarrow than you determined in #11 above and the water barrel begins to move up the ramp. When the water barrel is about half-way up the ramp, Bobo decides to throw in one more block to make it move faster. Unfortunately, Bobo didn't use a strong enough rope and it snaps. With what acceleration does the water barrel slide down the ramp?
B not D
(A) $0.5\,{}^{m}/_{s^2}$ (B) $1.0\,{}^{m}/_{s^2}$ (C) $1.5\,{}^{m}/_{s^2}$ (D) $2.0\,{}^{m}/_{s^2}$

13. Below is a strange physics demo set-up your teacher wants you to think about. Our 4-kg bowling ball is suspended from a 0.2-kg softball which is suspended from the ceiling. Before your teacher can do the planned demo, the top string snaps and both objects and the still-intact string between them fall to the ground. What is the **tension in the string between the balls** as they fall to the ground?

(A) $0N$ (B) $4N$
(C) $38N$ (D) $40N$



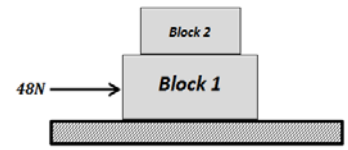
14. As shown below, two identical 1-kg masses are suspended by strings over frictionless massless pulleys. Each string is attached to two identical spring scales, labeled ***A*** & ***B***, on the tabletop. The spring scales are then attached to each other. Once assembled and released, the system surprisingly remains at rest. Which of the following choices represents the spring scale readings?



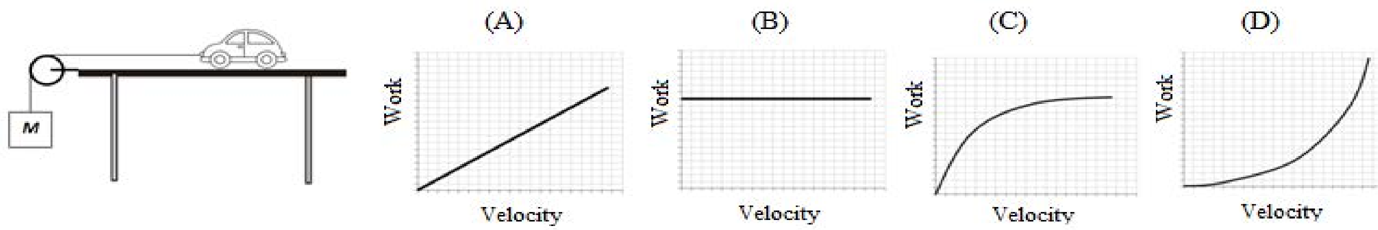
	Spring ***A***	Spring ***B***
(A)	0	0
(B)	5-N	5-N
(C)	10-N	10-N
(D)	20-N	20-N

15. As shown below, a 4-kg block, Block 2, is placed on top of a 12-kg block, Block 1. There is no friction between the surface and Block 1, but there is friction between the blocks themselves. A 48-N force is applied directly to the bottom block. What is the minimum coefficient of static friction between the blocks in order for the top block to move with Block 1 with no slippage?

(A) 0.1 (B) 0.3
(C) 0.5 (D) 0.7



16. As shown below, a toy car is at rest on a frictionless table. It is attached to a string which in turn is attached to a mass, ***M***, hanging from a frictionless pulley. When released from rest, which graph represents the relationship between the work done on the car as a function of the toy car velocity?

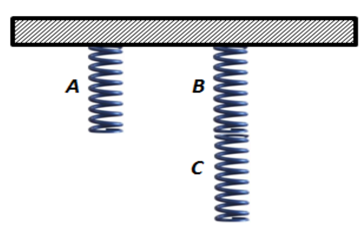


17. During Black Friday 2016, tens of thousands of shoppers descended on Westfield Garden State Plaza Mall in Paramus, NJ. Each escalator moving folks from the ground floor up to the 2nd floor 10-m above is designed to move 30 average people, of 75-kg each, per minute. What is the output power delivered by the escalator motor to do this assuming it operates at full capacity for one hour?

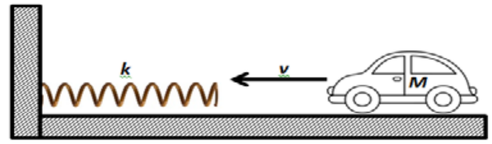
(A) 3.75×10^{3}W (B) 2.25×10^{5} W (C) 2.25×10^{6}W (D) 1.35×10^{7}W

18. An ideal spring with a pointer attached to its end is hung vertically next to a meter stick. When a 10-kg mass is attached to the spring, it stretches and the pointer is located at the 40-cm mark. When a 20-kg mass is used, the pointer is located at the 60-cm mark. An unknown mass causes the pointer to be located at 30-cm. What is this unknown mass? B is correct not D
(A) 2.5-kg (B) 5-kg (C) 7.5-kg ~~(D) 15-kg~~

19. You are given three **identical ideal springs** cleverly labeled ***A***, ***B***, & ***C***. They are arranged vertically as shown below with spring ***A*** alone and springs ***B*** & ***C*** connected. When a 4-kg mass is attached to the end of spring ***A***, it stretches a distance of 3-cm. If you attached a 6-kg mass to the end of spring ***C*** on the spring ***B/C*** combination, **how far would the mass descend**?
(A) 1.5-cm
(B) 3-cm
(C) 6-cm
(D) 9-cm



Use the following information for Questions #20 & #21: As shown below, a toy car of mass ***M*** is initially moving to the left with a speed v when it contacts and compresses a spring of constant ***k***.



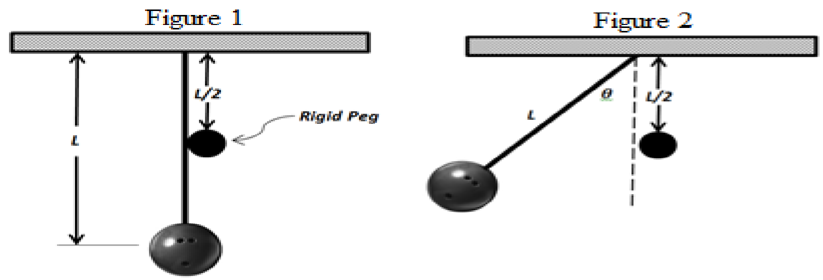
20. At the **instant** the kinetic energy of the car is equal to the potential energy of the spring, which expression below represents the distance the spring has compressed?

(A) $v\sqrt{M/2k}$ (B) $v\sqrt{M/k}$ (C) $Mv^2/4k$ (D) $\frac{1}{4}\sqrt{Mv/k}$

21. Which expression below represents the **maximum compression** of the spring?

(A) $v\sqrt{M/2k}$ (B) $v\sqrt{M/k}$ (C) $Mv^2/4k$ (D) $\frac{1}{4}\sqrt{Mv/k}$

Use the following information for Questions #22 & #23: The suspended bowling ball used in #9 earlier is now used as a pendulum. However, there is a horizontal rigid metal peg located at a distance of $L/2$ from the pivot point at the ceiling, as shown below in *Figure 1*. The ball is then pulled backward so the string makes an angle ***θ*** with the vertical, as shown in *Figure 2*. The ball is released from rest at that point. The string makes full contact with the rigid peg. Answers are in terms of ***L***, ***θ***, and ***g***.



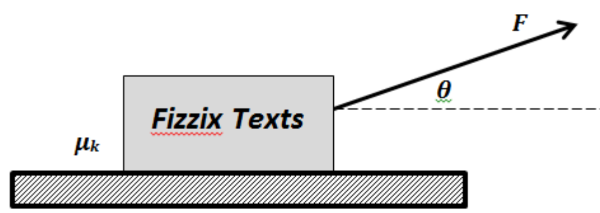
22. Which expression below represents the **speed of the ball** as it reaches the bottom of the swing?

(A) $\sqrt{2gL(1-\sin\theta)}$ (B) $\sqrt{2gL(1-\cos\theta)}$ (C) $\sqrt{2gL}$ (D) $\sqrt{gL/2}$

23. To what maximum height does the ball ascend on the right side of the swing?

(A) $L/2(1-\sin\theta)$ (B) $L/2(1-\cos\theta)$ (C) $L(1-\sin\theta)$ (D) $L(1-\cos\theta)$

Use the following information for Questions #24 & #25: Shown below, a box of unused Fizzix textbooks starts at rest and slides horizontally on a rough surface via the introduction of a force ***F*** acting upward at an angle ***θ*** to the horizontal. The box maintains full contact with the surface throughout. The coefficient of kinetic friction is μ_k, the box has a mass ***M***, and the box moves a through a displacement ***x***.



24. Which statement below is necessarily false about this situation?

(A) The Normal force between the box and the surface is not Mg.

(B) The work done by the force F is $Fx\cos\theta$.

(C) The acceleration of the box is $\frac{F\cos\theta-\mu_k(Mg+F\sin\theta)}{M}$.

(D) The change in the kinetic energy of the box is $(F\cos\theta-\mu_k(Mg-F\sin\theta))x$.

25. Given the following quantities, what is the value of the coefficient of kinetic friction, μ_k? Use $\sin 37^o = 0.6$ and $\cos 37^o = 0.8$.

(A) 0.2 (B) 0.4
(C) 0.5 (D) 0.6

F	200 N
M	20 kg
θ	37^o
a *(acceleration)*	$6\ m/s^2$

AP I and AP 2 PHYSICS FORMULAE Updated 12-16-2016

Constants & Conversion Factors

Proton and Neutron Mass	$m_p = 1.67x10^{-27} kg$	Fundamental charge	$e = 1.6x10^{-19} C$
Electron Mass	$m_e = 9.11x10^{-31} kg$	Electron Volt	$1eV = 1.6x10^{-19} J$
Avogadro's #	$6.02x10^{23} mol^{-1}$	Universal Gravitational constant	$G = 6.67x10^{-11} Nm^2/kg^2$
Universal gas constant	$R = 8.31 J/mol \cdot K$	Speed of Light	$c = 3.00x10^8 m/s$
Boltzmann's constant	$k_B = 1.38x10^{-23} J/K$	Magnetic constant	$k' = 1x10^{-7} T \cdot m/A$
1 unified atomic mass unit		$1u = 1.66x10^{-27} kg = 931 MeV/c^2$	
Planck's Constant		$h = 6.63x10^{-34} J \cdot s = 4.14x10^{-15} eV \cdot s$ $hc = 1.99x10^{-25} J \cdot m = 1240 eV \cdot nm$	
Coulomb's Law constant		$k = \frac{1}{4\pi\varepsilon_o} = 9.0x10^9 N \cdot m^2/kg^2$ $\varepsilon_o = 8.85x10^{-12} C^2/N \cdot m^2$	

MECHANICS

$\bar{v} = \frac{\Delta x}{\Delta t}$

$\bar{a} = \frac{\Delta v}{\Delta t}$

$v_f = v_i + at$

$\Delta x = v_i t + \frac{1}{2}at^2$

$2a\Delta x = v_f^2 - v_i^2$

$\Sigma F = ma$

$W = mg$

$F_g = G\frac{m_1 m_2}{r^2}$

$U_g = G\frac{m_1 m_2}{r}$

$\rho = mv$

$F\Delta t = m\Delta v$

$\mu = \frac{F_f}{F_N}$

- Δx = displacement (change of position)
- $\bar{v}$ = average velocity
- $\bar{a}$ = average acceleration
- v_i = initial velocity
- v_f = final velocity
- F = force
- F_f = force of friction
- F_N = normal force
- F_g = gravitational force
- G = Universal Gravitational Constant
- ρ = momentum
- μ = coefficient of friction
- r = distance between center of masses
- W = weight
- m = mass
- U_g = gravitational PE

ELECTRICITY

$F_e = k\frac{q_1 q_2}{r^2}$

$E = \frac{F}{q}$

$\Delta U_E = q\Delta V$

$V = \frac{W}{q} = Ed$

$I = \frac{\Delta q}{\Delta t}$

$V = IR$

$P = VI = I^2 R = \frac{V^2}{R}$

- C = Capacitance
- E = electric field intensity
- I = electric current
- k = electrostatic constant
- P = Power
- q = charge
- R = resistance
- U_E = electric potential Energy
- U_C = energy stored in capacitor
- V = electric potential difference
- W = Work

SERIES CIRCUIT

$I_T = I_1 = I_2 = I_3 = ...$

$V_T = V_1 + V_2 + V_3 + ...$

$R_T = R_1 + R_2 + R_3 + ...$

PARALLEL CIRCUITS

$I_T = I_1 + I_2 + I_3 + ...$

$V_T = V_1 = V_2 = V_3 = ...$

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...}$

$C = Q/\Delta V$

$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C\Delta V^2$

$C_{parallel} = \Sigma C_i$

$C_{series} = \frac{1}{\Sigma\left(\frac{1}{C_i}\right)}$

ENERGY AND WORK

$W = F\Delta x \cos\theta$

$P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv$

$PE_g = mgh$

$KE = \frac{1}{2}mv^2$

$F = -kx$

$PE_s = \frac{1}{2}kx^2$

- h = height
- k = spring constant
- KE = kinetic energy
- PE_g = gravitational potential energy
- PE_s = potential energy stored in a spring
- P = power
- W = work
- x = change in spring length from the equilibrium position

CIRCULAR MOTION & ROTATION

$a_c = \frac{v^2}{r}$

$F_c = m\frac{v^2}{r}$

$1rev = 2\pi rad = 360°$

$\tau = Fxr = I\alpha$

$I = \Sigma mr^2$

$L = I\omega$

$K_{rot} = \frac{1}{2}I\omega^2$

$x = A\cos(\omega t)$

$x = A\cos(2\pi ft)$

- a_c = centripetal acceleration
- F_c = centripetal force
- τ = Torque
- I = Rotational Inertia
- α =Angular acceleration
- ω =Angular velocity
- K_{rot} =Rotational KE
- x =position

HEAT AND THERMODYNAMICS

$Q = mc\Delta T$

$Q = mL_f$

$Q = mL_V$

$\Delta L = \alpha L_o \Delta T$

$\frac{Q}{\Delta t} = \frac{kA\Delta T}{L}$

$PV = nRT = NkT$

$K = \frac{3}{2}k_B T$

$\Delta U = \frac{3}{2}nR\Delta T$

$W = -P\Delta V$

$\Delta U = Q + W$

c = specific heat

L_f = latent heat of fusion

L_V = latent heat of vaporization

Q = amount of heat

ΔT = change in temperature

α = coefficient of linear expansion

L_o = original length

$c_{water} = 4186 \frac{J}{kg°K}$

K = kinetic energy

L = thickness

U = internal energy

W = work done on a system

WAVE PHENOMENA & SHM

$T = \frac{1}{f}$

$v = f\lambda$ OR $= \nu\lambda$

$n = \frac{c}{v}$

$n_i \sin\theta_i = n_r \sin\theta_r$

$\lambda = \frac{xd}{L}$

$\sin\theta_c = \frac{1}{n}$

$T_S = 2\pi\sqrt{\frac{m}{k}}$

$T_P = 2\pi\sqrt{\frac{L}{g}}$

c = speed of light in a vacuum

d = distance between slits

$f = \nu$ = frequency

L = distance from slit to screen

n = index of absolute refraction

T = period

v = speed

x = distance from central maximum to first-order maximum

λ = wavelength

θ = angle

θ_c = critical angle relative to air

GEOMETRIC OPTICS & SOUND

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

$\frac{h_i}{h_o} = \frac{d_i}{d_o}$

$\beta = 10\log\frac{I}{I_o}$

f = focal length

d_i = image distance

d_o = object distance

h_o = object size

h_i = image size

β = Sound level

I = Sound Intensity

I_o = Threshold Intensity

ELECTROMAGNETIC APPLICATIONS

$F_M = Bqv$

$F_M = BIL$

$\varepsilon = BLv$

$\frac{N_P}{N_S} = \frac{V_P}{V_S}$

$V_P I_P = V_S I_S$ (ideal)

$efficiency = \frac{V_S I_S}{V_P I_P}$

$\phi_B = B \cdot A$

$\Delta\phi_B = \varepsilon t$

B = magnetic field strength

I_P = current in primary

I_S = current in secondary

N_P = number of turns in primary coil

N_S = number of turns in secondary coil

V_P = voltage of primary

V_S = voltage of secondary

L = length of conductor

V = electric potential difference

v = speed of particle

FLUID MECHANICS

$\rho = \frac{m}{V}$

$P = \frac{F}{A}$

$P = P_o + mgh$

$F_b = \rho V g$

$A_1 v_1 = A_2 v_2$

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 =$

$= P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

A = Area

F = force

h = depth

P = pressure

V = volume

v = speed

y = height

ρ = density

MODERN PHYSICS

$E = hf$

$K_{max} = hf - \phi$

$\lambda = \frac{h}{p}$

$E = mc^2$

E = energy

f = frequency

K = kinetic energy

m = mass

p = momentum

λ = wavelength

ϕ = work function

AP PHYSICS I **Salmon Test**

JANUARY 12, 2017

SOLUTIONS Corrections

1. A	14. C
2. C	15. B
3. C	16. D
4. D	17. A
5. C	18. ~~D~~ B
6. B	19. D
7. C	20. A
8. B	21. B
9. D	22. B
10. B	23. D
11. B	24. C
12. C	25. C
13. A	

January Exam: Kinematic, Dynamics, work, energy, and conservation of energy
February Exam: impulse and linear momentum and conservation of linear momentum: collisions, Simple harmonic motion: simple pendulum and mass-spring systems, Mechanical waves and sound, Plus review of Jan topics
March Exam: Circular motion and universal gravitation, Rotational dynamics: torque, rotational kinematics and energy, rotational dynamics and conservation of angular momentum,
Plus review of Jan and Feb topics
April Exam: electrostatics: electric charge and electric force, DC circuits (resistors only)
Plus review of Jan, Feb, and March topics.

Dates for 2017 Season

Thursday January 12, 2017 Thursday February 9, 2017

Thursday March 9, 2017 Thursday April 13, 2017

All schools must complete the April exam and mail in the results by April 28th, 2017

New Jersey Science League
PO Box 65 Stewartsville, NJ 08886-0065
phone # 908-213-8923 fax # 908-213-9391 email: **newjsl@ptd.net**
Web address: **http://entnet.com/~personal/njscil/html/**

What is to be mailed back to our office?

PLEASE RETURN THE AREA RECORD AND ALL TEAM MEMBER SCANTRONS (ALL STUDENTS PLACING 1ST, 2ND, 3RD, AND 4TH).

If you return scantrons of alternates, then label them as ALTERNATES.

Dates 2018 Season

Thursday January 11, 2018 Thursday February 8, 2018

Thursday March 8, 2018 Thursday April 12, 2018

PHYSICS I **Salmon**

FEBRUARY 9, 2017 **Corrections None**

Directions: For each question or statement fill in the appropriate space on the answer sheet. Use the letter preceding the word, phrase, or quantity which best completes or answers the question. Each of the 25 questions is worth 4 points. Use: **$g = -10\ m/s^2$** and the vertically upward direction is positive unless specifically stated otherwise. Ignore air resistance unless specifically stated otherwise. Use 340m/s for speed of sound in air.

1. Two objects have equal kinetic energies. Object #1 has a mass of 9***M*** and Object #2 has a mass of ***M***. What is the ratio of the momenta of the two objects, p_1/p_2 ?

(A) $1/9$ (B) $1/3$ (C) $3/1$ (D) $9/1$

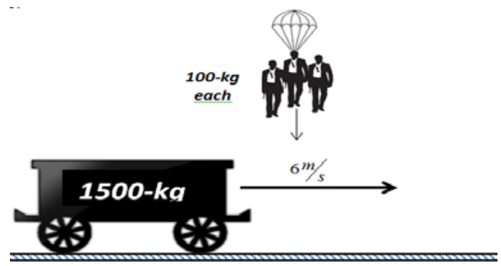
2. A 2-kg bowling ball is accidentally dropped from a window and strikes the sidewalk at a speed of 30 m/s. It bounces back up with an initial speed of 20 m/s from the sidewalk. What is the magnitude of the impulse the sidewalk imparts to the bowling ball?

(A) $20N \cdot s$ (B) $40N \cdot s$ (C) $60N \cdot s$ (D) $100N \cdot s$

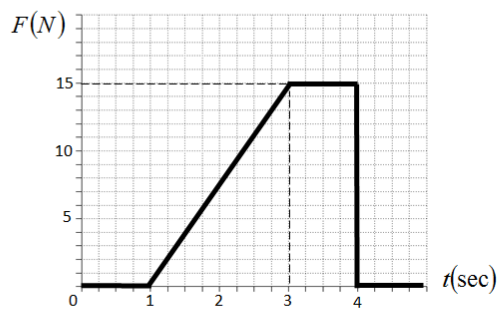
3. Bond, James Bond™. As shown below, after a particularly exciting adventure where *007* saves the world from the evil empire known as *SPECTRE*, our hero and his two assistant agents, each of mass 100-kg, are forced to jump out of an airliner. Bond has a parachute conveniently knitted into his tuxedo and all three safely land in a moving 1500-kg train car. The train car is traveling at an initial speed of 6 m/s on a level horizontal track and the agents are traveling vertically at a speed of 12 m/s when they land in the train car. What is the speed of the *train car* / *secret agent* system *after* the agents land in the train?

(A) $4 m/s$ (B) $5 m/s$

(C) $6 m/s$ (D) $7 m/s$



4. The graph below represents a force ***F*** as a function of time ***t*** applied to a 2-kg cart confined to moving in only one dimension on a linear air track. The cart has an initial speed of $3 m/s$ at ***t*** = 0. What is the change in velocity of the cart during the 5-second interval shown?



(A) $7.5 m/s$

(B) $15 m/s$

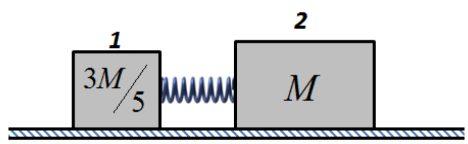
(C) $18 m/s$

(D) $30 m/s$

5. As shown below, two masses labeled #***1*** & #***2*** on a frictionless lab table are held together at rest with a spring compressed between them. When released from rest, what is the ratio of the kinetic energy of object #***1*** to that of object #***2***, KE_1/KE_2 ?

(A) $3/5$ (B) $5/3$

(C) $9/25$ (D) $25/9$



6. During the Hollywood blockbuster *Gravity* starring Sandra Bullock and George Clooney, Clooney's character senselessly sacrifices himself in order to save Bullock's character from being pulled out to space with him. In the scene, pictured below, Bullock (left) is attached to the International Space Station via cables wrapped around her ankle. She is holding a long cable at the other end of which is Clooney who keeps drifting further and further away even though the cable is tight. They are both motionless relative to the ISS. When Bullock pulls on the cable to pull in Clooney, she is pulled further away from the ISS and Clooney gets further away. Assuming Bullock's mass with spacesuit to be 90-kg and Clooney's to be 120-kg, what should be Clooney's change in velocity if Bullock pulls on the cable with a force of 600-N for 2 seconds?

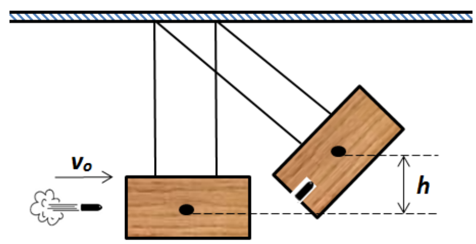
(A) $2\,{}^{m}\!/_{s}$ (B) $5\,{}^{m}\!/_{s}$

(C) $7\,{}^{m}\!/_{s}$ (D) $10\,{}^{m}\!/_{s}$

7. A baseball of mass ***M*** is thrown at a speed ***V*** toward a batter. The bat makes contact with the ball for a time ***t*** causing the ball to leave the bat with a speed ***V*** directly back toward the pitcher. What is the average force exerted on the ball by the bat?

(A) MV/t (B) $2MV/t$ (C) $MV/2t$ (D) $MV^2/2t$

8. In the "old days" the speed of a bullet was calculated by using a ballistics pendulum as imaged below. A bullet is fired horizontally into a suspended block of wood. The wood with the bullet impeded in it than swings upward as a pendulum. In one particular test, a 40-gram bullet is fired horizontally into a 4-kg block. The block/bullet system then swings upward to a height ***h*** of 5-cm. What is the initial speed of the bullet just before impact with the block of wood?



(A) 51 m/s (B) 101 m/s

(C) 151 m/s (D) 202 m/s

9. A mass ***M*** is suspended vertically from a spring of spring constant ***k***. It is pulled downward a distance ***x*** and released causing the mass to oscillate up and down with frequency ***f***. Which of the following would cause the frequency to double to 2***f***?

(A) Increase the mass to $4M$ (B) Double the mass to $2M$

(C) Decrease the mass to $M/2$ (D) Decrease the mass to $M/4$

10. A simple pendulum of length ***L*** and bob mass ***M*** is suspended from the ceiling of an elevator. While the elevator is accelerating upward at a value of ***a***, what is the period of this simple pendulum while the elevator is accelerating upward?

(A) $2\pi\sqrt{\frac{L}{g}}$ (B) $2\pi\sqrt{\frac{L}{(g+a)}}$ (C) $2\pi\sqrt{\frac{L}{(g-a)}}$ (D) $2\pi\sqrt{\frac{L}{a}}$

11. A standing wave is produced by two identical opposing waves each of frequency 100-Hz. The distance between the 3rd and 8th node of the standing wave is 100-cm. What is the wavelength of the original waves?

(A) 20-cm (B) 30-cm (C) 40-cm (D) 60-cm

12. A guitar string, clamped at both ends, is 100-cm long. Which of the following wavelengths cannot be attributed to this string?

(A) 50-cm (B) $\frac{200}{3}$-cm (C) 200-cm (D) 400-cm

13. A wave is sent down the length of a string to a fixed end attached securely to a door knob. What is the phase shift of the reflected wave compared to the original wave?

(A) Zero (B) $\pi/2 - radians$ (C) $\pi - radians$ (D) $2\pi - radians$

14. A tuning fork is struck and produces sound of frequency 136-Hz in air. If this tuning fork is used to cause resonance in a tube of air closed at one end, which of the following cannot be the length of the tube?

(A) 0.625-m (B) 1.25-m (C) 1.875-m (D) 3.125-m

15. Two identical tuning forks vibrate at 100-Hz. A common house fly lands on the end of one of them, and for some reason stays there, so that 20 beats per second is recorded. What is the period of the tuning fork the silly fly landed on?

(A) 0.0125 seconds (B) 0.010 seconds (C) 0.0083 seconds (D) 0.001 seconds

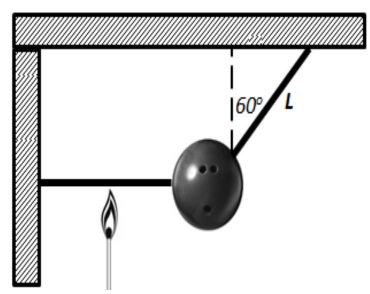
16. During simple harmonic motion, SHM, the acceleration is smallest:

(A) when the displacement from equilibrium is zero. (B) when the displacement from equilibrium is maximum.
(C) when the velocity is smallest. (D) when the restoring force is maximum.

Use the following information for Questions #17 - #19: The physics lab set-up shown below, which you may remember from the January Science League exam, shows a 4-kg bowling ball in equilibrium due to two strong ropes. One rope, 2-m long, is attached to a ceiling at an angle of 60^o to the vertical as shown and the other rope is horizontally attached to a rigid wall. An evil physics student lights a match and burns the horizontal rope while the teacher isn't watching.

17. After the horizontal rope burns, what maximum speed does the bowling ball attain during the ensuing motion?

(A) $2.2\,m/s$ (B) $3.2\,m/s$ (C) $4.5\,m/s$ (D) $6.3\,m/s$



18. What is the resulting frequency in s^{-1} of oscillation of the swinging bowling ball?

(A) $1.1/\pi$ (B) $1.6/\pi$ (C) 0.6π (D) 0.9π

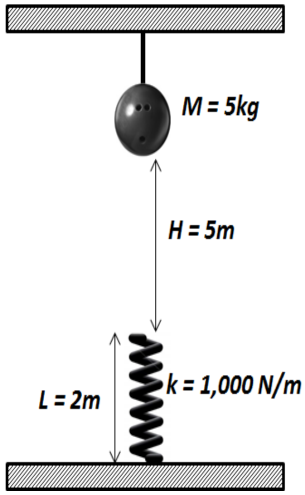
19. If both the length of the rope and the mass of the ball is doubled, the period would be:

(A) 0.6π (B) 0.9π (C) 1.26π (D) 1.8π

20. An oscillating pendulum on a lab table in your physics room has a length of 50-cm with a bob mass of 2-kg. What is the spring constant of the spring that would produce the same frequency as this pendulum using the same bob mass?

(A) $20\,N/m$ (B) $40\,N/m$ (C) $60\,N/m$ (D) $80\,N/m$

Use the following information for Questions #21 - #23*: As* shown below, our often used 5-kg bowling ball is suspended by a string above a relaxed 2-m long spring that is firmly attached to the floor. The bowling ball is 5-m above the top of the spring and the spring has a spring constant of $1{,}000\, {}^{N}\!/_{m}$. The string supporting the bowling ball is now cut.



21. With what speed does the bowling ball strike the top of the spring?

(A) $5\, {}^{m}\!/_{s}$ (B) $10\, {}^{m}\!/_{s}$

(C) $15\, {}^{m}\!/_{s}$ (D) $20\, {}^{m}\!/_{s}$

22. The spring and bowling ball become firmly attached after contact via heavy-duty Velcro™. At what height above the floor does the bowling ball come to rest?

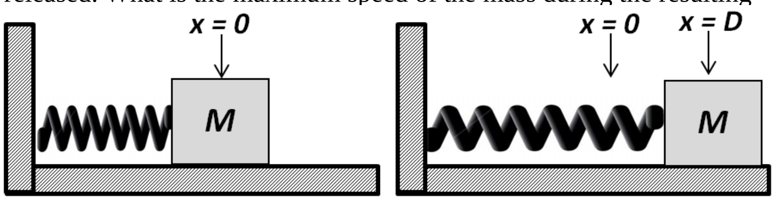
(A) 0.38-m (B) 0.71-m

(C) 0.76-m (D) 1.24-m

23. What is the ensuing frequency of oscillation?

(A) 0.44-Hz (B) 0.88-Hz (C) 2.25-Hz (D) 4.5-Hz

24. A mass ***M*** is attached to a horizontal spring of constant ***k***, as shown below left. The system is set into simple harmonic motion by pulling the mass to a distance of ***D*** as shown below right and released. What is the maximum speed of the mass during the resulting oscillation?



(A) $D\sqrt{{}^{k}\!/_{M}}$ (B) $D\sqrt{{}^{M}\!/_{k}}$

(C) $2\pi\sqrt{{}^{k}\!/_{M}}$ (D) $2\pi\sqrt{{}^{M}\!/_{k}}$

25. A large rubber bullet of mass ${}^{M}\!/_{2}$ is moving to the right with speed V when it collides with a stationary mass, M, resting on a frictionless surface. Mass M is attached to a spring of constant ***k***. After colliding, the rubber bullet rebounds to the left with a speed of ${}^{V}\!/_{2}$. How far does the mass M move to the right before coming to rest?

(A) ${}^{3}\!/_{4}V\sqrt{{}^{M}\!/_{k}}$ (B) ${}^{4}\!/_{3}V\sqrt{{}^{k}\!/_{M}}$

(C) ${}^{3}\!/_{4}V\sqrt{{}^{k}\!/_{M}}$ (D) ${}^{4}\!/_{3}V\sqrt{{}^{M}\!/_{k}}$

PHYSICS FORMULAE (UPDATED 2-20-2017)

Constants & Conversion Factors

Proton and Neutron Mass	$m_p = 1.67x10^{-27}\,kg$	Fundamental charge	$e = 1.6x10^{-19}\,C$
Electron Mass	$m_e = 9.11x10^{-31}\,kg$	Electron Volt	$1eV = 1.6x10^{-19}\,J$
Avogadro's #	$6.02x10^{23}\,mol^{-1}$	Universal Gravitational constant	$G = 6.67x10^{-11}\,Nm^2/kg^2$
Universal gas constant	$R = 8.31\,J/mol \cdot K$	Speed of Light	$c = 3.00x10^8\,m/s$
Boltzmann's constant	$k_B = 1.38x10^{-23}\,J/K$	Magnetic constant	$k' = 1x10^{-7}\,T \cdot m/A$

1 unified atomic mass unit	$1u = 1.66x10^{-27}\,kg = 931\,MeV/c^2$
Planck's Constant	$h = 6.63x10^{-34}\,J \cdot s = 4.14x10^{-15}\,eV \cdot s$ $hc = 1.99x10^{-25}\,J \cdot m = 1240eV \cdot nm$
Coulomb's Law constant	$k = \frac{1}{4\pi\varepsilon_o} = 9.0x10^9\,N \cdot m^2/kg^2$ $\varepsilon_o = 8.85x10^{-12}\,C^2/N \cdot m^2$

GEOMETRIC OPTICS	& SOUND	ELECTROMAGNETIC	APPLICATIONS
$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$ $\frac{h_i}{h_o} = \frac{d_i}{d_o}$ $\beta = 10\log\frac{I}{I_o}$	f = focal length d_i = image distance d_o = object distance h_o = object size h_i = image size β = Sound level I = Sound Intensity I_o = Threshold Intensity	$F_M = Bqv$ $F_M = BIL$ $\varepsilon = BLv$ $\frac{N_P}{N_S} = \frac{V_P}{V_S}$ $V_P I_P = V_S I_s$ (ideal) $efficiency = \frac{V_S I_S}{V_P I_P}$ $\phi_B = B \cdot A$ $\Delta\phi_B = \varepsilon t$	B = magnetic field strength I_P = current in primary I_S = current in secondary N_P = number of turns in primary coil N_S = number of turns in secondary coil V_P = voltage of primary V_S = voltage of secondary L = length of conductor V = electric potential difference v = speed of particle

MECHANICS

$\bar{v} = \frac{\Delta x}{\Delta t}$

$\bar{a} = \frac{\Delta v}{\Delta t}$

$v_f = v_i + at$

$\Delta x = v_i t + \frac{1}{2} a t^2$

$2a\Delta x = v_f^2 - v_i^2$

$\Sigma F = ma$

$W = mg$

$F_g = G \frac{m_1 m_2}{r^2}$

$U_g = G \frac{m_1 m_2}{r}$

$\rho = mv$

$F\Delta t = m\Delta v$

$\mu = \frac{F_f}{F_N}$

Δx = displacement (change of position)

$\bar{v}$ = average velocity

$\bar{a}$ = average acceleration

v_i = initial velocity

v_f = final velocity

F = force

F_f = force of friction

F_N = normal force

F_g = gravitational force

G = Universal Gravitational Constant

ρ = momentum

μ = coefficient of friction

r = distance between center of masses

W = weight

m = mass

U_g = gravitational PE

ELECTRICITY

$F_e = k \frac{q_1 q_2}{r^2}$

$E = \frac{F}{q}$

$\Delta U_E = q\Delta V$

$V = \frac{W}{q} = Ed$

$I = \frac{\Delta q}{\Delta t}$

$V = IR$

$P = VI = I^2 R = \frac{V^2}{R}$

SERIES CIRCUIT

$I_T = I_1 = I_2 = I_3 = \ldots$

$V_T = V_1 + V_2 + V_3 + \ldots$

$R_T = R_1 + R_2 + R_3 + \ldots$

PARALLEL CIRCUITS

$I_T = I_1 + I_2 + I_3 + \ldots$

$V_T = V_1 = V_2 = V_3 = \ldots$

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$

C = Capacitance

E = electric field intensity

I = electric current

k = electrostatic constant

P = Power

q = charge

R = resistance

U_E = electric potential Energy

U_C = energy stored in capacitor

V = electric potential difference

W = Work

$C = Q/\Delta V$

$U_C = \frac{1}{2} Q\Delta V = \frac{1}{2} C\Delta V^2$

$C_{parallel} = \Sigma C_i$

$C_{series} = \frac{1}{\Sigma\left(\frac{1}{C_i}\right)}$

ENERGY AND WORK

$W = F\Delta x \cos\theta$

$P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv$

$PE_g = mgh$

$KE = \frac{1}{2} mv^2$

$F = -kx$

$PE_s = \frac{1}{2} kx^2$

h = height

k = spring constant

KE = kinetic energy

PE_g = gravitational potential energy

PE_s = potential energy stored in a spring

P = power

W = work

x = change in spring length from the equilibrium position

CIRCULAR MOTION & ROTATION

$a_c = \frac{v^2}{r}$

$F_c = m\frac{v^2}{r}$

$1rev = 2\pi rad = 360°$

$\tau = Fxr = I\alpha$

$I = \Sigma mr^2$

$L = I\omega$

$K_{rot} = \frac{1}{2} I\omega^2$

$x = A\cos(\omega t)$

$x = A\cos(2\pi ft)$

a_c = centripetal acceleration

F_c = centripetal force

τ = Torque

I = Rotational Inertia

α =Angular acceleration

ω =Angular velocity

K_{rot} =Rotational KE

x =position

NJSL Physics Formula Sheet.

HEAT AND THERMODYNAMICS

$Q = mc\Delta T$

$Q = mL_f$

$Q = mL_V$

$\Delta L = \alpha L_o \Delta T$

$\frac{Q}{\Delta t} = \frac{kA\Delta T}{L}$

$PV = nRT = NkT$

$K = \frac{3}{2} k_B T$

$\Delta U = \frac{3}{2} nR\Delta T$

$W = -P\Delta V$

$\Delta U = Q + W$

c = specific heat
L_f = latent heat of fusion
L_V = latent heat of vaporization
Q = amount of heat
ΔT = change in temperature
α = coefficient of linear expansion
L_o = original length

$c_{water} = 4186 \frac{J}{kg°K}$

K = kinetic energy
L = thickness
U = internal energy
W = work done on a system

WAVE PHENOMENA & SHM

$T = \frac{1}{f}$

$v = f\lambda$ OR $= \nu\lambda$

$n = \frac{c}{v}$

$n_i \sin\theta_i = n_r \sin\theta_r$

$\lambda = \frac{xd}{L}$

$\sin\theta_c = \frac{1}{n}$

$T_S = 2\pi\sqrt{\frac{m}{k}}$

$T_P = 2\pi\sqrt{\frac{L}{g}}$

c = speed of light in a vacuum
d = distance between slits
$f = \nu$ = frequency
L = distance from slit to screen
n = index of absolute refraction
T = period
v = speed
x = distance from central maximum to first-order maximum
λ = wavelength
θ = angle
θ_c = critical angle relative to air

FLUID MECHANICS

$\rho = \frac{m}{V}$

$P = \frac{F}{A}$

$P = P_o + mgh$

$F_b = \rho V g$

$A_1 v_1 = A_2 v_2$

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 =$

$= P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

A = Area
F = force
h = depth
P = pressure
V = volume
v = speed
y = height
ρ = density

MODERN PHYSICS

$E = hf$

$K_{\max} = hf - \phi$

$\lambda = \frac{h}{p}$

$E = mc^2$

E = energy
f = frequency
K = kinetic energy
m = mass
ρ = momentum
λ = wavelength
ϕ = work function

AP PHYSICS I **Salmon Test**

FEBRUARY 9, 2017

SOLUTIONS Corrections None

1. C	14. B
2. D	15. A
3. B	16. A
4. B	17. C
5. B	18. A
6. D	19. C
7. B	20. B
8. B	21. B
9. D	22. D
10. B	23. C
11. C	24. A
12. D	25. A
13. C	

January Exam: Kinematic, Dynamics, work, energy, and conservation of energy
February Exam: impulse and linear momentum and conservation of linear momentum: collisions, Simple harmonic motion: simple pendulum and mass-spring systems, Mechanical waves and sound, Plus review of Jan topics
March Exam: Circular motion and universal gravitation, Rotational dynamics: torque, rotational kinematics and energy, rotational dynamics and conservation of angular momentum, Plus review of Jan and Feb topics
April Exam: electrostatics: electric charge and electric force, DC circuits (resistors only) Plus review of Jan, Feb, and March topics.

Dates for 2017 Season
Thursday January 12, 2017 Thursday February 9, 2017
Thursday March 9, 2017 Thursday April 13, 2017
All schools must complete the April exam and mail in the results by April 28th, 2017

New Jersey Science League
PO Box 65 Stewartsville, NJ 08886-0065
phone # 908-213-8923 fax # 908-213-9391 email: **newjsl@ptd.net**
Web address: **http://entnet.com/~personal/njscil/html/**

What is to be mailed back to our office?
PLEASE RETURN THE AREA RECORD AND ALL TEAM MEMBER SCANTRONS (ALL STUDENTS PLACING 1ST, 2ND, 3RD, AND 4TH).
If you return scantrons of alternates, then label them as ALTERNATES.

Dates 2018 Season
Thursday January 11, 2018 Thursday February 8, 2018
Thursday March 8, 2018 Thursday April 12, 2018

PHYSICS I Salmon Exam
MARCH 9, 2017 Corrections

Directions: For each question or statement fill in the appropriate space on the answer sheet. Use the letter preceding the word, phrase, or quantity which best completes or answers the question. Each of the 25 questions is worth 4 points. As prescribed by the College Board for AP Physics, the work done *on* a system is a *positive* quantity.
Use: g =10 m/s².

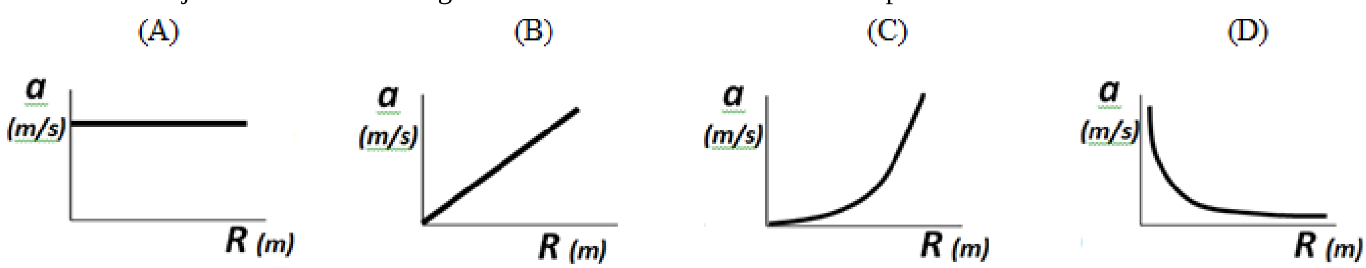
ADDITIONAL INFORMATION: *All axes of rotation are taken to be at the center of mass unless specifically stated otherwise.*

Rotational Inertia of a *solid disc*: $\frac{1}{2}MR^2$ Rotational Inertia of a *hollow disc* (hoop or ring): MR^2

Rotational Inertia of a *solid sphere*: $\frac{2}{5}MR^2$ Rotational Inertia of a *hollow sphere*: $\frac{2}{3}MR^2$

Fundamental charge: $e = 1.6x10^{-19}C$

1. Which of the following graphs, representing magnitude of acceleration as a function of the radius, correctly depicts the motion of an object of mass ***M*** moving in a circle of radius ***R*** at a constant speed of ***V***?



Use the following information for Questions #2 - #6: In the old "*David V Goliath*" story, a proverbial 98-pound weakling (David) bests a 550-pound giant (Goliath), as depicted below in the free source Google™ image. David accomplishes this by swinging a 2-kg rock in a circle at the end of a rope called a *sling* and letting go at a precise instant. This flings the rock and it strikes Goliath between the eyes, knocking him senseless. David's sling is 2-m long.

2. David releases the sling with an initial speed of $35\,{}^{m}\!/_{s}$ at a height of 2-m above the level ground. What is the horizontal distance between David and Goliath if the rock is to hit Goliath at a spot 5-m above the ground when the rock is at the maximum height of its projectile trajectory? Picture blocked out part of the question. All full credit
(A) 13.2m (B) 26.5m (C) 39.7m (D) 55m

3. During practice, David twirled the sling in a horizontal circle around his head in such a way that the rope made an angle of 20° below the horizontal. What is the tension, ***T***, in the rope of the sling?
(A) 25-N (B) 85-N (C) 115-N (D) 625-N

4. Consider the following possibilities for David:

I. Double the length of the rope of the sling.
II. Double the tension in the rope of the sling.
III. Use a 1-kg rock.

If David wanted to double the speed of the rock upon release, which of the following choices would work?
(A) I only (B) II only (C) III only (D) None of these would work individually.

5. If David doubles all three parameters he controls (the mass ***M***, the speed ***V***, and the length of the rope ***R***) while keeping the rope at the practice angle of 30° below horizontal, what is the new tension in the rope compared to the original tension, ***T***, in #3 above?
(A) T (B) $2T$ (C) $4T$ (D) $8T$

6. If David had decided to twirl his sling in a vertical circle instead of a horizontal one while keeping the speed of the rock constant, what would be the ratio of the tension in the rope at the top to that at the bottom, T_{Top}/T_{Bottom} ? Answer in terms of ***M***, ***V***, ***R***, and acceptable constants.

(A) $\dfrac{\frac{MV^2}{R}-g}{\frac{MV^2}{R}+g}$ (B) $\dfrac{V^2-Rg}{V^2+Rg}$ (C) $\dfrac{\frac{MV^2}{R}+g}{\frac{MV^2}{R}-g}$ (D) $\dfrac{V^2+Rg}{V^2-Rg}$

7. You may have been required to read the 1605 Spanish novel *Don Quixote*, by Miguel de Cervantes. The story follows the adventures of a Spanish nobleman who reads so many heroic/chivalric stories that he loses his sanity and decides to set out to revive chivalry, undo wrongs, and bring justice to the world. The "tilting at windmills" pictured below is the culmination of his "alternate view" of reality as he saw windmills as evil giants. If the windmill shown below is initially at rest and catches a strong sudden wind causing it to begin rotating clockwise, what is the direction of the net acceleration of the point ***A*** located on the outside of the top left arm of the windmill?

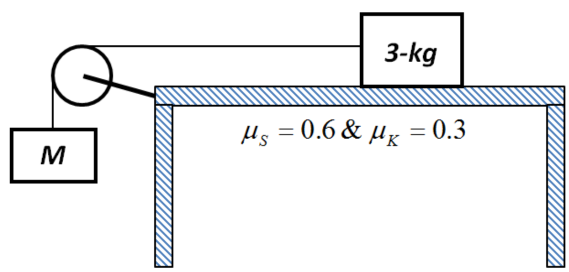
(A) (B) (C) (D)

Use the following information for Questions #8 & #9: A 3-kg mass rests on a level table. The coefficients of static and kinetic friction between the mass and the table are $\mu_S = 0.6$ and $\mu_K = 0.3$, respectively. A massless string is attached to the mass, wrapped around a pulley, and hung over the edge of the table with another mass M attached to the suspended end.

8. If using a massless frictionless pulley as shown below, what is the acceleration of the system when released from rest if $M = 1kg$?

(A) Zero (B) $a = 1 m/s^2$

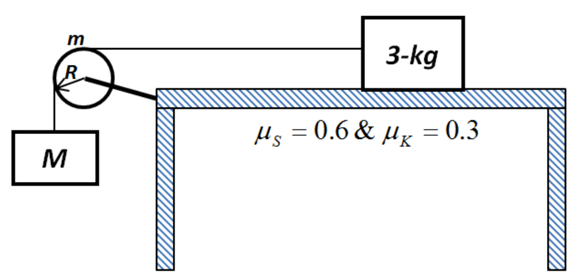
(C) $a = 2.5 m/s^2$ (D) $a = 5 m/s^2$



9. If using a solid disc pulley, shown below, of mass $m = 0.5kg$, radius $R = 20cm$, and frictionless bearings, what is the minimum value of the suspended mass M, if the system accelerates at $4 m/s^2$ **<u>once set into motion</u>**?

(A) $M = 0.83\,kg$ (B) $M = 1.67\,kg$

(C) $M = 3.33\,kg$ (D) $M = 6.67\,kg$



Use the following information for Questions #10 & #11: A solid metal sphere is placed at the top of an inclined plane. The sphere has a mass of $M = 2kg$ and a radius of $R = 5cm$. The inclined plane has a length of $L = 6m$ and is inclined at $\theta = 30^o$ above the horizontal.

10. The sphere is released from rest at the top of the *frictionless* incline and slides without rolling to the bottom. What is the speed of the sphere at the bottom of the incline?

(A) $3.28 \, {}^{m}\!/_{s}$ (B) $6.55 \, {}^{m}\!/_{s}$ (C) $7.75 \, {}^{m}\!/_{s}$ (D) $9.26 \, {}^{m}\!/_{s}$

11. You now repeat #10 above after replacing the incline with a rough wooden plank of the same length and angle where the sphere rolls without slipping all the way to the bottom after being released from rest. What is the speed of the sphere at the bottom of the incline?

(A) $3.28 \, {}^{m}\!/_{s}$ (B) $6.55 \, {}^{m}\!/_{s}$ (C) $7.75 \, {}^{m}\!/_{s}$ (D) $9.26 \, {}^{m}\!/_{s}$

12. When starting a typical gas-powered lawn mower you must pull on a rope that is wrapped around a solid cylinder. If the cylinder has a radius of $10cm$, a rotational inertia of $2kg \cdot m^2$, and you pull the starter rope with a force of $45N$, what is the angular acceleration of the cylinder in ${}^{rad}\!/_{s^2}$?

(A) 2.25 (B) 22.5 (C) 225 (D) Not enough information to determine

13. What is the magnitude and direction of the angular momentum of the Earth as it rotates on its axis? Consider the Earth as a solid sphere where $I = \frac{2}{5}MR^2$, $M = 6x10^{24} kg$, and $R = 6.4x10^6 m$.

Use conventional Earth geographic north/south directions.

(A) $7.15x10^{33} \, {}^{kg \cdot m^2}\!/_{s}$ South (B) $7.15x10^{33} \, {}^{kg \cdot m^2}\!/_{s}$ North

(C) $6.18x10^{38} \, {}^{kg \cdot m^2}\!/_{s}$ South (D) $6.18x10^{38} \, {}^{kg \cdot m^2}\!/_{s}$ North

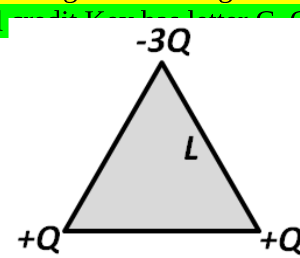
14. In the 2003 movie, *The Core*, the core of the Earth unexpectedly and unexplainably stops rotating; setting off a chain of Geo-Magnetic disasters. A group of science folks are tasked with drilling into the Earth and "kick-starting" the core back into rotation by a few well-placed nuclear bombs. Note that in the movie there is no distinction between *inner* and *outer* cores or that they actually rotate in *opposite* directions, so we will treat them as one object rotating in one direction like they did. How much rotational kinetic energy must be supplied to the stationary core by these bombs in order to get it to rotate at its current rate once again? Use the following information: Mass of the core (*inner* + *outer*) is $2x10^{24} kg$, radius of the core is $3500km$, and it presently completes one rotation per Earth day.

(A) $1.9x10^{28} J$ (B) $2.6x10^{28} J$ (C) $1.9x10^{38} J$ (D) $2.6x10^{38} J$

15. As shown below, a small positively charged sphere of mass $m = 50grams$ and charge $q = +5\mu C$ is placed at the $72cm$ mark of a meter stick near a stationary immovable negative charge of $Q = -30\mu C$ located at the $98cm$ mark. When released, what is the initial acceleration of the small sphere? *Diagram not drawn to scale and consider electrostatic charges only*. All full credit Off topic key has letter D

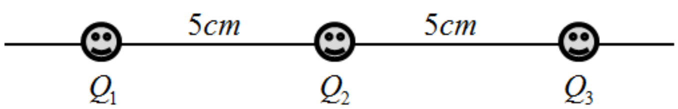
(A) $10 \, {}^{m}\!/_{s^2}$ (B) $40 \, {}^{m}\!/_{s^2}$ (C) $100 \, {}^{m}\!/_{s^2}$ (D) $400 \, {}^{m}\!/_{s^2}$

16. As imaged below right, three point charges are placed at the vertices of an equilateral triangle with sides of length L and vertex angles of θ. Two charges have magnitude of positive Q while the third charge has a magnitude of negative $3Q$. What is the magnitude and direction of the net electrostatic force on the -3Q charge? All full credit Key has letter C. Off topic.



	Magnitude	***Direction***
(A)	$\frac{3kQ^2}{L^2}\cos\theta/2$	↑
(B)	$\frac{3kQ^2}{L^2}\cos\theta/2$	↓
(C)	$\frac{6kQ^2}{L^2}\cos\theta/2$	↓
(D)	$\frac{6kQ^2}{L^2}\cos\theta/2$	↑

17. Three point charges are placed in close proximity to each other as shown below. What is the magnitude and direction of the net electrostatic force on the middle charge, Q_2, if $Q_1 = +4\mu C$, $Q_2 = +2\mu C$, and $Q_3 = +6\mu C$? All full credit. Off topic Key has



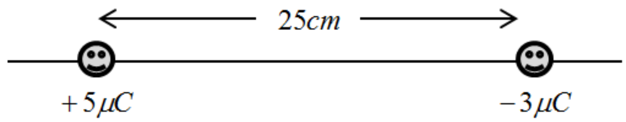
(A) $72N$ to the left (B) $72N$ to the right (C) $14.4N$ to the left (D) $14.4N$ to the right

18. If you have ever wrapped a present using clear cellophane tape, normally called Scotch™ tape, you notice that it often becomes electrically charged and curls up; sticking to your fingers and other objects you don't want it to stick to and becomes frustrating. This electrostatic charge is enough to cause one small piece of tape to "levitate" above a similar piece of tape. Assume each piece of tape is a point charge (poor assumption, but needed for this approximation problem) of mass $10mg$ and one piece is $1cm$ above the other. What is the electrostatic charge on each piece of tape assuming they each have the same charge? Off topic all full credit. Key has letter A.

(A) $1nC$ (B) $10\ nC$ (C) $1\ \mu C$ (D) $10\ \mu C$

19. How far apart should two single protons be placed from each other in order to cause an electrostatic force equal to the weight of one electron? Off topic all full credit. Key has letter C.
(A) $5cm$ (B) $25cm$ (C) $5m$ (D) $25m$

20. Two point charges are placed $25cm$ apart along an imaginary *x*-axis, as shown below. Where, on the *x*-axis, can a third charge be placed so that the net electrostatic force acting on it is zero? All full credit. Off topic Key has letter B.



(A) $86cm$ to the left of the positive charge (B) $86cm$ to the right of the negative charge
(C) $43cm$ to the left of the positive charge (D) $43cm$ to the right of the negative charge

21. Two point charges are held in place at a distance of $3m$ apart. The sum total of the charges on these two is $20\mu C$ and the net electrostatic force between them is $0.075N$. Which pair of charges provided below represents the magnitudes of the two charges? All full credit. Off topic. Key has letter D.
(A) $10\mu C$ & $10\mu C$ (B) $20\mu C$ & $0\mu C$ (C) $12\mu C$ & $8\mu C$ (D) $5\mu C$ & $15\mu C$

22. The late great Muhammed Ali consistently registered strong punches in the boxing ring. In order for him to extend his arm quickly, a force of $5{,}000N$ is supplied by his triceps, the muscles in the back of the arm. These triceps are effectively $3cm$ long and can be considered to act perpendicularly to the lower arm. Under these parameters, he was able to produce an angular acceleration of his forearm of $240\,{}^{rad}/_{s^2}$. What is the moment of inertia of Ali's forearm?
(A) $0.625\,kg\cdot m^2$ (B) $1.6\,kg\cdot m^2$ (C) $625\,kg\cdot m^2$ (D) $1{,}600\,kg\cdot m^2$

23. Lex Luthor, Superman's™ constant arch-enemy and evil genius, has set up a machine on the equator of Earth that is designed to slow the rotation of the Earth down to a 30-hr day. This is done by producing a force of $4x10^9\,N$, about the equivalent of 100 of NASA's large Saturn rockets, parallel to the equator at that point. Superman doesn't seem too terribly worried and ignores Lex in favor of saving the world from other villains. How long would it take Lex to accomplish this dastardly deed? As with #13 above, treat the Earth as a uniform solid sphere.
(A) $1.77x10^9$ sec (B) $1.77x10^9$ *years* (C) $5.59x10^9$ sec (D) $5.59x10^{16}$ *years*

Use the following information for Questions #24 & #25: NJ Transit is planning on investing in all-electric busses that operate on large disc-shaped flywheels that can produce enough energy to keep the bus moving. This is accomplished by causing the flywheel to rotate rapidly via an electric motor and then using the rotational energy stored within the flywheel to produce motion of the bus. The bus has a mass of $M = 10{,}000\,kg$, the flywheel has a mass $m = 1{,}500\,kg$ and radius of $R = 60\,cm$.

24. Assuming 100% efficiency, a poor assumption, in converting rotational kinetic energy into translational kinetic energy, what angular velocity must the flywheel have to accelerate the bus from zero to $v = 20\,{}^{m}/_{s}$?
(A) $86\,{}^{rad}/_{s}$ (B) $122\,{}^{rad}/_{s}$ (C) $172\,{}^{rad}/_{s}$ (D) $244\,{}^{rad}/_{s}$

25. The bus is at rest at the bottom of a hill when the flywheel has a rotational velocity of $50\,{}^{rad}/_{s}$. How high can the hill be in order for the bus to just make it to the top of the hill? Again, assume all of the rotational kinetic energy of the flywheel is converted to mechanical energy.
(A) $1.7m$ (B) $3.4m$ (C) $5.1m$ (D) $6.8m$

AP I and AP 2 PHYSICS FORMULAE Updated 3-22-2017

Constants & Conversion Factors

Proton and Neutron Mass	$m_p = 1.67x10^{-27} kg$	Fundamental charge	$e = 1.6x10^{-19} C$
Electron Mass	$m_e = 9.11x10^{-31} kg$	Electron Volt	$1eV = 1.6x10^{-19} J$
Avogadro's #	$6.02x10^{23} mol^{-1}$	Universal Gravitational constant	$G = 6.67x10^{-11} Nm^2/kg^2$
Universal gas constant	$R = 8.31 J/mol \cdot K$	Speed of Light	$c = 3.00x10^8 m/s$
Boltzmann's constant	$k_B = 1.38x10^{-23} J/K$	Magnetic constant	$k' = 1x10^{-7} T \cdot m/A$
1 unified atomic mass unit		$1u = 1.66x10^{-27} kg = 931 MeV/c^2$	
Planck's Constant		$h = 6.63x10^{-34} J \cdot s = 4.14x10^{-15} eV \cdot s$ $hc = 1.99x10^{-25} J \cdot m = 1240 eV \cdot nm$	
Coulomb's Law constant		$k = \frac{1}{4\pi\varepsilon_o} = 9.0x10^9 N \cdot m^2/kg^2$ $\varepsilon_o = 8.85x10^{-12} C^2/N \cdot m^2$	

MECHANICS

$\bar{v} = \frac{\Delta x}{\Delta t}$	Δx = displacement (change of position)
$\bar{a} = \frac{\Delta v}{\Delta t}$	$\bar{v}$ = average velocity
$v_f = v_i + at$	$\bar{a}$ = average acceleration
$\Delta x = v_i t + \frac{1}{2}at^2$	v_i = initial velocity
$2a\Delta x = v_f^2 - v_i^2$	v_f = final velocity
$\Sigma F = ma$	F = force
$W = mg$	F_f = force of friction
$F_g = G\frac{m_1 m_2}{r^2}$	F_N = normal force
$U_g = G\frac{m_1 m_2}{r}$	F_g = gravitational force
$\rho = mv$	G = Universal Gravitational Constant
$F\Delta t = m\Delta v$	ρ = momentum
$\mu = \frac{F_f}{F_N}$	μ = coefficient of friction
	r = distance between center of masses
	W = weight
	m = mass
	U_g = gravitational PE

ELECTRICITY

$F_e = k\frac{q_1 q_2}{r^2}$

$E = \frac{F}{q}$

$\Delta U_E = q\Delta V$

$V = \frac{W}{q} = Ed$

$I = \frac{\Delta q}{\Delta t}$

$V = IR$

$P = VI = I^2 R = \frac{V^2}{R}$

$C = Q/\Delta V$

C = Capacitance
E = electric field intensity
I = electric current
k = electrostatic constant
P = Power
q = charge
R = resistance
U_E = electric potential Energy
U_C = energy stored in capacitor
V = electric potential difference
W = Work

SERIES CIRCUIT

$I_T = I_1 = I_2 = I_3 = \ldots$

$V_T = V_1 + V_2 + V_3 + \ldots$

$R_T = R_1 + R_2 + R_3 + \ldots$

PARALLEL CIRCUITS

$I_T = I_1 + I_2 + I_3 + ..$

$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C\Delta V^2$

$V_T = V_1 = V_2 = V_3 = \ldots$

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$

$C_{parallel} = \Sigma C_i$

$C_{series} = \frac{1}{\Sigma\left(\frac{1}{C_i}\right)}$

ENERGY AND WORK

$W = F\Delta x \cos\theta$	h = height
$P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv$	k = spring constant
$PE_g = mgh$	KE = kinetic energy
$KE = \frac{1}{2}mv^2$	PE_g = gravitational potential energy
$F = -kx$	PE_s = potential energy stored in a spring
$PE_s = \frac{1}{2}kx^2$	P = power
	W = work
	x = change in spring length from the equilibrium position

CIRCULAR MOTION & ROTATION

$a_c = \frac{v^2}{r}$	a_c = centripetal acceleration
$F_c = m\frac{v^2}{r}$	F_c = centripetal force
$1rev = 2\pi rad = 360°$	τ = Torque
$\tau = Fxr = I\alpha$	I = Rotational Inertia
$I = \Sigma mr^2$	α =Angular acceleration
$L = I\omega$	ω =Angular velocity
$K_{rot} = \frac{1}{2}I\omega^2$	K_{rot} =Rotational KE
$x = A\cos(\omega t)$	x =position
$x = A\cos(2\pi ft)$	

HEAT AND THERMODYNAMICS

$Q = mc\Delta T$

$Q = mL_f$

$Q = mL_V$

$\Delta L = \alpha L_o \Delta T$

$\frac{Q}{\Delta t} = \frac{kA\Delta T}{L}$

$PV = nRT = NkT$

$K = \frac{3}{2}k_B T$

$\Delta U = \frac{3}{2}nR\Delta T$

$W = -P\Delta V$

$\Delta U = Q + W$

c = specific heat
L_f = latent heat of fusion
L_V = latent heat of vaporization
Q = amount of heat
ΔT = change in temperature
α = coefficient of linear expansion
L_o = original length
$c_{water} = 4186\frac{J}{kg°K}$
K = kinetic energy
L = thickness
U = internal energy
W = work done on a system

WAVE PHENOMENA & SHM

$T = \frac{1}{f}$

$v = f\lambda$ OR $= \nu\lambda$

$n = \frac{c}{v}$

$n_i \sin\theta_i = n_r \sin\theta_r$

$\lambda = \frac{xd}{L}$

$\sin\theta_c = \frac{1}{n}$

$T_S = 2\pi\sqrt{\frac{m}{k}}$

$T_P = 2\pi\sqrt{\frac{L}{g}}$

c = speed of light in a vacuum
d = distance between slits
$f = \nu$ = frequency
L = distance from slit to screen
n = index of absolute refraction
T = period
v = speed
x = distance from central maximum to first-order maximum
λ = wavelength
θ = angle
θ_c = critical angle relative to air

GEOMETRIC OPTICS & SOUND

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

$\frac{h_i}{h_o} = \frac{d_i}{d_o}$

$\beta = 10\log\frac{I}{I_o}$

f = focal length
d_i = image distance
d_o = object distance
h_o = object size
h_i = image size
β = Sound level
I = Sound Intensity
I_o = Threshold Intensity

ELECTROMAGNETIC APPLICATIONS

$F_M = Bqv$

$F_M = BIL$

$\varepsilon = BLv$

$\frac{N_P}{N_S} = \frac{V_P}{V_S}$

$V_P I_P = V_S I_S$ (ideal)

$efficiency = \frac{V_S I_S}{V_P I_P}$

$\phi_B = B \cdot A$

$\Delta\phi_B = \varepsilon t$

B = magnetic field strength
I_P = current in primary
I_S = current in secondary
N_P = number of turns in primary coil
N_S = number of turns in secondary coil
V_P = voltage of primary
V_S = voltage of secondary
L = length of conductor
V = electric potential difference
v = speed of particle

FLUID MECHANICS

$\rho = \frac{m}{V}$

$P = \frac{F}{A}$

$P = P_o + mgh$

$F_b = \rho Vg$

$A_1 v_1 = A_2 v_2$

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 =$

$= P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

A = Area
F = force
h = depth
P = pressure
V = volume
v = speed
y = height
ρ = density

MODERN PHYSICS

$E = hf$

$K_{max} = hf - \phi$

$\lambda = \frac{h}{p}$

$E = mc^2$

E = energy
f = frequency
K = kinetic energy
m = mass
p = momentum
λ = wavelength
ϕ = work function

PHYSICS I **Salmon Exam**

MARCH 9, 2017

SOLUTIONS Corrections

1. D	14. B
2. B All full Credit	15. D All full credit off topic
3. C	16. C All full credit off topic
4. D	17. C All full credit off topic
5. C	18. A All full credit off topic
6. B	19. C All full credit off topic
7. B	20. B All full credit off topic
8. A	21. D All full credit off topic
9. B	22. A
10. C	23. B
11. B	24. B
12. A	25. B
13. B	

January Exam: Kinematic, Dynamics, work, energy, and conservation of energy
February Exam: impulse and linear momentum and conservation of linear momentum: collisions, Simple harmonic motion: simple pendulum and mass-spring systems, Mechanical waves and sound, Plus review of Jan topics
March Exam: Circular motion and universal gravitation, Rotational dynamics: torque, rotational kinematics and energy, rotational dynamics and conservation of angular momentum, Plus review of Jan and Feb topics
April Exam: electrostatics: electric charge and electric force, DC circuits (resistors only)
Plus review of Jan, Feb, and March topics.

Dates for 2017 Season

Thursday March 9, 2017 Thursday April 13, 2017

All schools must complete the April exam and mail in the results by April 28th, 2017

New Jersey Science League
PO Box 65 Stewartsville, NJ 08886-0065
phone # 908-213-8923 fax # 908-213-9391 email: **newjsl@ptd.net**
Web address: **http://entnet.com/~personal/njscil/html/**

What is to be mailed back to our office?

PLEASE RETURN THE AREA RECORD AND ALL TEAM MEMBER SCANTRONS (ALL STUDENTS PLACING 1ST, 2ND, 3RD, AND 4TH).

If you return scantrons of alternates, then label them as ALTERNATES.

Dates 2018 Season

Thursday January 11, 2018 Thursday February 8, 2018

Thursday March 8, 2018 Thursday April 12, 2018

PHYSICS 1 Salmon
APRIL, 2017 Corrections:

Directions: For each question or statement fill in the appropriate space on the answer sheet. Use the letter preceding the word, phrase, or quantity which best completes or answers the question. Each of the 25 questions is worth 4 points. ***Use: g =10 m/s^2 and speed of sound in air is 340 m/s.***

ADDITIONAL INFORMATION:

Fundamental charge: $e = 1.6x10^{-19}C$

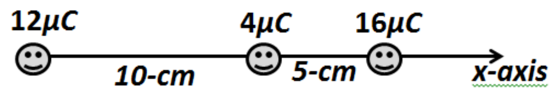
1. A modern automobile battery typically supplied 750 CCA, *Cold Cranking Amps*, during motor start-up. How many electrons are being delivered to the starter motor during a typical 2 second start assuming all 750 amperes are delivered?

(A) 1500 (B) 1.6 x 10^{-19} (C) 6.25 x 10^{18} (D) 9.38 x 10^{21}

2. A microorganism being observed under a large microscope contains a total of $1x10^{17}$ protons and a net electric charge of $-4pC, \left(-4x10^{-12}C\right)$. What is the number of deficient or excess electrons is this microorganism?

(A) 2.5 x 10^7deficient (B) 2.5 x 10^7excess (C) $1x10^{17}$ deficient (D) $1x10^{17}$ excess

3. As shown below, three charges are placed along an imaginary x-axis isolated from any other forces. A 12μC charge is placed at the origin, a 4μC charge is placed 10-*cm* to the right of the origin, and a 16μC charge is placed 5-*cm* to the right of the 4μC charge. What is magnitude and direction of the net electrostatic force acting on the 4μC charge?



(A) 230.4-N to the left (B) 230.4-N to the right (C) 187.2-N to the left (D) 187.2-N to the right

4. Nuclear fusion is the "simple" combining of smaller nuclei to form larger ones where massive amounts of energy are released. However, the trick is getting these smaller nuclei close enough to "fuse" together to make the larger ones. To show this difficulty, calculate the initial acceleration of two isolated hydrogen nuclei held within 3*nm* of each other then released from rest; this is the typical distance between air molecules at STP. Ignore gravitational effects between the nuclei since they are negligible.

(A) 1.5x10^{16} m/s^2 (B) 2.56x10^{-11} m/s^2 (C) 2.56x10^{16} m/s^2 (D) 1.5x10^{-11} m/s^2

5. By what factor must you change the distance between two negative point charges in order to increase the force between them by a factor of ten?

(A) increase by 10 (B) decrease by 10 (C) increase by 3.16 (D) decrease by 3.16

6. Listed below are four possibilities for two isolated point charges separated by a distance, d . Which of these possibilities do *not* change the magnitude of the electrostatic force between them?

I. Double the magnitude of each charge and double the separation between them.

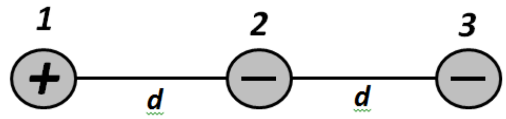
II. Double the magnitude of each charge and reduce the separation between them to $d/2$.

III. Double the magnitude of one of the charges and double the separation between them.

IV. Double the magnitude of one of the charges and increase the separation between them to $\sqrt{2}\,d$.

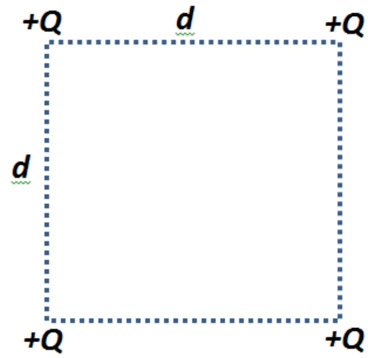
(A) *I* only (B) *I* & *II* only (C) *I* & *III* only (D) *I* & *IV* only

7. Three equal magnitude point charges are placed in a straight line as shown below. Charge ***1*** and charge ***2*** are separated by distance ***d***; the same distance as between charge ***2*** and charge ***3***. The polarities of the charges are indicated with ***1*** being positive and ***2*** & ***3*** being negative. Rank the magnitude of the net electrostatic force on each charge caused by the other two charges in increasing order, smallest force first.

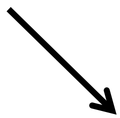
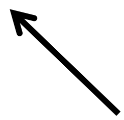


(A) 3, 1, 2 (B) 3, 2, 1
(C) 1, 2, 3 (D) 1, 3, 2

Use the following information for Questions #8 - #10: Four identical positive point charges are placed at the corners of a square measuring ***d*** on each side.



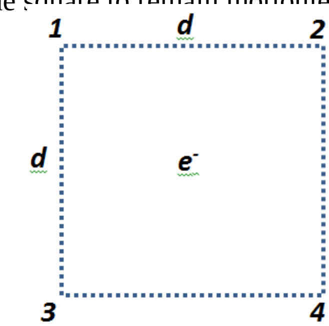
8. What is the direction of the net electrostatic force acting on the charge placed at the lower right corner caused by the other three charges?

(A)  (B)  (C)  (D) 

9. What is the magnitude of the net electrostatic force on the charge placed at the top left corner caused by the other three charges?

(A) $\sqrt{2}\frac{kQ^2}{d^2}$ (B) $\left(\frac{1}{2}+\sqrt{2}\right)\frac{kQ^2}{d^2}$ (C) $\left(\frac{1}{2}+\sqrt{2}\right)\frac{kQ^2}{2d^2}$ (D) $\frac{2kQ^2}{\sqrt{2}d^2}$

10. Based on the numbered corners that represent the corners of the square where the charges are placed, what polarity change(s) could be made in order to cause a single electron placed at the center of the square to remain motionless when released from rest?



I. Change the charges in corners ***1*** & ***2*** to negative charges.
II. Change the charges in corners ***2*** & ***4*** to negative charges.
III. Change the charges in corners ***1*** & ***4*** to negative charges.
IV. Change all the charges to negative charges.

(A) *I* & *II* only (B) *II* & *III* only
(C) *III* & *IV* only (D) None of these choices will work.

11. You are provided ten equal 200Ω resistors. You first connect them in series to a voltage source. You then connect them all in parallel to the same voltage source. What is the ratio of the effective resistances of these ten resistors connected in series to connected in parallel, $R_{Series}/R_{Parallel}$?

(A) $10/1$ (B) $100/1$ (C) $1000/1$ (D) $10,000/1$

12. Which of the following **cannot** be an effective resistance by connecting three resistors of values 36Ω, 50Ω, and 700Ω?

(A) 20.3Ω (B) 26.7Ω (C) 82.7Ω (D) 786Ω

13. You dangerously plug in three home appliances to the same extension cord that is plugged into a 15-A 120-V outlet at home. The appliances are an 1800-W heater, a 1400-W toaster oven, and a single 100-W lightbulb. What is the total current this configuration requires?

(A) 0.83-A (B) 11.7-A (C) 15-A (D) 27.5-A

Use the following information for Questions #14 & #15: You are provided a constant 48-V battery and two resistors of values 24Ω and 96Ω.

14. Which choice in the following table represents the current flowing through and the power used by each resistor if the resistors are connected in series?

	$I_{24\Omega}$	$I_{96\Omega}$	$P_{24\Omega}$	$P_{96\Omega}$
(A)	0.4-A	0.4-A	3.8-W	15.4-W
(B)	0.4-A	0.4-A	15.4-W	3.8-W
(C)	2-A	0.5-A	15.4-W	3.8-W
(D)	0.5-A	2-A	3.8-W	15.4-W

15. Which choice in the following table represents the current flowing through and the power used by each resistor if the resistors are connected in parallel?

	$I_{24\Omega}$	$I_{96\Omega}$	$P_{24\Omega}$	$P_{96\Omega}$
(A)	2.5-A	2.5-A	120-W	120-W
(B)	2.5-A	2.5-A	24-W	96-W
(C)	2-A	0.5-A	96-W	24-W
(D)	2-A	0.5-A	24-W	96-W

16. What is the terminal voltage of a NiCad (Nickel-Cadmium) battery that has an *emf* of 1.54-V, delivers 2-A to the circuit, and has an internal resistance of 0.1Ω?

(A) 1.14-V (B) 1.34-V (C) 1.54-V (D) 1.74-V

17. Electric eels generate electrical current using cells called *electroplaques*; essentially small natural *emf* devices. The electroplaques in the deadly South American eel are arranged in 140 rows connected in parallel. Each row runs the length of the eel's body and each row contains 5,000 electroplaques in series. Each electroplaque has an *emf* of 0.15-V with an internal resistance of 0.25Ω. If the water surrounding this creepy fish has a resistance of 800Ω, what is the electrical current produced from its head to its tail? NOTE: *A current of 0.1-A is generally considered to be fatal for humans.*
All full credit. No answer is correct.

(A) $1.9x10^{-4}A$ (B) $0.027A$ (C) $0.37A$ (D) $51A$

18. Two resistors have values of *r* and *R*, where $r < R$. As shown below, these two resistors are connected to a 12-V battery in two different ways. The configuration in Figure 1 yields a total current from the battery of 1.2-A whereas in Figure 2 the total current from the battery is 7.5-A. What are the values of the two resistors, *r* and *R*?

(A) $r = 5\Omega$ & $R = 15\Omega$
(B) $r = 1\Omega$ & $R = 9\Omega$
(C) $r = 2\Omega$ & $R = 8\Omega$
(D) $r = 4\Omega$ & $R = 6\Omega$

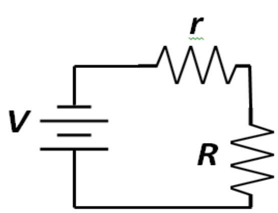


Figure 1

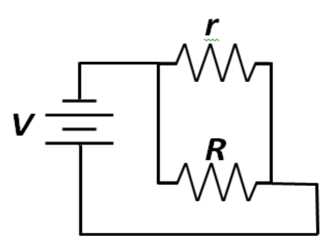
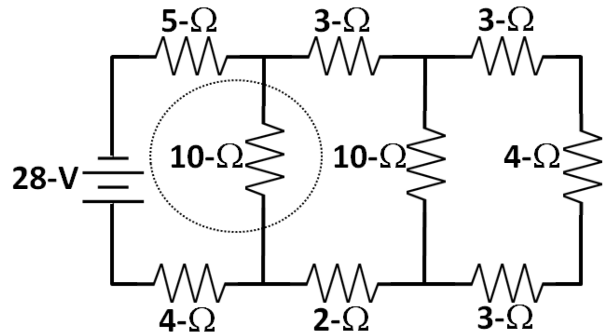


Figure 2

Use the following information for Questions #19 - #21: The image below represents a circuit with nine resistors of the provided values connected to a 28-V battery.



19. What is the equivalent resistance of this circuit?
(A) 4.6Ω
(B) 14Ω
(C) 34Ω
(D) 44Ω

20. What is the power dissipated by the 5Ω resistor?
(A) 5-W (B) 10-W (C) 15-W (D) 20-W

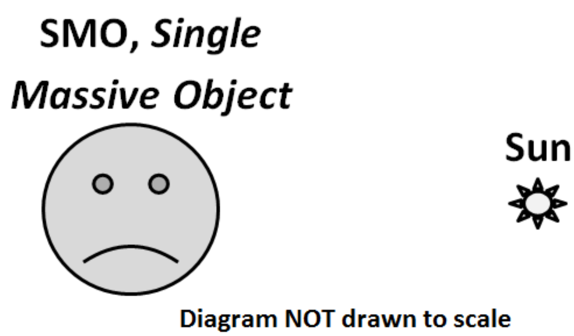
21. What percentage of the total current leaving the battery passes through the 10Ω resistor circled in the diagram?
(A) 25% (B) 50% (C) 75% (D) 100%

Use the following information for Questions #22 & #23: Our Sun orbits the supermassive blackhole at the center of our Milky Way galaxy once every 250,000,000 years. The orbit is roughly circular and has an average radius of 30,000 light years.

22. Calculate the centripetal acceleration of our Sun during its galactic orbit.
(A) $2x10^{-10}\ {}^{m}/_{s^2}$ (B) $2x10^{10}\ {}^{m}/_{s^2}$ (C) $1.8x10^{10}\ {}^{m}/_{s^2}$ (D) $1.8x10^{20}\ {}^{m}/_{s^2}$

23. The mass throughout our Milky Way galaxy is distributed over an immensely large area that makes gravity difficult to calculate algebraically. We know there are billions of massive objects between our Sun and the center of the galaxy and that our galaxy is surrounded by an unbelievably large dark matter halo. However, for mathematical simplicity, let's assume the mass at the center of the galaxy that keeps the Sun travelling in a circular path around it is a *single* regular massive object, as shown below. What would be the mass of this fictional single object? The mass of our Sun is $2x10^{30}\,kg$.

(A) $2.4x10^{20}\,kg$
(B) $8.5x10^{20}\,kg$
(C) $2.4x10^{41}\,kg$
(D) $8.5x10^{41}\,kg$



24. Saturn's largest moon is called Titan. It is about 1.5 times the size of our moon. Its orbital period is 15.95 Earth days and average orbital radius is $1.22x10^{6}\,km$. Based on this information, calculate the mass of Saturn.
(A) $3.7x10^{26}\,kg$ (B) $5.7x10^{26}\,kg$ (C) $7.7x10^{26}\,kg$ (D) $9.7x10^{26}\,kg$

25. Calculate the speed of a satellite in circular orbit 900-km above the surface of Earth. The mass of the Earth is $5.98x10^{24}\,kg$. All full credit. Ans is 7391
(A) $21{,}100\ {}^{m}/_{s}$ (B) $2{,}110\ {}^{m}/_{s}$ (C) $667\ {}^{m}/_{s}$ (D) $667{,}240\ {}^{m}/_{s}$

AP I and AP 2 PHYSICS FORMULAE Updated 3-22-2017

Constants & Conversion Factors

Proton and Neutron Mass	$m_p = 1.67x10^{-27} kg$	Fundamental charge	$e = 1.6x10^{-19} C$
Electron Mass	$m_e = 9.11x10^{-31} kg$	Electron Volt	$1eV = 1.6x10^{-19} J$
Avogadro's #	$6.02x10^{23} mol^{-1}$	Universal Gravitational constant	$G = 6.67x10^{-11} Nm^2/kg^2$
Universal gas constant	$R = 8.31 J/mol \cdot K$	Speed of Light	$c = 3.00x10^8 m/s$
Boltzmann's constant	$k_B = 1.38x10^{-23} J/K$	Magnetic constant	$k' = 1x10^{-7} T \cdot m/A$
1 unified atomic mass unit		$1u = 1.66x10^{-27} kg = 931 MeV/c^2$	
Planck's Constant		$h = 6.63x10^{-34} J \cdot s = 4.14x10^{-15} eV \cdot s$ $hc = 1.99x10^{-25} J \cdot m = 1240 eV \cdot nm$	
Coulomb's Law constant		$k = \frac{1}{4\pi\varepsilon_o} = 9.0x10^9 N \cdot m^2/kg^2$ $\varepsilon_o = 8.85x10^{-12} C^2/N \cdot m^2$	

MECHANICS

$\bar{v} = \frac{\Delta x}{\Delta t}$

$\bar{a} = \frac{\Delta v}{\Delta t}$

$v_f = v_i + at$

$\Delta x = v_i t + \frac{1}{2}at^2$

$2a\Delta x = v_f^2 - v_i^2$

$\Sigma F = ma$

$W = mg$

$F_g = G\frac{m_1 m_2}{r^2}$

$U_g = G\frac{m_1 m_2}{r}$

$\rho = mv$

$F\Delta t = m\Delta v$

$\mu = \frac{F_f}{F_N}$

Δx = displacement (change of position)
$\bar{v}$ = average velocity
$\bar{a}$ = average acceleration
v_i = initial velocity
v_f = final velocity
F = force
F_f = force of friction
F_N = normal force
F_g = gravitational force
G = Universal Gravitational Constant
ρ = momentum
μ = coefficient of friction
r = distance between center of masses
W = weight
m = mass
U_g = gravitational PE

ELECTRICITY

$F_e = k\frac{q_1 q_2}{r^2}$

$E = \frac{F}{q}$

$\Delta U_E = q\Delta V$

$V = \frac{W}{q} = Ed$

$I = \frac{\Delta q}{\Delta t}$

$V = IR$

$P = VI = I^2 R = \frac{V^2}{R}$

SERIES CIRCUIT

$I_T = I_1 = I_2 = I_3 = ...$

$V_T = V_1 + V_2 + V_3 + ...$

$R_T = R_1 + R_2 + R_3 + ...$

PARALLEL CIRCUITS

$I_T = I_1 + I_2 + I_3 + ..$

$U_C = \frac{1}{2}Q\Delta V = \frac{1}{2}C\Delta V^2$

$V_T = V_1 = V_2 = V_3 = ...$

$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...}$

$C = Q/\Delta V$

$C_{parallel} = \Sigma C_i$

$C_{series} = \frac{1}{\Sigma\left(\frac{1}{C_i}\right)}$

C = Capacitance
E = electric field intensity
I = electric current
k = electrostatic constant
P = Power
q = charge
R = resistance
U_E = electric potential Energy
U_C = energy stored in capacitor
V = electric potential difference
W = Work

ENERGY AND WORK

$W = F\Delta x \cos\theta$

$P = \frac{W}{\Delta t} = \frac{\Delta E}{\Delta t} = Fv$

$PE_g = mgh$

$KE = \frac{1}{2}mv^2$

$F = -kx$

$PE_s = \frac{1}{2}kx^2$

h = height
k = spring constant
KE = kinetic energy
PE_g = gravitational potential energy
PE_s = potential energy stored in a spring
P = power
W = work
x = change in spring length from the equilibrium position

CIRCULAR MOTION & ROTATION

$a_c = \frac{v^2}{r}$

$F_c = m\frac{v^2}{r}$

$1rev = 2\pi rad = 360°$

$\tau = Fxr = I\alpha$

$I = \Sigma mr^2$

$L = I\omega$

$K_{rot} = \frac{1}{2}I\omega^2$

$x = A\cos(\omega t)$

$x = A\cos(2\pi ft)$

a_c = centripetal acceleration
F_c = centripetal force
τ = Torque
I = Rotational Inertia
α = Angular acceleration
ω = Angular velocity
K_{rot} = Rotational KE
x = position

HEAT AND THERMODYNAMICS

$Q = mc\Delta T$

$Q = mL_f$

$Q = mL_V$

$\Delta L = \alpha L_o \Delta T$

$\frac{Q}{\Delta t} = \frac{kA\Delta T}{L}$

$PV = nRT = NkT$

$K = \frac{3}{2}k_B T$

$\Delta U = \frac{3}{2}nR\Delta T$

$W = -P\Delta V$

$\Delta U = Q + W$

c = specific heat

L_f = latent heat of fusion

L_V = latent heat of vaporization

Q = amount of heat

ΔT = change in temperature

α = coefficient of linear expansion

L_o = original length

$c_{water} = 4186\frac{J}{kg°K}$

K = kinetic energy

L = thickness

U = internal energy

W = work done on a system

WAVE PHENOMENA & SHM

$T = \frac{1}{f}$

$v = f\lambda$ OR $= \nu\lambda$

$n = \frac{c}{v}$

$n_i \sin\theta_i = n_r \sin\theta_r$

$\lambda = \frac{xd}{L}$

$\sin\theta_c = \frac{1}{n}$

$T_S = 2\pi\sqrt{\frac{m}{k}}$

$T_P = 2\pi\sqrt{\frac{L}{g}}$

c = speed of light in a vacuum

d = distance between slits

$f = \nu$ = frequency

L = distance from slit to screen

n = index of absolute refraction

T = period

v = speed

x = distance from central maximum to first-order maximum

λ = wavelength

θ = angle

θ_c = critical angle relative to air

GEOMETRIC OPTICS & SOUND

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

$\frac{h_i}{h_o} = \frac{d_i}{d_o}$

$\beta = 10\log\frac{I}{I_o}$

f = focal length

d_i = image distance

d_o = object distance

h_o = object size

h_i = image size

β = Sound level

I = Sound Intensity

I_o = Threshold Intensity

ELECTROMAGNETIC APPLICATIONS

$F_M = Bqv$

$F_M = BIL$

$\varepsilon = BLv$

$\frac{N_P}{N_S} = \frac{V_P}{V_S}$

$V_P I_P = V_S I_S$ (ideal)

$efficiency = \frac{V_S I_S}{V_P I_P}$

$\phi_B = B \cdot A$

$\Delta\phi_B = \varepsilon t$

B = magnetic field strength

I_P = current in primary

I_S = current in secondary

N_P = number of turns in primary coil

N_S = number of turns in secondary coil

V_P = voltage of primary

V_S = voltage of secondary

L = length of conductor

V = electric potential difference

v = speed of particle

FLUID MECHANICS

$\rho = \frac{m}{V}$

$P = \frac{F}{A}$

$P = P_o + mgh$

$F_b = \rho V g$

$A_1 v_1 = A_2 v_2$

$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 =$

$= P_2 + \rho g y_2 + \frac{1}{2}\rho v_2^2$

A = Area

F = force

h = depth

P = pressure

V = volume

v = speed

y = height

ρ = density

MODERN PHYSICS

$E = hf$

$K_{max} = hf - \phi$

$\lambda = \frac{h}{p}$

$E = mc^2$

E = energy

f = frequency

K = kinetic energy

m = mass

p = momentum

λ = wavelength

ϕ = work function

PHYSICS 1 **Salmon**

APRIL, 2017

SOLUTIONS Corrections:

1. D	14. A
2. B	15. C
3. C	16. B
4. A	17. ~~D~~All full credit
5. D	18. C
6. D	19. B
7. A	20. D
8. C	21. B
9. B	22. A
10. C	23. C
11. B	24. B
12. B	25. ~~A~~ All full credit
13. D	

January Exam: Kinematic, Dynamics, work, energy, and conservation of energy
February Exam: impulse and linear momentum and conservation of linear momentum: collisions, Simple harmonic motion: simple pendulum and mass-spring systems, Mechanical waves and sound,
Plus review of Jan topics
March Exam: Circular motion and universal gravitation, Rotational dynamics: torque, rotational kinematics and energy, rotational dynamics and conservation of angular momentum, Plus review of Jan and Feb topics
April Exam: electrostatics: electric charge and electric force, DC circuits (resistors only)
Plus review of Jan, Feb, and March topics.

Dates for 2017 Season

Thursday April 13, 2017

All schools must complete the April exam and mail in the results by April 28th, 2017

New Jersey Science League
PO Box 65 Stewartsville, NJ 08886-0065
phone # 908-213-8923 fax # 908-213-9391 email: **newjsl@ptd.net**
Web address: **http://entnet.com/~personal/njscil/html/**

What is to be mailed back to our office?

PLEASE RETURN THE AREA RECORD AND ALL TEAM MEMBER SCANTRONS (ALL STUDENTS PLACING 1ST, 2ND, 3RD, AND 4TH).

If you return scantrons of alternates, then label them as ALTERNATES.

Dates 2018 Season

Thursday January 11, 2018 ***Thursday February 8, 2018***
Thursday March 8, 2018 **Thursday April 12, 2018**