Physics C AP Exam

Mechanics

T1

Name: ________________ School: ________________ Score:

1.	11.	21.	31.
2.	12.	22.	32.
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ADVANCED PLACEMENT PHYSICS C TABLE OF INFORMATION

Mechanics T1

CONSTANTS AND CONVERSION FACTORS			
Proton mass,	$m_p = 1.67 \times 10^{-27}$ kg	Electron charge magnitude,	$e = 1.60 \times 10^{-19}$ C
Neutron mass,	$m_n = 1.67 \times 10^{-27}$ kg	1 electron volt,	$1\text{ eV} = 1.60 \times 10^{-19}$ J
Electron mass,	$m_e = 9.11 \times 10^{-31}$ kg	Speed of light,	$c = 3.00 \times 10^{8}$ m/s
Avogadro's number,	$N_A = 6.02 \times 10^{23}\text{ mol}^{-1}$	Universal gravitational constant,	$G = 6.67 \times 10^{-11}\ (\text{N}\cdot\text{m}^2)/\text{kg}^2$
Universal gas constant,	$R = 8.31$ J/(mol K)	Acceleration due to gravity at Earth's surface,	$g = 9.8\text{ m/s}^2$
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}$ J/K		

1 unified atomic mass unit,	$1\text{ u} = 1.66 \times 10^{-27}\text{ kg} = 931\text{ MeV}/c^2$
Planck's constant,	$h = 6.63 \times 10^{-34}\text{ J}\cdot\text{s} = 4.14 \times 10^{-15}\text{ eV}\cdot\text{s}$
	$hc = 1.99 \times 10^{-25}\text{ J}\cdot\text{m} = 1.24 \times 10^{3}\text{ eV}\cdot\text{nm}$
Vacuum permittivity,	$\varepsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$
Coulomb's law constant,	$k = 1/(4\pi\varepsilon_0) = 9.0 \times 10^{9}\ (\text{N}\cdot\text{m}^2)/\text{C}^2$
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$
Magnetic constant,	$k' = \mu_0/(4\pi) = 1 \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$
1 atmosphere pressure,	$1\text{ atm} = 1.0 \times 10^{5}\text{ N/m}^2 = 1.0 \times 10^{5}\text{ Pa}$

UNIT SYMBOLS								
	meter,	m	mole,	mol	watt,	W	farad,	F
	kilogram,	kg	hertz,	Hz	coulomb,	C	tesla,	T
	second,	s	newton,	N	volt,	V	degree Celsius,	°C
	ampere,	A	pascal,	Pa	ohm,	Ω	electron volt,	eV
	kelvin,	K	joule,	J	henry,	H		

VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

θ	0°	30°	37°	45°	53°	60°	90°
$\sin\theta$	0	1/2	3/5	$\sqrt{2}/2$	4/5	$\sqrt{3}/2$	1
$\cos\theta$	1	$\sqrt{3}/2$	4/5	$\sqrt{2}/2$	3/5	1/2	0
$\tan\theta$	0	$\sqrt{3}/3$	3/4	1	4/3	$\sqrt{3}$	∞

PREFIXES

Factor	Prefix	Symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

The following assumptions are used in this exam.

I. The frame of reference of any problem is inertial unless otherwise stated.

II. The direction of current is the direction in which positive charges would drift.

III. The electric potential is zero at an infinite distance from an isolated point charge.

IV. All batteries and meters are ideal unless otherwise stated.

V. Edge effects for the electric field of a parallel-plate capacitor are negligible unless otherwise stated.

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MECHANICS

$v_x = v_{x0} + a_x t$

$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$

$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$

$\vec{a} = \frac{\Sigma\vec{F}}{m} = \frac{\vec{F}_{net}}{m}$

$\vec{F} = \frac{d\vec{p}}{dt}$

$\vec{J} = \int \vec{F}\,dt = \Delta\vec{p}$

$\vec{p} = m\vec{v}$

$\left|\vec{F}_f\right| \le \mu \left|\vec{F}_N\right|$

$\Delta E = W = \int \vec{F}\cdot d\vec{r}$

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

$P = \frac{dE}{dt}$

$P = \vec{F}\cdot\vec{v}$

$\Delta U_g = mg\Delta h$

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

$\vec{\tau} = \vec{r} \times \vec{F}$

$\vec{\alpha} = \frac{\Sigma\vec{\tau}}{I} = \frac{\vec{\tau}_{net}}{I}$

$I = \int r^2 dm = \Sigma m r^2$

$x_{cm} = \frac{\Sigma m_i x_i}{\Sigma m_i}$

$v = r\omega$

$\vec{L} = \vec{r} \times \vec{p} = I\vec{\omega}$

$K = \frac{1}{2}I\omega^2$

$\omega = \omega_0 + \alpha t$

$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$

a = acceleration
E = energy
F = force
f = frequency
h = height
I = rotational inertia
J = impulse
K = kinetic energy
k = spring constant
ℓ = length
L = angular momentum
m = mass
P = power
p = momentum
r = radius or distance
T = period
t = time
U = potential energy
v = velocity or speed
W = work done on a system
x = position
μ = coefficient of friction
θ = angle
τ = torque
ω = angular speed
α = angular acceleration
ϕ = phase angle

$\vec{F}_S = -k\Delta\vec{x}$

$U_S = \frac{1}{2}k(\Delta x)^2$

$x = x_{max}\cos(\omega t + \phi)$

$T = \frac{2\pi}{\omega} = \frac{1}{f}$

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

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

$\left|\vec{F}_G\right| = \frac{Gm_1m_2}{r^2}$

$U_G = \frac{Gm_1m_2}{r}$

ELECTRICITY & MAGNETISM

$\left|\vec{F}_E\right| = \frac{1}{4\pi\varepsilon_0}\left|\frac{q_1q_2}{r^2}\right|$

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

$\oint \vec{E}\cdot d\vec{A} = \frac{Q}{\varepsilon_0}$

$E_x = -\frac{dV}{dx}$

$\Delta V = -\int \vec{E}\cdot d\vec{r}$

$V = \frac{1}{4\pi\varepsilon_0}\sum_i \frac{q_i}{r_i}$

$U_E = qV = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$

$\Delta V = \frac{Q}{C}$

$C = \frac{\kappa\varepsilon_0 A}{d}$

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$I = \frac{dQ}{dt}$

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

$R = \frac{\rho\ell}{A}$

$\vec{E} = \rho\vec{J}$

$I = Nev_d A$

$I = \frac{\Delta V}{R}$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

$P = I\Delta V$

A = area
B = magnetic field
C = capacitance
d = distance
E = electric field
ε = emf
F = force
I = current
J = current density
L = inductance
ℓ = length
n = number of loops of wire per unit length
N = number of charge carriers per unit volume
P = power
Q = charge
q = point charge
R = resistance
r = radius or distance
t = time
U = potential or stored energy
V = electric potential
v = velocity or speed
ρ = resistivity
Φ = flux
κ = dielectric constant

$\vec{F}_M = q\vec{v} \times \vec{B}$

$\oint \vec{B}\cdot d\vec{\ell} = \mu_0 I$

$d\vec{B} = \frac{\mu_0}{4\pi}\frac{I\,d\vec{\ell} \times \vec{r}}{r^2}$

$\vec{F} = \int I\,d\vec{\ell} \times \vec{B}$

$B_s = \mu_0 nI$

$\Phi_B = \int \vec{B}\cdot d\vec{A}$

$\varepsilon = \oint \vec{E}\cdot d\vec{\ell} = -\frac{d\Phi_B}{dt}$

$\varepsilon = -L\frac{dI}{dt}$

$U_L = \frac{1}{2}LI^2$

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PHYSICS C: MECHANICS
SECTION I
Time—45 minutes
35 Questions

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then mark it on your answer sheet.

1. A rock is dropped off a cliff and falls the first half of the distance to the ground in t_1 seconds. If it falls the second half of the distance in t_2 seconds, what is the value of t_2/t_1? (Ignore air resistance.)

   (A) $1/(2\sqrt{2})$
   (B) $1/\sqrt{2}$
   (C) 1/2
   (D) $1-(1/\sqrt{2})$
   (E) $\sqrt{2}-1$

2. A bubble starting at the bottom of a soda bottle experiences constant acceleration, a, as it rises to the top of the bottle in some time, t. How much farther does it travel in the last second of its journey than in the first second? Assume that the journey takes longer than 2 seconds.

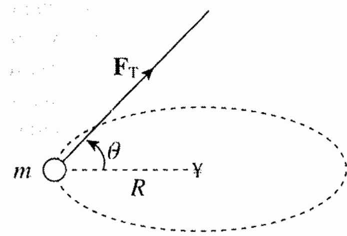
   (A) $a(t + 1\text{ s})^2$
   (B) $a(t - 1\text{ s})^2$
   (C) at^2
   (D) $a(t + 1\text{ s})(1\text{ s})$
   (E) $a(t - 1\text{ s})(1\text{ s})$

3. An object initially at rest experiences a time-varying acceleration given by $a = (2\text{ m/s}^3)t$ for $t \geq 0$. How far does the object travel in the first 3 seconds?

   (A) 9 m
   (B) 12 m
   (C) 18 m
   (D) 24 m
   (E) 27 m

4. What is the benefit of raising an object using an inclined plane instead of simply lifting the object? Assume ideal conditions.

   (A) The amount of force needed to move the object is reduced.
   (B) The amount of time needed to move the object is reduced.
   (C) The distance the object must be moved is reduced.
   (D) The amount of work needed to move the object is reduced.
   (E) The power that must be exerted will be reduced.



5. In the figure shown, a tension force $\mathbf{F}_T$ causes a particle of mass m to move with constant angular speed ω in a horizontal circular path (in a plane perpendicular to the page) of radius R. Which of the following expressions gives the magnitude of $\mathbf{F}_T$? (Ignore air resistance.)

   (A) $m\omega^2R$
   (B) $m\sqrt{\omega^4R^2 - g^2}$
   (C) $m\sqrt{\omega^4R^2 + g^2}$
   (D) $m(\omega^2R - g)$
   (E) $m(\omega^2R + g)$

6. An object (mass = m) above the surface of the Moon (mass = M) is dropped from an altitude h equal to the Moon's radius (R). With what speed will the object strike the lunar surface?

   (A) $\sqrt{GM/R}$
   (B) $\sqrt{GM/(2R)}$
   (C) $\sqrt{2GM/R}$
   (D) $\sqrt{2GMm/R}$
   (E) $\sqrt{GMm/(2R)}$

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7. Two pendulums are constructed in such a way that they are identical except that one has a hanging mass of m and the other has a hanging mass of $2m$. Both hanging masses are set into motion such that each system has the same total mechanical energy. Assume that the motion approximates simple harmonic motion. Comparatively, the system with the lesser mass will have greater

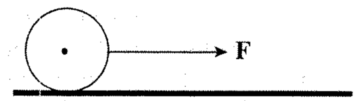
(A) maximum speed and maximum angle of displacement
(B) frequency and maximum angle of displacement
(C) period and maximum speed
(D) frequency only
(E) maximum angle of displacement only

8. A uniform cylinder of mass m and radius r unrolls without slipping from two strings tied to a vertical support. If the rotational inertia of the cylinder is $\frac{1}{2}mr^2$, find the acceleration of its center of mass.

(A) $\frac{1}{4}g$
(B) $\frac{1}{2}g$
(C) $\frac{1}{3}g$
(D) $\frac{2}{3}g$
(E) $\frac{3}{4}g$

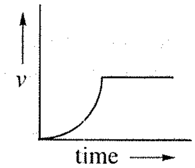
9. A space shuttle is launched from Earth. As it travels up, it moves at a constant velocity of 150 m/s straight up. If its engines provide 1.5×10^8 W of power, what is the shuttle's mass? You may assume that the shuttle's mass and the acceleration due to gravity are constant.

(A) 6.7×10^2 kg
(B) 1.0×10^5 kg
(C) 6.7×10^5 kg
(D) 1.0×10^6 kg
(E) 2.3×10^6 kg

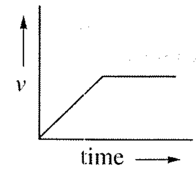


10. A uniform cylinder, initially at rest on a frictionless, horizontal surface, is pulled by a constant force **F** from time $t = 0$ to time $t = T$. From time $t = T$ on, this force is removed. Which of the following graphs best illustrates the speed, v, of the cylinder's center of mass from $t = 0$ to $t = 2T$?

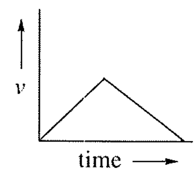
(A)



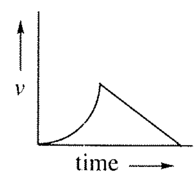
(B)



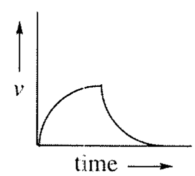
(C)



(D)



(E)



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11. A satellite is in circular orbit around Earth. If the work required to lift the satellite to its orbital height is equal to the satellite's kinetic energy while in this orbit, how high above the surface of Earth (radius = R) is the satellite?

(A) $\frac{1}{2}R$
(B) $\frac{2}{3}R$
(C) R
(D) $\frac{3}{2}R$
(E) $2R$

12. A block of length ℓ_1 = 10 cm, mass m_1 = 10 kg, and v_1 = 2 m/s is currently moving toward a second block. The second block has length ℓ_2 = 20 cm, m_2 = 2 kg, and v_2 = 8 m/s, and is moving toward the first block. The blocks' closest edges are currently 1 m apart. The blocks will experience a perfectly inelastic collision. How long after the collision does it take for the center of mass of the new object to cross the point midway between the blocks' starting positions? Assume the mass of each block is uniformly distributed.

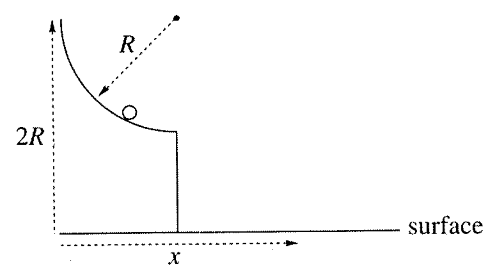
(A) 0.225 s
(B) 0.325 s
(C) 0.525 s
(D) 0.900 s
(E) 0.975 s

13. A rubber ball (mass = 0.08 kg) is dropped from a height of 3.2 m and, after bouncing off the floor, rises almost to its original height. If the impact time with the floor is measured to be 0.04 s, what average force did the floor exert on the ball?

(A) 0.16 N
(B) 16 N
(C) 32 N
(D) 36 N
(E) 64 N

14. A disk of radius 0.1 m initially at rest undergoes an angular acceleration of 2.0 rad/s². If the disk only rotates, find the total distance traveled by a point on the rim of the disk in 4.0 s.

(A) 0.4 m
(B) 0.8 m
(C) 1.2 m
(D) 1.6 m
(E) 2.0 m



15. In the figure above, a small object slides down a frictionless quarter-circular slide of radius R. If the object starts from rest at a height equal to $2R$ above a horizontal surface, find its horizontal displacement, x, at the moment it strikes the surface.

(A) $2R$
(B) $\frac{5}{2}R$
(C) $3R$
(D) $\frac{7}{2}R$
(E) $4R$

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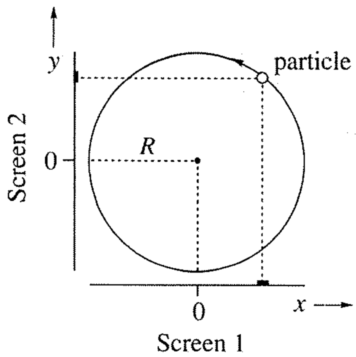
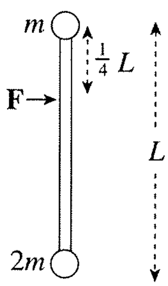


16. The figure above shows a particle executing uniform circular motion in a circle of radius R. Light sources (not shown) cause shadows of the particle to be projected onto two mutually perpendicular screens. The positive directions for x and y along the screens are denoted by the arrows. When the shadow on Screen 1 is at position $x = -(0.5)R$ and moving in the $+x$ direction, what is true about the position and velocity of the shadow on Screen 2 at that same instant?

(A) $y = -(0.866)R$; velocity in $-y$ direction
(B) $y = -(0.866)R$; velocity in $+y$ direction
(C) $y = -(0.5)R$; velocity in $-y$ direction
(D) $y = +(0.866)R$; velocity in $-y$ direction
(E) $y = +(0.866)R$; velocity in $+y$ direction



17. The figure above shows a view from above of two objects attached to the end of a rigid massless rod at rest on a frictionless table. When a force **F** is applied as shown, the resulting rotational acceleration of the rod about its center of mass is $kF/(mL)$. What is k?

(A) $\frac{3}{8}$

(B) $\frac{1}{2}$

(C) $\frac{5}{8}$

(D) $\frac{3}{4}$

(E) $\frac{5}{6}$

18. Old cars were made with rigid frames that could retain their shape in a collision. Modern cars are made with frames that crumple in a collision. If each type of vehicle were to crash into a wall and come to a complete stop, which of the following would NOT be true regarding those collisions? Assume the vehicles were of equal mass and traveling at the same speed before the collision.

(A) The modern vehicle would experience less force.
(B) The modern vehicle would experience less impulse.
(C) The modern vehicle's magnitude of acceleration would be less.
(D) The modern vehicle's collision would take less time.
(E) More than one of the above would not be true.

19. A homogeneous bar is lying on a flat table. Besides the gravitational and normal forces (which cancel), the bar is acted upon by exactly two other external forces, $\mathbf{F}_1$ and $\mathbf{F}_2$, which are parallel to the surface of the table. If the net force on the rod is zero, which one of the following is also true?

(A) The net torque on the bar must also be zero.
(B) The bar cannot accelerate translationally or rotationally.
(C) The bar can accelerate translationally if $\mathbf{F}_1$ and $\mathbf{F}_2$ are not applied at the same point.
(D) The net torque will be zero if $\mathbf{F}_1$ and $\mathbf{F}_2$ are applied at the same point.
(E) None of the above

20. An astronaut lands on a planet whose mass and radius are each twice that of Earth. If the astronaut weighs 800 N on Earth, how much will he weigh on this planet?

(A) 200 N
(B) 400 N
(C) 800 N
(D) 1,600 N
(E) 3,200 N

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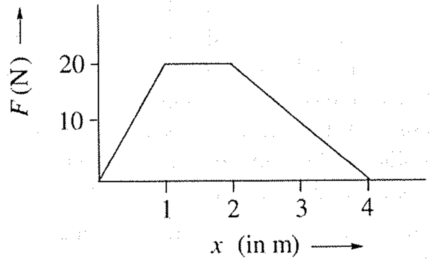
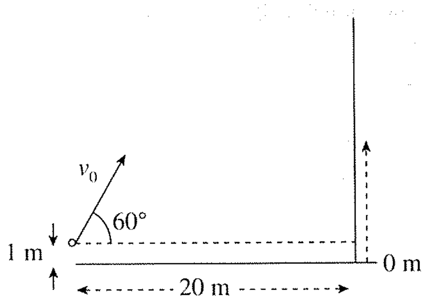


21. A particle of mass $m = 1.0$ kg is acted upon by a variable force, $F(x)$, whose strength is given by the graph above. If the particle's speed was zero at $x = 0$, what is its speed at $x = 4$ m?

(A) 5.0 m/s
(B) 8.7 m/s
(C) 10 m/s
(D) 14 m/s
(E) 20 m/s

22. The radius of a collapsing spinning star (assumed to be a uniform sphere with a constant mass) decreases to $\frac{1}{16}$ of its initial value. What is the ratio of the final rotational kinetic energy to the initial rotational kinetic energy?

(A) 4
(B) 16
(C) 16^2
(D) 16^3
(E) 16^4

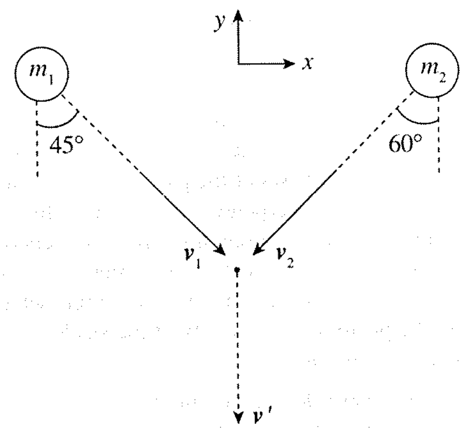


23. A ball is projected with an initial velocity of magnitude $v_0 = 40$ m/s toward a vertical wall as shown in the figure above. How long does the ball take to reach the wall?

(A) 0.25 s
(B) 0.6 s
(C) 1.0 s
(D) 2.0 s
(E) 3.0 s

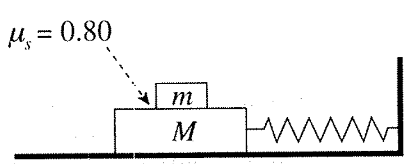
24. If M, L, and T represent the dimensions of mass, length, and time, respectively, what are the dimensions of the universal gravitational constant, G?

(A) $L^2/(MT^2)$
(B) $L^3/(MT^2)$
(C) $(MT^2)/L^3$
(D) $(ML^3)/T^2$
(E) $L^3/(MT)$



25. The figure shown above is a view from above of two clay balls moving toward each other on a frictionless surface. They collide perfectly inelastically at the indicated point and are observed to then move in the direction indicated by the post-collision velocity vector, v'. If $m_1 = 2m_2$, and v' is parallel to the negative y-axis, what is v_2?

(A) $v_1(\sin 45°)/(2\sin 60°)$
(B) $v_1(\cos 45°)/(2\cos 60°)$
(C) $v_1(2\cos 45°)/(\cos 60°)$
(D) $v_1(2\sin 45°)/(\sin 60°)$
(E) $v_1(\cos 45°)/(2\sin 60°)$



26. In the figure above, the coefficient of static friction between the two blocks is 0.80. If the blocks oscillate with a frequency of 2.0 Hz, what is the maximum amplitude of the oscillations if the small block is not to slip on the large block?

(A) 3.1 cm
(B) 5.0 cm
(C) 6.2 cm
(D) 7.5 cm
(E) 9.4 cm

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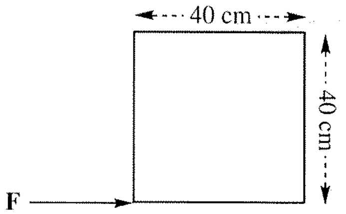
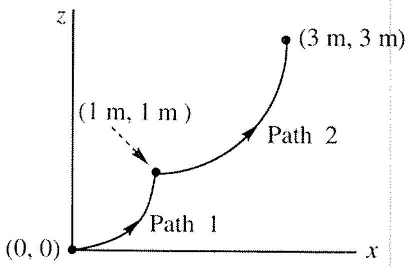
27. When two objects collide, the ratio of the relative speed after the collision to the relative speed before the collision is called the *coefficient of restitution*, e. If a ball is dropped from height H_1 onto a stationary floor, and the ball rebounds to height H_2, what is the coefficient of restitution of the collision?

(A) H_1/H_2
(B) H_2/H_1
(C) $\sqrt{H_1/H_2}$
(D) $\sqrt{H_2/H_1}$
(E) $(H_1/H_2)^2$



28. The figure above shows a square metal plate of side length 40 cm and uniform density, lying flat on a table. A force **F** of magnitude 10 N is applied at one of the corners, as shown. Determine the torque produced by **F** relative to the center of rotation.

(A) 0 N•m
(B) 1.0 N•m
(C) 1.4 N•m
(D) 2.0 N•m
(E) 4.0 N•m

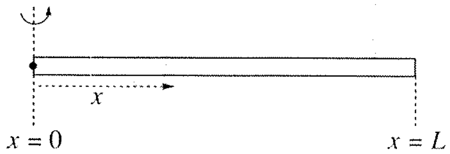


29. A small block of mass $m = 2.0$ kg is pushed from the initial point $(x_i, z_i) = (0 \text{ m}, 0 \text{ m})$ upward to the final point $(x_f, z_f) = (3 \text{ m}, 3 \text{ m})$ along the path indicated. Path 1 is a portion of the parabola $z = x^2$, and Path 2 is a quarter circle whose equation is $(x-1)^2 + (z-3)^2 = 4$. How much work is done by gravity during this displacement?

(A) –60 J
(B) –80 J
(C) –90 J
(D) –100 J
(E) –120 J

30. A horizontal spring of spring constant k is experiencing simple harmonic motion between points $x = -A$ and $x = A$ with a block of mass M attached to the end. A bullet of mass m is fired from a gun with speed v so that it collides perfectly inelastically with the block when it is at position $x = -A$. How far beyond $x = -A$ will the spring be compressed as a result of this collision?

(A) $mv\sqrt{kM}$
(B) $mv\sqrt{k(M+m)}$
(C) $mv\sqrt{\dfrac{1}{k(M+m)}}$
(D) $\sqrt{\dfrac{mv}{k(M+m)}}$
(E) $mv\sqrt{\dfrac{1}{kM}}$



31. The rod shown above can pivot about the point $x = 0$ and rotates in a plane perpendicular to the page. Its linear density, λ, increases with x such that $\lambda(x) = kx$, where k is a positive constant. Determine the rod's moment of inertia in terms of its length, L, and its total mass, M.

(A) $\frac{1}{6}ML^2$
(B) $\frac{1}{4}ML^2$
(C) $\frac{1}{3}ML^2$
(D) $\frac{1}{2}ML^2$
(E) $2ML^2$

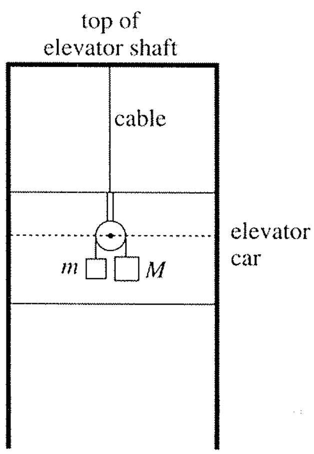
GO ON TO THE NEXT PAGE.

32. A particle is subjected to a conservative force whose potential energy function is

$$U(x) = (x - 2)^3 - 12x$$

where U is given in joules when x is measured in meters. Which of the following represents a position of stable equilibrium?

(A) $x = -4$
(B) $x = -2$
(C) $x = 0$
(D) $x = 2$
(E) $x = 4$



33. A light, frictionless pulley is suspended from a rigid rod attached to the roof of an elevator car. Two masses, m and M (with $M > m$), are suspended on either side of the pulley by a light, inextensible cord. The elevator car is descending at a constant velocity. Determine the acceleration of the masses.

(A) $(M - m)g$

(B) $(M + m)g$

(C) $\dfrac{M + m}{M - m}g$

(D) $\dfrac{M - m}{M + m}g$

(E) $(M - m)(M + m)g$

34. A block of mass $m = 2$ kg starts at rest at the top of a ramp of angle θ_r such that $\sin \theta_r = 0.45$ and $\cos \theta_r = 0.9$. The length of the ramp consists of alternating stretches of frictionless portions followed by portions with a coefficient of friction $\mu = \frac{2}{3}$. The first meter of the ramp's length is frictionless, followed by 1 m of friction. The next meter is frictionless again, followed by 2 m of friction. This alternating pattern continues with the frictionless stretch always being 1 m and the friction stretch increasing in length by 1 m each time. How far does the block travel before coming to a stop? Assume the ramp has infinite length.

(A) 4 m
(B) 8 m
(C) 12 m
(D) 19 m
(E) 24 m

35. An object of mass 2 kg is acted upon by three external forces, each of magnitude 4 N. Which of the following could NOT be the resulting acceleration of the object?

(A) 0 m/s^2
(B) 2 m/s^2
(C) 4 m/s^2
(D) 6 m/s^2
(E) 8 m/s^2

STOP

END OF SECTION I, MECHANICS

PHYSICS C: MECHANICS

SECTION II

Time—45 minutes

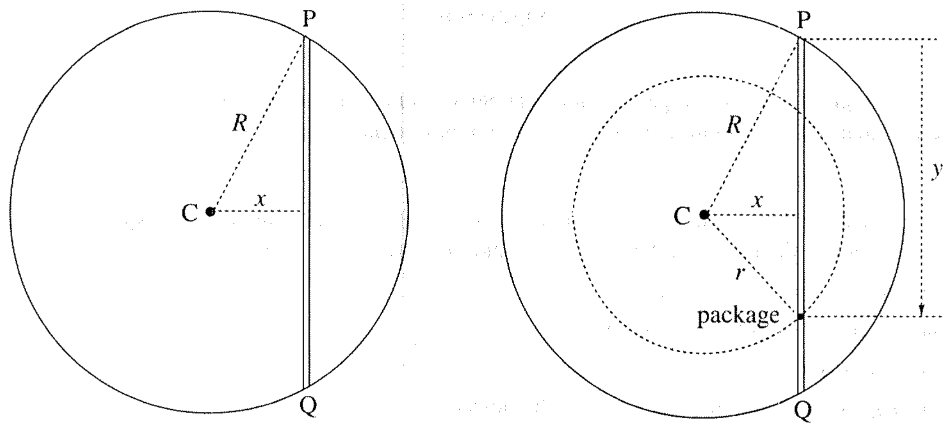
3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes per question for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight.

1. An ideal projectile is launched from the ground at an angle θ to the horizontal, with an initial speed of v_0. The ground is flat and level everywhere. Write all answers in terms of v_0, θ, and fundamental constants.
   (a) Calculate the time the object is in the air.
   (b) Calculate the maximum height the object reaches.
   (c) What is the *net* vertical displacement of the object?
   (d) Calculate the range (horizontal displacement) of the object.
   (e) What should θ be so that the projectile's range is equal to its maximum vertical displacement?

GO ON TO THE NEXT PAGE.

2. A narrow tunnel is drilled through Earth (mass = M, radius = R), connecting points P and Q, as shown in the diagram on the left below. The perpendicular distance from Earth's center, C, to the tunnel is x. A package (mass = m) is dropped from point P into the tunnel; its distance from P is denoted y and its distance from C is denoted r. See the diagram on the right.



(a) Assuming that Earth is a homogeneous sphere, the gravitational force F on the package is due to m and the mass contained within the sphere of radius $r < R$. Use this fact to show that

$$F = -\frac{GMm}{R^3}r$$

(b) Use the equation $F(r) = -dU/dr$ to find an expression for the change in gravitational potential energy of the package as it moves from point P to a point where its distance from Earth's center is r. Write your answer in terms of G, M, m, R, and r.

(c) Apply Conservation of Energy to determine the speed of the package in terms of G, M, R, x, and y. (Ignore friction.)

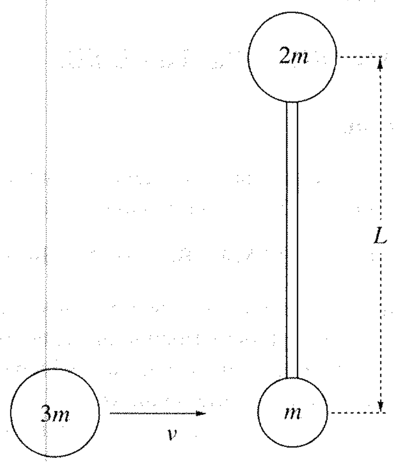
(d)

i. At what point in the tunnel—that is, for what value of y—will the speed of the package be maximized?

ii. What is this maximum speed? (Write your answer in terms of G, M, R, and x.)

GO ON TO THE NEXT PAGE.

3. The diagram below is a view from above of three sticky hockey pucks on a frictionless horizontal surface. The pucks with masses m and $2m$ are connected by a massless, rigid rod of length L and are initially at rest. The puck of mass $3m$ is moving with velocity v directly toward puck m. When puck $3m$ strikes puck m, the collision is perfectly inelastic.



(a) Immediately after the collision,

i. where is the center of mass of the system?

ii. what is the speed of the center of mass? (Write your answer in terms of v.)

iii. what is the angular speed of the system? (Write your answer in terms of v and L.)

(b) What fraction of the system's initial kinetic energy is lost as a result of the collision?

STOP

END OF SECTION II, MECHANICS

T1

1. E	11. A	21. C	31. D
2. E	12. E	22. C	32. E
3. A	13. C	23. C	33. D
4. A	14. D	24. B	34. E
5. C	15. C	25. D	35. E
6. A	16. A	26. B	
7. A	17. C	27. D	
8. D	18. E	28. D	
9. B	19. D	29. A	
10. B	20. B	30. C	