AP Physics Free Response Practice – Dynamics – ANSWERS

SECTION A – Linear Dynamics

1976B1

a.

 

b. ΣF = ma; T – W – 2Ff = 800 N; T = 5000 N

c. Looking at the FBD for the counterweight we have ΣF = ma; Mg – T = Ma
M = T/(g – a) where T = 5000 N gives M = 625 kg

 

1979B2

a. ΣF = ma; 50 N – f = ma where f = μN and N = mg gives 50 N – μmg = ma; a = 3 m/s2

b.

 

c. ΣF = ma for each block gives W5 – T = m5a and T – f = m10a. Adding the two equations gives
W5 – f = (m5 + m10)a, or a = 2 m/s2

1982B2

a.

 

b. T1 is in internal system force and will cancel in combined equations. Using ΣFexternal = mtotala gives
T2 – m1g – m2g = (m1 + m2)a, solving yields T2 = 6600 N. Now using ΣF = ma for the load gives
T1 – m1g = m1a and T1 = 6000 N

1985B2

a. Note that the system is at rest. The only forces on the hanging block are gravity and the tension in the rope, which means the tension must equal the weight of the hanging block, or 100 N. You cannot use the block on the incline because friction is acting on that block and the amount of friction is unknown.

b.

 

c. ΣF = 0; *f*s + mg sinθ – T = 0 gives *f*s = 13 N

1986B1

a. ΣFexternal = mtotala; m4g – m1g – m2g = (m4 + m2 + m1)a gives a = 1.4 m/s2

b. For the 4 kg block:

 ΣF = ma

mg – T4 = ma gives

T4 = 33.6 N

c. Similarly for the 1 kg block: T1 – mg = ma gives T1 = 11.2 N

1987B1

a. 

b. ΣFext = mtota; Where the maximum force of static friction on mass M1 is μsN and N = M1g; M2g – μsM1g = 0 gives μs = M2/M1

c/d. ΣFext = mtota where we now have kinetic friction acting gives M2g – μkM1g = (M1 + M2)a
so a = (M2g – μkM1g)/(M1 + M2)
ΣF = ma for the hanging block gives M2g – T = M2a and substituting a from above gives $T=\frac{M\_{1}M\_{2}g}{M\_{1}+M\_{2}}(1+μ\_{k})$

1988B1

a.

b. ΣF = ma gives T – mg = ma and T = 1050 N

c. The helicopter and the package have the same initial velocity, 30 m/s upward. Use d = vit + ½ at2
dh = (+30 m/s)t + ½ (+5.2 m/s2)t2 and dp = (+30 m/s)t + ½ (–9.8 m/s2)t2.
The difference between dh and dp is 30 m, but they began 5 m apart so the total distance is 35 m.

1998B1

a. ΣFext = mtota gives mg = 2ma, or a = g/2

b. d = v0t + ½ at2; h = 0 + ½ (g/2)t2 gives $t=2\sqrt{\frac{h}{g}}$

c. Block A accelerates across the table with an acceleration equal to block B (g/2).

d. Block A is still in motion, but with no more applied force, Block A will move at constant speed across the table.

e. Since block B falls straight to the floor and stops, the distance between the landing points is equal to the horizontal distance block A lands from the edge of the table. The speed with which block A leaves the tabletop is the speed with which block B landed, which is found from v = v0 + at = $\frac{g}{2}\left(2\sqrt{\frac{h}{g}}\right)=\sqrt{hg}$ and the time for block A to reach the floor is found from 2h = ½ gt2, which gives $t=2\sqrt{\frac{h}{g}}$ .
The distance is now d = vt = $\sqrt{hg}$ × $2\sqrt{\frac{h}{g}}$ = 2h

2000B2

a. 

b. *f* = μN where N = m1g cos θ gives $μ=\frac{f}{m\_{1}g\cos(θ)}$

c. constant velocity means ΣF = 0 where ΣFexternal = m1g sinθ + m2g sin θ – *f* – 2*f* – Mg = 0
solving for M gives M = (m1 + m2) sin θ – (3*f*)/g

d. Applying Newton’s second law to block 1 gives ΣF = m1g sin θ – *f* = m1a which gives a = g sin θ – *f*/m1

2003B1

a.

b. The tension in the rope is equal to the weight of student B: T = mBg = 600 N
ΣFA = T + N – mAg = 0 gives N = 100 N

c. For the climbing student ΣF = ma; T – mBg = mBa gives T = 615 N

d. For student A to be pulled off the floor, the tension must exceed the weight of the student, 700 N. No, the student is not pulled off the floor.

e. Applying Newton’s second law to student B with a tension of 700 N gives ΣF = T – mBg = mBa and solving gives a = 1.67 m/s2

2003Bb1

a.

b. We can find the acceleration from a = Δv/t = 2.17 m/s2 and use d = ½ at2 to find d = 975 m

c. The x and y components of the tension are Tx = T sin θ and Ty = T cos θ (this is using the angle to the vertical)
Relating these to the other variables gives T sin θ = ma and T cos θ = mg.
Dividing the two equations gives tan θ = a/g = (2.17 m/s2)/(9.8 m/s2) and θ = 12.5º

1996B2

a. There are other methods, but answers are restricted to those taught to this point in the year.

 i. A device to measure distance and a calibrated mass or force scale or sensor

 ii. Hang the mass from the bottom of the spring and measure the spring extension (Δx) or pull on the spring with a known force and measure the resulting extension.

 iii. Use hooke’s law with the known force or weight of the known mass F = kΔx or mg = kΔx and solve for k

b. Many methods are correct, for example, place the object held by the scale on an inclined plane and find the weight using Wsinθ = kΔx. One could similarly use a pulley system to reduce the effort applied by the spring scale.

2007B1

a. x = vt gives t = (21 m)/(2.4 m/s) = 8.75 s

b. 

c. ΣF = 0 if the sled moves at constant speed. This gives mg sin θ – f = 0, or f = mg sin θ = 63.4 N

d. f = μN where N = mg cos θ so μ = f/N = (mg sin θ)/(mg cos θ) = tan θ = 0.27

e. i. The velocity of the sled decreases while its acceleration remains constant

 ii. 

2007B1B

a.

b. ΣFy = 0; N + T sin θ – mg = 0 gives N = mg – T sin θ = 177 N

c. f = μN = 38.9 N and ΣFx = ma; T cos θ – f = ma yields a = 0.64 m/s2

d.

1981M1

a.

b. F can be resolved into two components: F sin θ acting into the incline and F cos θ acting up the incline.
The normal force is then calculated with ΣF = 0; N – F sin θ – mg cos θ = 0 and f = μN
Putting this together gives ΣF = ma; F cos θ – mg sin θ – μ(F sin θ + mg cos θ) = ma, solve for a

c. for constant velocity, a = 0 in the above equation becomes F cos θ – mg sin θ – μ(F sin θ + mg cos θ) = 0
solving for F gives $F=mg\left(\frac{μ\cos(θ+\sin(θ))}{\cos(θ-μ\sin(θ))}\right)$ In order that F remain positive (acting to the right), the denominator must remain positive. That is cos θ > μ sin θ, or tan θ < 1/μ

1986M1

a. Combining the person and the platform into one object, held up by two sides of the rope we have ΣF = ma;
2T = (80 kg + 20 kg)g giving T = 500 N

b. Similarly, ΣF = ma; 2T – 1000 N = (100 kg)(2 m/s2) giving T = 600 N

c. For the person only: ΣF = ma; N + 600 N – mg = ma gives N = 360 N

2007M1

a.

b. ΣFy = 0; N + F1 sin θ – mg = 0 gives N = mg – F1 sin θ

c. ΣFx = ma; F1 cos θ – μN = ma1. Substituting N from above gives μ = (F1 cos θ – ma1)/(mg – F1 sin θ)

d.

 

e. The condition for the block losing contact is when the normal force goes to zero, which means friction is zero as well. ΣFx = Fmax cos θ = mamax and ΣFy = Fmax sin θ – mg = 0 giving Fmax = mg/(sin θ) and amax = (Fmax cos θ)/m which results in amax = g cot θ

1996M2

a. ΣF = ma; using downward as the positive direction, mg – N = may gives N = m(g – ay) = 2490 N

b. Friction is the only horizontal force exerted; ΣF = f = max = 600 N

c. At the minimum coefficient of friction, static friction will be at its maximum value f = μN, giving μ = f/N = (600 N)/(2490 N) = 0.24

d. y = y0 + v0yt + ½ ayt2 = 2 m + ½ (–1.5 m/s2)t2 and x = x0 + v0xt + ½ axt2 = ½ (2 m/s2)t2, solving for t2 in the x equation gives t2 = x. Substituting into the y equation gives y as a function of x: y = 2 – 0.75x

e.

1998M3

a. i.

 ii.



 iii.

 iv.



 v.

b. The maximum friction force on the blocks on the table is f2max = μs2N2 = μs2(m1 + m2)g which is balanced by the weight of the hanging mass: Mg = μs2(m1 + m2)g giving M = μs2(m1 + m2)

c.

 For the hanging block: Mg – T = Ma; For the two blocks on the plane: T – f2 = (m1 + m2)a
Combining these equations (by adding them to eliminate T) and solving for a gives $a=\left[\frac{M-μ\_{k2}(m\_{1}+m\_{2})}{M+m\_{1}+m\_{2}}\right]g$

d. i. f1 = μk1m1g = m1a1 giving a1 = μk1g

 ii.

 For the two blocks: Mg – T = Ma2 and T – f1 – f2 = m2a2. Eliminating T and substituting values for friction gives $a\_{2}=\left[\frac{M-μ\_{k1}m\_{1}-μ\_{k2}(m\_{1}+m\_{2})}{M+m\_{2}}\right]g$

2005M1

a. The magnitude of the acceleration decreases as the ball moves upward. Since the velocity is upward, air resistance is downward, in the same direction as gravity. The velocity will decrease, causing the force of air resistance to decrease. Therefore, the net force and thus the total acceleration both decrease.

b. At terminal speed ΣF = 0. ΣF = –Mg + kvT giving vT = Mg/k

c. It takes longer for the ball to fall. Friction is acting on the ball on the way up and on the way down, where it begins from rest. This means the average speed is greater on the way up than on the way down. Since the distance traveled is the same, the time must be longer on the way down.

d.

2005B2.

(a) (b) Apply Fnet(X) = 0 Fnet(Y) = 0

 TP cos 30 = mg TP sin 30 = TH

 TP = 20.37 N TH = 10.18 N

1991B1.

a) (b) SIMULTANEOUS EQUATIONS

 Fnet(X) = 0 Fnet(Y) = 0

 Ta cos 30 = Tb cos 60 Ta sin 30 + Tb sin 60 – mg = 0

 …. Solve above for Tb and plug into Fnet(y) eqn and solve

 Ta = 24 N Tb = 42 N

1995B3

a) i)

 

ii) T = mg = 1 N

b) The horizontal component of the tension supplies the horizontal acceleration.

*Th* = *ma* = 0.5 N

 The vertical component of the tension is equal to the weight of the ball, as in (a) ii. *Tv* = 1 N



c) Since there is no acceleration, the sum of the forces must be zero, so the tension is equal and opposite to the weight of the ball. T*h* =zero, T*v* = 1N

d) The horizontal component of the tension is responsible for the horizontal component of the acceleration. Applying Newton's second law:

T*h* = *ma* cos θ, where θ is the angle between the acceleration and horizontal

T*h* = (0.10 kg)(5.0 m/s2) cos 30°, T*h* = 0.43 N

The vertical component of the tension counteracts only part of the gravitational force, resulting in a vertical component of the acceleration. Applying Newton's second law. *Tv* = *mg* – *ma* sin θ

*Tv* = (0.10 kg)(10 m/s2) – (0.10 kg)(5.0 m/s2) sin 30°, *Tv* =0.75 N

e) Since there is no horizontal acceleration, there is no horizontal component of the tension. T*h* = zero

Assuming for the moment that the string is hanging downward, the centripetal is the difference between the gravitational force and the tension. Applying Newton's second law.

mv2/r = mg – T*v*, Solving for the vertical component of tension:
T*v* = – 1.5 N i.e. the string is actually pulling down on the ball.

SECTION B – Circular Motion

1977B2

a. 1 = normal force; 2 = friction; 3 = weight

b. Friction, f ≤ μN where N = Mg. Friction provides the necessary centripetal force so we have f = Mv2/R
Mv2/R ≤ μMg, or μ ≥ v2/Rg



c.

d. from the diagram below, a component of the normal force N′ balances gravity so N′ must be greater than mg



1984B1

a. At the top of the path, tension and gravity apply forces downward, toward the center of the circle.
ΣF = T + mg = 2Mg + Mg = 3Mg

b. In the circular path, F = mv2/r which gives 3Mg = mv02/L and v0 = $\sqrt{3Lg}$

c. The ball is moving horizontally (v0y = 0) from a height of 2L so this gives 2L = ½ gt2 or $t=2\sqrt{^{L}/\_{g}}$

d. x = v0t = $\sqrt{3Lg}$ × $2\sqrt{^{L}/\_{g}}=2\sqrt{3}L$

1989B1

a. i. viy = 0 so we have h = ½ gt2 which gives $t=\sqrt{\frac{2h}{g}}$

 ii. x = v0t = v0$\sqrt{\frac{2h}{g}}$

 iii. vx = v0; vy = viy + gt = $\sqrt{2gh}$

 $v=\sqrt{v\_{x}^{2}+v\_{y}^{2}}=\sqrt{v\_{0}^{2}+2gh}$

b.

c. Horizontal forces: T cos θ = Mv02/R; Vertical forces: T sin θ = Mg. Squaring and adding the equations gives
$T=M\sqrt{g^{2}+\frac{v\_{0}^{4}}{R^{2}}}$

1997B2

a. The circumference of the path, d, can be calculated from the given radius. Use the timer to obtain the period of revolution, t, by timing a number of revolutions and dividing the total time by that number of revolutions. Calculate the speed using v = d/t.

b. If the cord is horizontal, T = mv2/r = 5.5 N

c. (5.5 N – 5.8 N)/(5.8 N) × 100 = –5.2%

d. i.

 ii. The cord cannot be horizontal because the tension must have a vertical component to balance the weight of the ball.

 iii. Resolving tension into components gives T sin θ = mg and T cos θ = mv2/r which gives θ = 21º

1999B5

a.

b. v = circumference/period = 2πR/T = 2π(0.14 m)/(1.5 s) = 0.6 m/s

c. The coin will slip when static friction has reached its maximum value of μsN = μsmg = mv2/r which gives $v=\sqrt{μ\_{s}gr}$ = 0.83 m/s

d. It would not affect the answer to part (c) as the mass cancelled out of the equation for the speed of the coin.

2001B1

a.

b. The minimum speed occurs when gravity alone supplies the necessary centripetal force at the top of the circle (i.e. tension is zero and is not required). Therefore we have Mg = M*v*min2/R which gives $v\_{min}=\sqrt{Rg}$

c. At the bottom of the swing ΣF = ma becomes T – Mg = M*v*2/R which gives Tmax – Mg = M*v*max2/R and solving for *v*max gives $v\_{max}=\sqrt{\frac{R}{M}(T\_{max}-Mg)}$

d. At point P the ball is moving straight up. If the string breaks at that point, the ball would continue to move straight up, slowing down until it reaches a maximum height and fall straight back to the ground.

2002B2B

a.

b. ΣFy = 0; T cos θ – mg = 0 gives m = (T cos θ)/g

c. The centripetal force is supplied by the horizontal component of the tension: FC = T sin θ = mv2/r. Substituting the value of m found in part b. and the radius as (*l* sin θ) gives $v=\sqrt{gl\sin(θ\tan(θ))}$

d. substituting the answer above into *v* = 2πr*f* gives $f=\frac{1}{2π}\sqrt{\frac{g}{l\cos(θ)}}$

e. The initial velocity of the ball is horizontal and the subsequent trajectory is parabolic.

2009B1B

a. The centripetal force is provided by the weight of the hanging mass: FC = m2g = m1*v*2/r and *v* is related to the period of the motion *v* = 2πr/P. This gives $m\_{2}g=\frac{m\_{1}v^{2}}{r}=\frac{m\_{1}}{r}\frac{4π^{2}r^{2}}{P^{2}}$ and thus $P^{2}=4π^{2}\left(\frac{m\_{1}r}{m\_{2}g}\right)$

b. The quantities that may be graphed to give a straight line are P2 and 1/m2, which will yield a straight line with a slope of $4π^{2}\left(\frac{m\_{1}r}{g}\right)$

c.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1/m2 (kg–1) | 50 | 25 | 16.7 | 12.5 |
| *m*2 (kg) | 0.020 | 0.040 | 0.060 | 0.080 |
| *P* (s) | 1.40 | 1.05 | 0.80 | 0.75 |
| P2 (s2) | 1.96 | 1.10 | 0.64 | 0.56 |

d. Using the slope of the line (0.038 kg/s2) in the equation from part b. gives g = 9.97 m/s2

1984M1

a.

b. F = mv2/r where v = 2πrf = 2πr(1/π) = 2r = 10 m/s giving F = 1000 N provided by the normal force

c. ΣFy = 0 so the upward force provided by friction equals the weight of the rider = mg = 490 N

d. Since the frictional force is proportional to the normal force and equal to the weight of the rider, m will cancel from the equation, meaning a rider with twice the mass, or any different mass, will not slide down the wall as mass is irrelevant for this condition.

1988M1

a.

 Toward the center of the turn we have ΣF = N sin θ = mv2/r and vertically N cos θ = mg. Dividing the two expressions gives us tan θ = v2/rg and v = 16 m/s

b.

c. ΣFy = N cos θ – f sin θ – mg = 0 and ΣFx = N sin θ + f cos θ = mv2/r solve for N and f and substitute into f = μN gives μmin = 0.32

1998B6

a. i. ii.



b. i.

The horizontal velocity is constant, the vertical motion is in free fall and the path is parabolic

 ii. 

The ball falls straight down in free fall