- Solutions -

PHYSICS C

SECTION I, MECHANICS

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 fill in the corresponding oval on the answer sheet.

1. In the absence of air friction, an object dropped near the surface of the Earth experiences a constant acceleration of about 9.8 m/s^2. This means that the

   (A) speed of the object increases 9.8 m/s during each second
   (B) speed of the object as it falls is 9.8 m/s
   (C) object falls 9.8 meters during each second
   (D) object falls 9.8 meters during the first second only
   (E) derivative of the distance with respect to time for the object equals 9.8 m/s^2

$9.8 \frac{m/s}{s}$

2. A 500-kilogram sports car accelerates uniformly from rest, reaching a speed of 30 meters per second in 6 seconds. During the 6 seconds, the car has traveled a distance of

   (A) 15 m
   (B) 30 m
   (C) 60 m
   (D) 90 m
   (E) 180 m

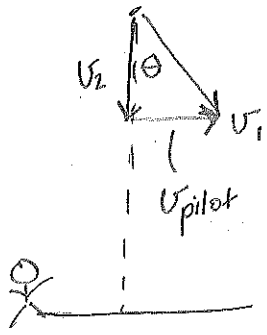
$a = \frac{\Delta v}{\Delta t} = \frac{30}{6} = 5$

$\Delta x = \frac{1}{2} a t^2 = \frac{1}{2}(5)(6)^2$

$= 5(18) = 90$

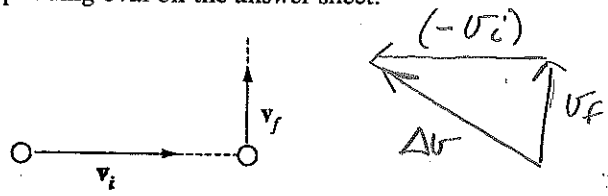
3. At a particular instant, a stationary observer on the ground sees a package falling with speed v_1 at an angle to the vertical. To a pilot flying horizontally at constant speed relative to the ground, the package appears to be falling vertically with a speed v_2 at that instant. What is the speed of the pilot relative to the ground?

   (A) $v_1 + v_2$
   (B) $v_1 - v_2$
   (C) $v_2 - v_1$
   (D) $\sqrt{v_1^2 - v_2^2}$
   (E) $\sqrt{v_1^2 + v_2^2}$

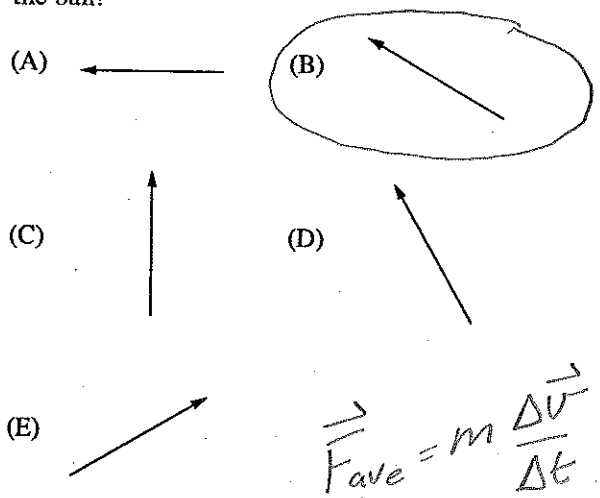


$v_p^2 + v_2^2 = v_1^2$

$v_p = \sqrt{v_1^2 - v_2^2}$



4. A ball initially moves horizontally with velocity $\mathbf{v}_i$, as shown above. It is then struck by a stick. After leaving the stick, the ball moves vertically with a velocity $\mathbf{v}_f$, which is smaller in magnitude than $\mathbf{v}_i$. Which of the following vectors best represents the direction of the average force that the stick exerts on the ball?



$\vec{F}_{ave} = m \frac{\Delta \vec{v}}{\Delta t}$

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5. If F_1 is the magnitude of the force exerted by the Earth on a satellite in orbit about the Earth and F_2 is the magnitude of the force exerted by the satellite on the Earth, then which of the following is true?

(A) F_1 is much greater than F_2.
(B) F_1 is slightly greater than F_2.
(C) F_1 is equal to F_2.
(D) F_2 is slightly greater than F_1.
(E) F_2 is much greater than F_1.

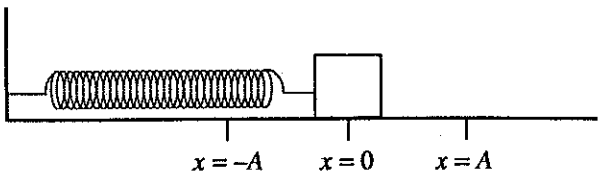
3rd law
$F_{on\,1\ by\,2} = F_{on\,2\ by\,1}$

6. A ball is thrown upward. At a height of 10 meters above the ground, the ball has a potential energy of 50 joules (with the potential energy equal to zero at ground level) and is moving upward with a kinetic energy of 50 joules. Air friction is negligible. The maximum height reached by the ball is most nearly

(A) 10 m
(B) 20 m
(C) 30 m
(D) 40 m
(E) 50 m

20 m
$\Delta U = 50\ J$
10 m
$50J = \Delta U$
$+50\ J = KE$
$0J = U_1$

Questions 7-8



A block on a horizontal frictionless plane is attached to a spring, as shown above. The block oscillates along the x-axis with simple harmonic motion of amplitude A.

7. Which of the following statements about the block is correct?

(A) At $x = 0$, its velocity is zero.
(B) At $x = 0$, its acceleration is at a maximum.
(C) At $x = A$, its displacement is at a maximum.
(D) At $x = A$, its velocity is at a maximum.
(E) At $x = A$, its acceleration is zero.

$\Delta X = max$ at $X = A$

8. Which of the following statements about energy is correct?

(A) The potential energy of the spring is at a minimum at $x = 0$.
(B) The potential energy of the spring is at a minimum at $x = A$.
(C) The kinetic energy of the block is at a minimum at $x = 0$.
(D) The kinetic energy of the block is at a maximum at $x = A$.
(E) The kinetic energy of the block is always equal to the potential energy of the spring.

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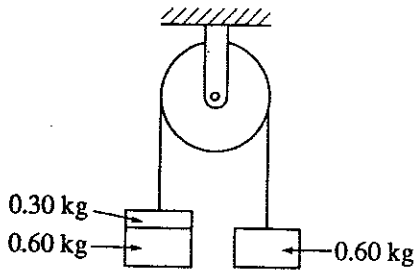

9 Two 0.60-kilogram objects are connected by a thread that passes over a light, frictionless pulley, as shown above. The objects are initially held at rest. If a third object with a mass of 0.30 kilogram is added on top of one of the 0.60-kilogram objects as shown and the objects are released, the magnitude of the acceleration of the 0.30-kilogram object is most nearly

(A) 10.0 m/s^2
(B) 6.0 m/s^2
(C) 3.0 m/s^2
(D) 2.0 m/s^2
(E) 1.0 m/s^2

10. During a certain time interval, a constant force delivers an average power of 4 watts to an object. If the object has an average speed of 2 meters per second and the force acts in the direction of motion of the object, the magnitude of the force is

(A) 16 N
(B) 8 N
(C) 6 N
(D) 4 N
(E) 2 N

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

$4 = F(2)$

$F = 2$

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3N to left

$3 = 1.5\,kg\,(a)$

$2 = a$

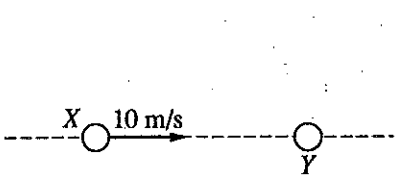


Figure I

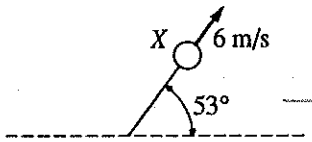
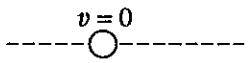


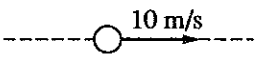
Figure II

11. Two balls are on a frictionless horizontal tabletop. Ball X initially moves at 10 meters per second, as shown in Figure I above. It then collides elastically with identical ball Y, which is initially at rest. After the collision, ball X moves at 6 meters per second along a path at 53° to its original direction, as shown in Figure II above. Which of the following diagrams best represents the motion of ball Y after the collision?

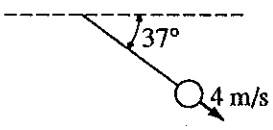
(A)



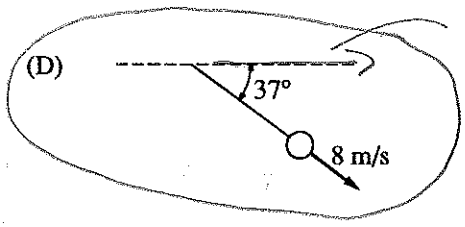
(B)



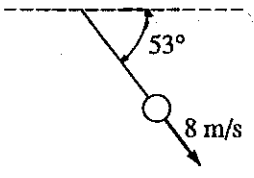
(C)



(D)



(E)



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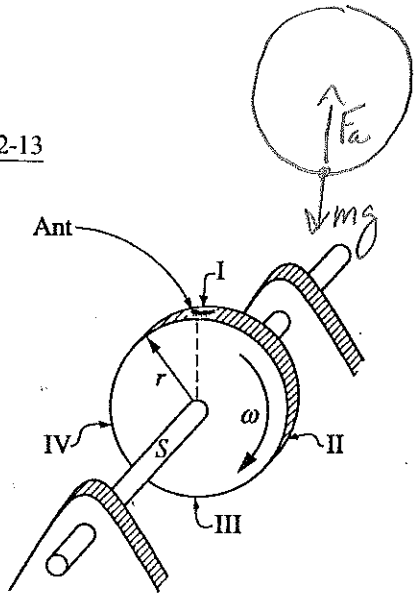
Questions 12-13



An ant of mass m clings to the rim of a flywheel of radius r, as shown above. The flywheel rotates clockwise on a horizontal shaft S with constant angular velocity ω. As the wheel rotates, the ant revolves past the stationary points I, II, III, and IV. The ant can adhere to the wheel with a force much greater than its own weight.

12. It will be most difficult for the ant to adhere to the wheel as it revolves past which of the four points?

(A) I
(B) II
(C) III
(D) IV
(E) It will be equally difficult for the ant to adhere to the wheel at all points.

13. What is the magnitude of the minimum adhesion force necessary for the ant to stay on the flywheel at point III ?

(A) mg
(B) $m\omega^2r^2$
(C) $m\omega^2r^2 + mg$
(D) $m\omega^2r - mg$
(E) $m\omega^2r + mg$

$F_{rad} - mg = m\frac{v^2}{r}$

$F_{rad} = m\frac{v^2}{r} + mg$

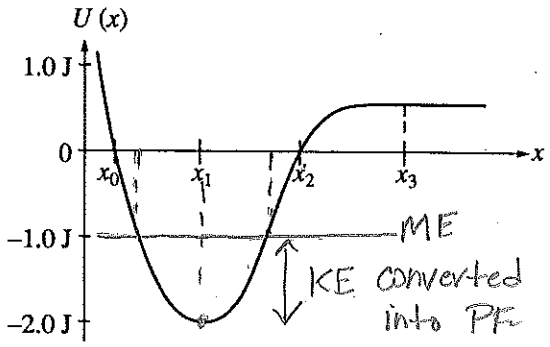
$v = \omega r$

$F_{rad} = m\omega^2 r + mg$

14. A weight lifter lifts a mass m at constant speed to a height h in time t. How much work is done by the weight lifter?

(A) mg
(B) mh
(C) mgh
(D) $mght$
(E) mgh/t

$W = F \cdot \Delta x$
$= mgh$



15. A conservative force has the potential energy function $U(x)$, shown by the graph above. A particle moving in one dimension under the influence of this force has kinetic energy 1.0 joule when it is at position x_1. Which of the following is a correct statement about the motion of the particle?

(A) It oscillates with maximum position x_2 and minimum position x_0.
(B) It moves to the right of x_3 and does not return.
(C) It moves to the left of x_0 and does not return.
(D) It comes to rest at either x_0 or x_2.
(E) It cannot reach either x_0 or x_2.

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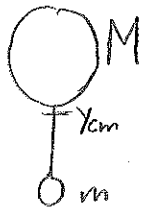
$0 = Mv_B + mv$

16. A balloon of mass M is floating motionless in the air. A person of mass less than M is on a rope ladder hanging from the balloon. The person begins to climb the ladder at a uniform speed v relative to the ground. How does the balloon move relative to the ground?

(A) Up with speed v
(B) Up with a speed less than v
(C) Down with speed v
(D) Down with a speed less than v
(E) The balloon does not move.



17. If one knows only the constant resultant force acting on an object and the time during which this force acts, one can determine the

$\Delta P = \int F dt$

(A) change in momentum of the object
(B) change in velocity of the object
(C) change in kinetic energy of the object
(D) mass of the object
(E) acceleration of the object

18. When an object is moved from rest at point A to rest at point B in a gravitational field, the net work done by the field depends on the mass of the object and

Conservative force

(A) the positions of A and B only
(B) the path taken between A and B only
(C) both the positions of A and B and the path taken between them
(D) the velocity of the object as it moves between A and B
(E) the nature of the external force moving the object from A to B

19. An object is shot vertically upward into the air with a positive initial velocity. Which of the following correctly describes the velocity and acceleration of the object at its maximum elevation?

	Velocity	Acceleration
(A)	Positive	Positive
(B)	Zero	Zero
(C)	Negative	Negative
(D)	Zero	Negative
(E)	Positive	Negative

$v_y = 0$

g

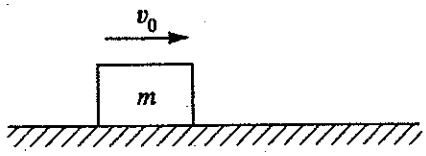
20. A turntable that is initially at rest is set in motion with a constant angular acceleration α. What is the angular velocity of the turntable after it has made one complete revolution?

(A) $\sqrt{2\alpha}$
(B) $\sqrt{2\pi\alpha}$
(C) $\sqrt{4\pi\alpha}$
(D) 2α
(E) $4\pi\alpha$

$\omega_f = \omega_i + \alpha t$

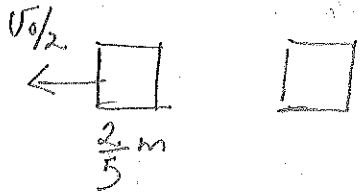
$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$

$\omega_f^2 = 2\alpha(2\pi)$



21. An object of mass m is moving with speed v_0 to the right on a horizontal frictionless surface, as shown above, when it explodes into two pieces. Subsequently, one piece of mass $\frac{2}{5}m$ moves with a speed $\frac{v_0}{2}$ to the left. The speed of the other piece of the object is

(A) $\frac{v_0}{2}$
(B) $\frac{v_0}{3}$
(C) $\frac{7v_0}{5}$
(D) $\frac{3v_0}{2}$
(E) $2v_0$



$mv_0 = \frac{2}{5}m\left(\frac{v_0}{2}\right) + P$

$\frac{5}{5}mv_0 = -\left(\frac{1}{5}m\right)v_0 + \left(\frac{3}{5}m\right)v$

$6mv_0 = 3mv$ $\quad v = 2v_0$

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22. A newly discovered planet has twice the mass of the Earth, but the acceleration due to gravity on the new planet's surface is exactly the same as the acceleration due to gravity on the Earth's surface. The radius of the new planet in terms of the radius R of Earth is

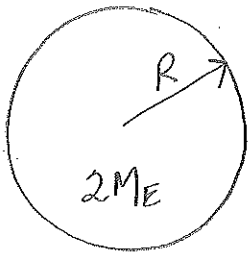
(A) $\frac{1}{2}R$

(B) $\frac{\sqrt{2}}{2}R$

(C) $\sqrt{2}R$

(D) $2R$

(E) $4R$



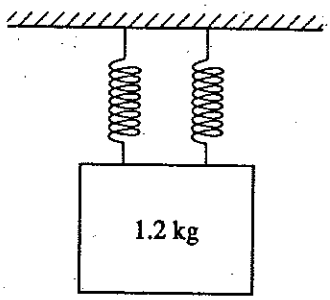
$\frac{GM_E m}{R_E^2} = ma$

$\frac{G(2M_E)}{R^2} = \frac{GM_E}{R_E^2}$

$R^2 = 2R_E$

$R = \sqrt{2}\,R_E$

Questions 23-24



Two identical massless springs are hung from a horizontal support. A block of mass 1.2 kilograms is suspended from the pair of springs, as shown above. When the block is in equilibrium, each spring is stretched an additional 0.15 meter.

23. The force constant of each spring is most nearly

(A) 40 N/m
(B) 48 N/m
(C) 60 N/m
(D) 80 N/m
(E) 96 N/m

$2kx = 12\ N$

$k = \frac{6}{.15} = \frac{6}{15} \cdot 100 = \frac{600}{15} = 40$

24. When the block is set into oscillation with amplitude A, it passes through its equilibrium point with a speed v. In which of the following cases will the block, when oscillating with amplitude A, also have speed v when it passes through its equilibrium point?

I. The block is hung from only one of the two springs. → only 1 k

II. The block is hung from the same two springs, but the springs are connected in series rather than in parallel.

III. A 0.5-kilogram mass is attached to the block.

(A) None
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

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

2 identical springs put together has $\frac{1}{2}k$ of either one individual

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25. A spring-loaded gun can fire a projectile to a height h if it is fired straight up. If the same gun is pointed at an angle of 45° from the vertical, what maximum height can now be reached by the projectile?

(A) $\frac{h}{4}$

(B) $\frac{h}{2\sqrt{2}}$

(C) $\frac{h}{2}$

(D) $\frac{h}{\sqrt{2}}$

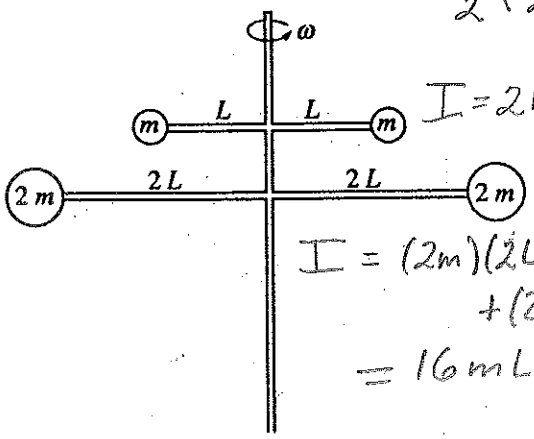
(E) h

$mgh = \frac{1}{2}mv_0^2$

$v_0 \sin 45° = \frac{v_0}{\sqrt{2}}$

$gh_N = \frac{1}{2}\left(\frac{v_0}{\sqrt{2}}\right)^2$

$= \frac{1}{2}\left(\frac{1}{2}v_0^2\right)$



$I = 2mL^2$

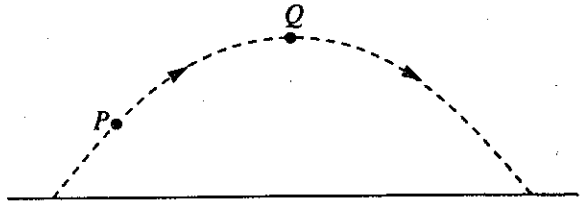
$I = (2m)(2L)^2 + (2m)(2L)^2$

$= 16mL^2$

26. The rigid body shown in the diagram above consists of a vertical support post and two horizontal crossbars with spheres attached. The masses of the spheres and the lengths of the crossbars are indicated in the diagram. The body rotates about a vertical axis along the support post with constant angular speed ω. If the masses of the support post and the crossbars are negligible, what is the ratio of the angular momentum of the two upper spheres to that of the two lower spheres?

(A) 2/1
(B) 1/1
(C) 1/2
(D) 1/4
(E) 1/8

Questions 27-28



A ball is thrown and follows a parabolic path, as shown above. Air friction is negligible. Point Q is the highest point on the path.

27. Which of the following best indicates the direction of the acceleration, if any, of the ball at point Q?

(A) →
(B) ↘
(C) ↓
(D) ←
(E) There is no acceleration of the ball at point Q.

28. Which of the following best indicates the direction of the net force on the ball at point P?

(A) ↗
(B) →
(C) ↘
(D) ↓
(E) ↙

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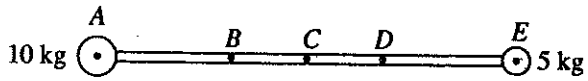
Questions 29-30



A 5-kilogram sphere is connected to a 10-kilogram sphere by a rigid rod of negligible mass, as shown above.

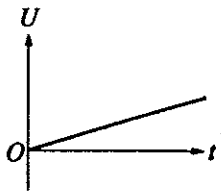
29. Which of the five lettered points represents the center of mass of the sphere-rod combination?

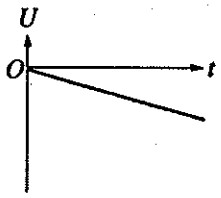
(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *E*

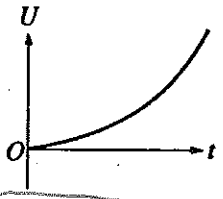
30. The sphere-rod combination can be pivoted about an axis that is perpendicular to the plane of the page and that passes through one of the five lettered points. Through which point should the axis pass for the moment of inertia of the sphere-rod combination about this axis to be greatest?

(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) *E*

31. A small mass is released from rest at a very great distance from a larger stationary mass. Which of the following graphs best represents the gravitational potential energy U of the system of the two masses as a function of time t?

(A)


(B)


(C)


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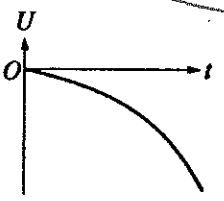

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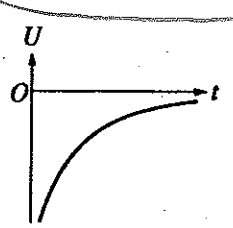

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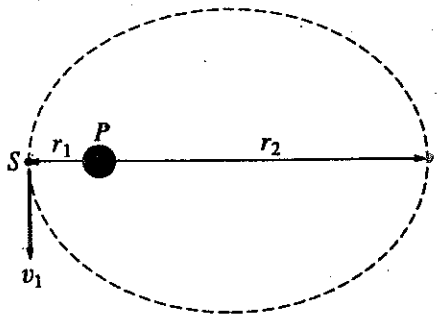
$\omega = \sqrt{\frac{g}{l}} = 2\pi \frac{1}{T}$

$T = 2\pi \sqrt{\frac{l}{g}} = 2\pi \sqrt{\frac{l}{4g}}$



32. A satellite S is in an elliptical orbit around a planet P, as shown above, with r_1 and r_2 being its closest and farthest distances, respectively, from the center of the planet. If the satellite has a speed v_1 at its closest distance, what is its speed at its farthest distance?

$I\omega = I\omega$

(A) $\frac{r_1}{r_2} v_1$

$m r_1^2 \omega_1 =$

(B) $\frac{r_2}{r_1} v_1$

$m r_1^2 \frac{v_1}{r_1} =$

(C) $(r_2 - r_1) v_1$

$m r_1 v_1 = m r_2 v_2$

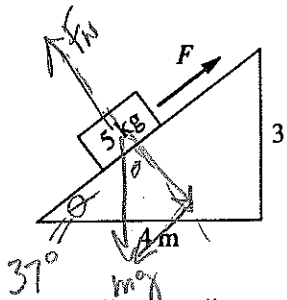
(D) $\frac{r_1 + r_2}{2} v_1$

(E) $\frac{r_2 - r_1}{r_1 + r_2} v_1$

$\frac{r_1}{r_2} v_1 = v_2$

33. A simple pendulum consists of a 1.0-kilogram brass bob on a string about 1.0 meter long. It has a period of 2.0 seconds. The pendulum would have a period of 1.0 second if the

(A) string were replaced by one about 0.25 meter long
(B) string were replaced by one about 2.0 meters long
(C) bob were replaced by a 0.25-kg brass sphere
(D) bob were replaced by a 4.0-kg brass sphere
(E) amplitude of the motion were increased

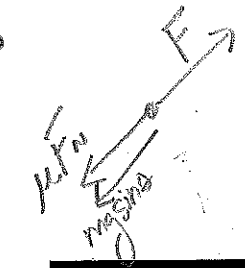


$\sin 37° = \frac{3}{5}$

$\cos 37° = \frac{4}{5}$

34. A block of mass 5 kilograms lies on an inclined plane, as shown above. The horizontal and vertical supports for the plane have lengths of 4 meters and 3 meters, respectively. The coefficient of friction between the plane and the block is 0.3. The magnitude of the force F necessary to pull the block up the plane with constant speed is most nearly

(A) 30 N
(B) 42 N
(C) 49 N
(D) 50 N
(E) 58 N

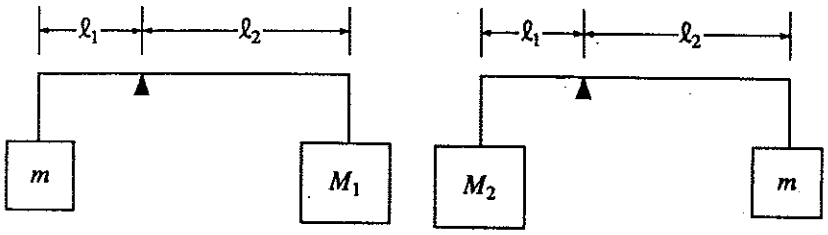


GO ON TO THE NEXT PAGE

$F = \mu F_N + mg \sin 37°$

$= \frac{3}{10}\left[5(10)\frac{4}{5} + 5(10)\frac{3}{5}\right]$

$= 12 + 30 = 42$



35. A rod of negligible mass is pivoted at a point that is off-center, so that length ℓ_1 is different from length ℓ_2. The figures above show two cases in which masses are suspended from the ends of the rod. In each case the unknown mass m is balanced by a known mass, M_1 or M_2, so that the rod remains horizontal. What is the value of m in terms of the known masses?

(A) $M_1 + M_2$

(B) $\frac{M_1 + M_2}{2}$

(C) $M_1 M_2$

(D) $\frac{M_1 M_2}{2}$

(E) $\sqrt{M_1 M_2}$

$\ell_1 m g = \ell_2 M_1 g$ $\quad \ell_1 = \frac{\ell_2 M_1}{m}$

$\ell_1 M_2 g = \ell_2 m g$

$\ell_2 \frac{M_1}{m} M_2 = \ell_2 m$

$M_1 M_2 = m^2$

STOP

END OF SECTION I, MECHANICS

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON SECTION I, MECHANICS, ONLY.
DO NOT TURN TO ANY OTHER TEST MATERIALS.

Chapter III

Answers to the 19 AP Physics C Examination

■ SECTION I: MULTIPLE CHOICE

Listed below are the correct answers to the multiple-choice questions and the percentage of AP candidates who attempted each question and answered it correctly. As a general rule, candidates who correctly answered an individual question in this section also achieved a higher mean score on the exam as a whole than candidates who did not answer that question correctly. An answer sheet gridded with the correct responses appears on the next page.

Answer Key and Percent Answering Correctly

Mechanics			Electricity & Magnetism		
Item No.	Correct Answer	Percent Correct	Item No.	Correct Answer	Percent Correct
1	A	85	36	C	50
2	D	80	37	B	69
3	D	52	38	E	82
4	B	63	39	C	77
5	C	72	40	C	38
6	B	77	41	D	62
7	C	77	42	B	33
8	A	75	43	E	61
9	D	37	44	C	55
10	E	71	45	A	72
11	D	57	46	C	52
12	C	65	47	C	47
13	E	51	48	E	60
14	C	80	49	D	55
15	E	17	50	E	12
16	D	49	51	A	59
17	A	57	52	E	22
18	A	60	53	D	30
19	D	80	54	D	37
20	C	49	55	D	64
21	E	49	56	C	44
22	C	61	57	B	40
23	A	63	58	A	60
24	A	45	59	A	45
25	C	28	60	B	36
26	E	44	61	E	63
27	C	80	62	C	83
28	D	55	63	B	55
29	B	92	64	D	48
30	E	56	65	D	50
31	D	32	66	E	59
32	A	40	67	A	38
33	A	68	68	A	26
34	B	53	69	E	47
35	E	51	70	E	25