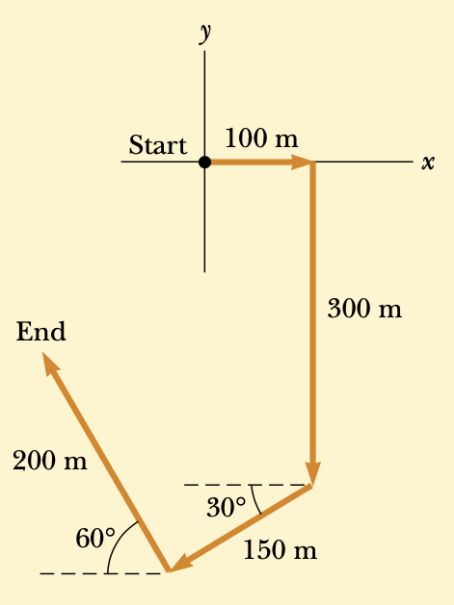
Phys 206UP Fall 2022 Comprehensive Exam
180 minutes
Flavor 1

**1)** A person going for a walk follows the path shown in Figure. The total trip consists of four straight-line paths. At the end of the walk, what is the person's resultant displacement vector $\vec{r}$ measured from the starting point?




A) $\vec{r} = (-75\sqrt{3})\,\hat{i} + (100\sqrt{3})\,\hat{j}$ m

B) $\vec{r} = (100\sqrt{3})\,\hat{i} + (200)\,\hat{j}$ m

C) $\vec{r} = (25\sqrt{3} - 100)\,\hat{i} + (100 - 25\sqrt{3})\,\hat{j}$ m

D) $\vec{r} = (-75\sqrt{3})\,\hat{i} + (100\sqrt{3} - 375)\,\hat{j}$ m LO: 1, 1, 2, 4

E) $\vec{r} = (25 - 100\sqrt{3})\,\hat{i} + (200 - 75\sqrt{3})\,\hat{j}$ m LO: 1, 2, 4

**2)** At the surface of the earth, an astronaut in all their gear has a potential energy $U_E$. A distant planet that we will call Planet X has a radius 5 times the radius of earth and a mass 24 times earth's mass. What is the potential energy the astronaut will have on Planet X?

A) $\frac{3}{5}U_E$

B) $\frac{24}{5}U_E$ LO: 60, 61

C) $U_E$

D) $\frac{3}{25}U_E$

E) $\frac{24}{25}U_E$

**3)** A mass is connected to a spring and allowed to oscillate in simple harmonic motion. The spring has a maximum compression of 0.25 m and the mass reaches a maximum speed of 4 m/s. What is the angular frequency of the oscillation?

A) 0.5 rad/s

B) 1 rad/s LO: 34, 38, 40, 65, 66

C) 4 rad/s

D) 16 rad/s LO: 3, 34, 38, 40, 65, 66

E) 256 rad/s LO: 34, 38, 40, 65, 66

**4)** An object is being swung in a circle using a cable with a length of 0.5 m. The angular velocity as a function of time for this object is $\omega(t) = (2t^2 + 3t + 1)$ rad/s. What is the tangential acceleration of this object at $t = 2$ s?

A) $\frac{3}{2}\, m/s^2$

B) $\frac{5}{2}\, m/s^2$

C) $\frac{7}{2}\, m/s^2$

D) $\frac{9}{2}\, m/s^2$ LO: 12, 14, 16

E) $\frac{11}{2}\, m/s^2$ LO: 8, 12, 14, 16, 17

**5)** A jet engine can go from rest to 40 rev/s in 20 seconds. How many revolutions does it go through in the first 10 seconds? Assume a constant angular acceleration for this problem.

A) 2 revolutions LO:14

B) 20 revolutions

C) 40 revolutions

D) 100 revolutions LO: 4, 12, 14, 14

E) 200 revolutions LO: 12, 14

**6)** An object oscillates with simple harmonic motion along the $x$ axis. Its displacement from the origin varies with time according to the equation $x = (2.00)\cos(\pi t + \pi/4)$ m where $t$ is in seconds and the angles in the parentheses are in radians. Determine the period $T$ of the motion.

A) $T = 1\,s$

B) $T = 2\,s$ LO: 65, 66

C) $T = 4\,s$

D) $T = \frac{1}{2}\,s$

E) $T = \frac{1}{4}\,s$

**7)** Continuing from the previous problem, determine the maximum speed $v_{max}$ of the object.

A) $v_{max} = (\pi)\,m/s$

B) $v_{max} = (2\pi)\,m/s$ LO: 65, 66

C) $v_{max} = (4\pi)\,m/s$

D) $v_{max} = (\frac{\pi}{2})\,m/s$

E) $v_{max} = (\frac{\pi}{4})\,m/s$

**8)** A planet is in circular orbit around a star. How would the gravitational potential energy of the planet-star system change if the star becomes a red-giant by expanding to double its size without its mass changing?

A) The gravitational potential would be two times larger.

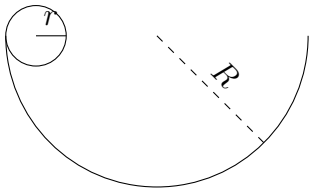
B) The gravitational potential would be four times larger.

C) The gravitational potential would not change. LO: 60, 61

D) The gravitational potential would be half as large.

E) The gravitational potential would be one fourth as large.

**9)** A *small hollow sphere* with radius $r$ and mass $m$ is at rest at the very edge of a half-pipe as shown in the figure below. The radius of the half-pipe is $R$. What is the center of mass speed of the sphere when it is at the bottom of the pipe? There is enough friction between the sphere and the pipe that the sphere will roll without slipping, but not enough that it will remove mechanical energy from the system. Assume also $r \ll R$.




A) $\sqrt{3gR}$ LO: 35, 38, 40

B) $\sqrt{2gR}$ LO: 34, 38, 40

C) $\sqrt{\frac{8}{7}gR}$

D) $\sqrt{\frac{7}{6}gR}$

E) $\sqrt{\frac{6}{5}gR}$ LO: 3, 6, 34, 35, 38, 40

**10)** A bottle rocket is a small firework that uses a chemical reaction to generate thrust. Assume that a bottle rocket is fired from rest, straight upward and the chemical reaction provides 125 J of work. Assuming the rocket has a mass of 0.05 kg and it reaches a maximum height of 100 m, what is the work done by air resistance on the rocket? (Take $g = 10\,m/s^2$).

A) -125 J

B) -100 J

C) -75 J LO: 38, 39

D) -50 J LO: 38

E) -25 J

F) 0 J

**11)** A 0.100 kg rubber ball has a speed of 15 m/s right before it hits a wall and 5 m/s right after it leaves the wall. If the wall applied a force of 10 N to the ball, how much time was it in contact with the wall. Assume the velocities are only horizontal for this problem.

A) 0.050 s

B) 0.100 s LO: 47

C) 0.150 s

D) 0.200 s LO: 2, 47, 49

E) 0.250 s

**12)** A bullet of mass 0.2 kg and unknown velocity strike a cubical wooden block of mass 1 kg. The bullet becomes embedded in the wooden block and they slide across the surface of a rough table. The block has coefficients of friction $\mu_s = 0.5$ and $\mu_k = 0.25$ with the surface of the table. If the block slides a total distance 2 m along the table, determine the initial velocity of the bullet. (Take $g = 10\,m/s^2$).

A) $6\sqrt{10}$ m/ s LO: 4, 21, 23, 26, 27, 28, 32, 34, 39, 46, 48, 50

B) $5\sqrt{10}$ m/s LO: 21, 23, 26, 27, 28, 32, 34, 39, 46, 48

C) $6\sqrt{20}$ m/s LO: 4, 21, 23, 26, 32, 34, 39, 46, 48, 50

D) $5\sqrt{20}$ m/s LO: 21, 23, 26, 32, 34, 39, 46, 48

E) $\sqrt{60}$ m/s LO: 21, 23, 26, 27, 28, 32, 34, 39

F) $\sqrt{50}$ m/s

G) $\sqrt{120}$ m/s LO: 21, 23, 26, 32, 34, 39

H) $\sqrt{100}$ m/s

**13)** A dart player throws a dart *exactly horizontal* at velocity $v = 10\,m/s$ in order to hit the bullseye. If the dart board is a distance 3 m away, what is the $y$-coordinate of the dart assuming the bullseye has $y = 0$? (take above $y = 0$ as + and below $y = 0$ as - directions. Also take $g = 10\,m/s^2$).

A) $\frac{3}{2}$ m

B) $-\frac{3}{2}$ m

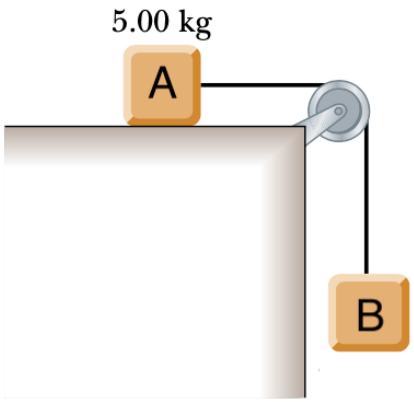
C) $\frac{9}{20}$ m LO: 4, 14

D) $-\frac{9}{20}$ m LO: 4, 13, 14

E) $\frac{9}{10}$ m

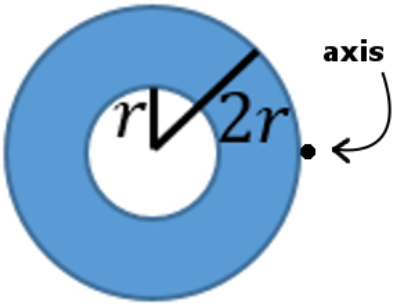
F) $-\frac{9}{10}$ m

**14)** Two blocks are attached to a *massless* pulley. Block A has mass $m_A = 5\,kg$ and rests on a flat, rough surface with coefficients of friction $\mu_s = 0.3$ and $\mu_k = 0.2$. Block B has an unknown mass and is attached to block A by a massless string looped over the pulley and is suspended over the edge of the table. The system is released from rest to move. What is the maximum mass of block B such that the system stays at rest? (Take $g = 10\,m/s^2$).




A) 0.5 kg
B) 1 kg LO: 4, 21, 23, 24, 26
C) 1.5 kg LO: 4, 21, 23, 24, 26, 27, 29
D) 2 kg
E) 2.5 kg
F) 5 kg

**15)** A thick walled hollow cylinder of inner radius $r$ and outer radius $2r$ and mass $3m$ is positioned to rotate around a point attached to the outer edge of the cylinder as shown below. What is the angular acceleration of the system at the instant it is released from rest from this position? (In the Figure, force of gravity acts downwards).




A) $\frac{2}{13}\frac{g}{r}$ LO: 51, 52, 55

B) $\frac{4}{5}\frac{g}{r}$ LO: 3, 51, 54, 55

C) $\frac{2}{5}\frac{g}{r}$ LO: 51, 55

D) $\frac{4}{7}\frac{g}{r}$

E) $\frac{2}{7}\frac{g}{r}$

F) $\frac{7}{13}\frac{g}{r}$

G) $\frac{5}{7}\frac{g}{r}$

H) $\frac{4}{13}\frac{g}{r}$ LO: 3, 51, 52, 54, 55

**16)** Two objects have velocities $\vec{v}_1 = -3\hat{i} + 2\hat{j}$ m/s and $\vec{v}_2 = 4\hat{i} - 3\hat{j}$ m/s relative to the ground. What is the *speed* of object 2 relative to object 1?

A) $7\hat{i}$–$5\hat{j}$ m/s LO: 2, 20

B) $\hat{i} - \hat{j}$ m/s

C) $7\hat{i} - \hat{j}$ m/s

D) $\hat{i}$–$5\hat{j}$ m/s

E) $\sqrt{74}$ m/s LO: 2, 2, 20

F) $\sqrt{2}$ m/s

G) $\sqrt{50}$ m/s

H) $\sqrt{26}$ m/s

**17)** How much energy is required to move a mass $m$ from the Earth's surface to an altitude twice the Earth's radius? ($M$ and $R$ denote the mass and the radius of the Earth, respectively).

A) $\frac{GMm}{R}$

B) $\frac{GMm}{3R}$

C) $\frac{2GMm}{R}$

D) $\frac{2GMm}{3R}$ LO: 60, 61

E) $\frac{GMm}{R^2}$

**18)** A force $F(x) = (18 - 2x)$ N is applied in the $x$-direction to a block of mass $m = 4$ kg initially at rest on a frictionless surface. Assuming the force is the only one acting on the block, what is the speed of the block after it has travelled from $x = 0$ to $x = 6$ m under this force?

A) $\sqrt{3}$ m/s LO: 6, 34

B) 3 m/s

C) $\sqrt{12}$ m/s

D) 12 m/s

E) $\sqrt{6}$ m/s

F) 6 m/s LO: 3, 6, 8, 32, 34, 39

**19)** A child of mass $m$ runs and jumps on the edge of a merry-go-round of mass $M$ and radius $r$. The child was running at a velocity $v$ and was approaching tangent to the merry-go-round which is initially at rest. If the child stays on the ride near the edge, what is the final rotational velocity of the child? Assume the merry-go-round is best approximated as a disk.

A) $\frac{mv}{mr+\frac{Mr}{2}}$ LO: 3, 51, 53, 57, 59

B) $\frac{v}{r}$

C) $\frac{2mv}{Mr}$ LO: 51, 57, 59

D) $\frac{2mv}{mr+Mr}$ LO: 57, 59

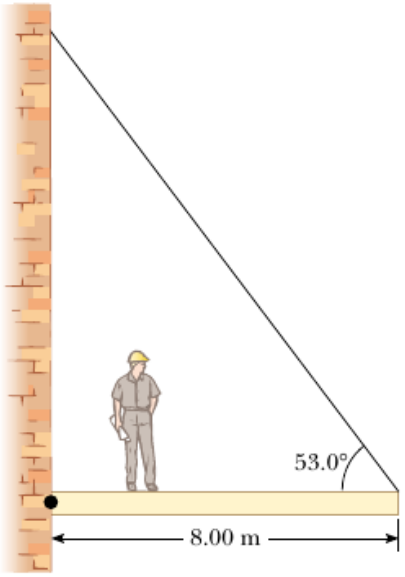
E) $\frac{Mv}{mr+\frac{Mr}{2}}$ LO: 51, 53, 57, 59

F) $\frac{Mv}{mr}$

G) $\frac{2v}{r}$

H) $\frac{2Mv}{mr+Mr}$

**20)** A uniform horizontal beam with a length of 8.00 m and a weight of 400N is attached to a wall by a pin connection. Its far end is supported by a cable that makes an angle of 53.0° with the horizontal, see Figure. If a 800N person stands 2.00 m from the wall, find the tension in the cable.




A) 250 N

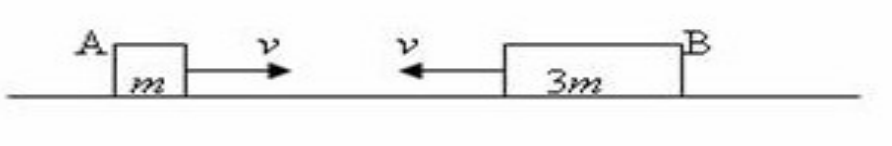
B) 500 N LO: 1, 21, 23, 31, 45, 54

C) 750 N

D) $\frac{1000}{3}$ N

E) $\frac{2000}{3}$ N LO: 21, 23, 31, 45, 54

**21)** Two blocks A and B of masses $m$ and $3m$ respectively travel in opposite directions with the same speed $v$ along a smooth surface. They collide head-on and *stick together*. What is the *mechanical energy lost* during the collision?




A) $\frac{1}{2}mv^2$ LO: 34, 39, 40, 46, 48

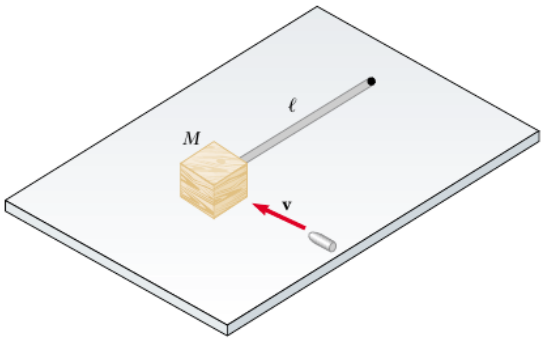
B) $mv^2$

C) $\frac{3}{2}mv^2$ LO: 6, 34, 39, 40, 46, 48

D) $2mv^2$ LO: 34

E) $3mv^2$

**22)** A wooden block of mass $M$ resting on a frictionless horizontal surface is attached to a rigid rod of length $l$ and of *negligible mass*. The rod is pivoted at the other end. A bullet of same mass $M$ traveling parallel to the horizontal surface and normal to the rod with speed $v$ hits the block and becomes embedded in it. What is the angular velocity of the bullet – block system?




A) $\omega = \frac{v}{16l}$

B) $\omega = \frac{v}{10l}$

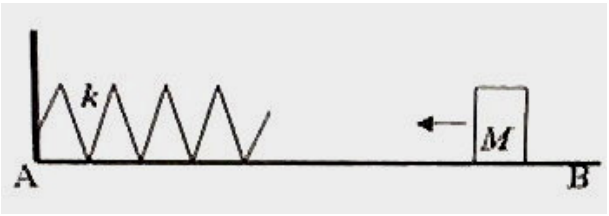
C) $\omega = \frac{v}{8l}$

D) $\omega = \frac{v}{4l}$

E) $\omega = \frac{v}{2l}$ LO: 19, 51, 53, 57, 59

F) $\omega = \frac{v}{l}$ LO: 19

**23)** The Figure shows a block of mass $M = 4$ kg, moving with constant velocity along a horizontal frictionless surface towards a spring of force constant $k = 100$ N/m. One end of the spring is fixed to a rigid vertical wall. The block collides with the spring and produces in it a *maximum compression* of 0.1 m. What was the *momentum* of the block before the collision?




A) 0.5 kg m/s LO: 34, 38, 39, 40

B) 2 kg m/s LO: 34, 38, 39, 40, 46

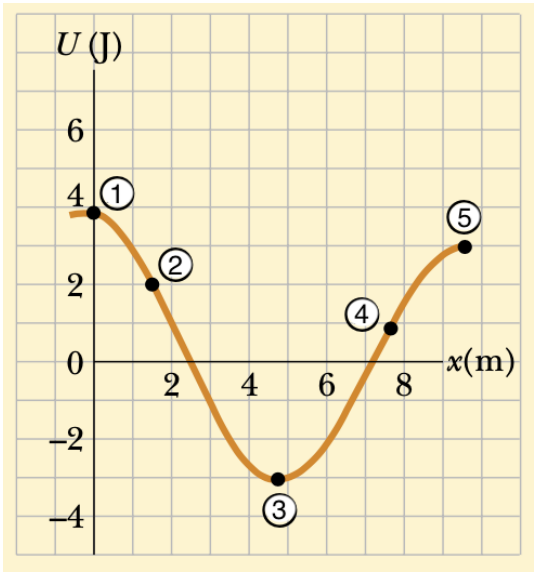
C) 2.5 kg m/s

D) 4 kg m/s

E) 8 kg m/s

**24)** For the potential energy curve shown in Figure, which point represents a stable equilibrium and at which point the force $F_x$ is positive.

| Stable Eq. | $F_x$ positive |
|---|---|
| A) 1 | 2 LO: 8 |
| B) 2 | 4 |
| C) 3 | 2 LO: 8, 42, 44 |
| D) 4 | 4 |
| E) 5 | 3 |
| F) 1 | 5 |
| G) 2 | 2 LO:8 |
| H) 3 | 4 LO: 42, 44 |




**25)** A satellite of mass $m$ moves in an elliptical orbit around the Earth, see the Figure. The minimum distance of the satellite from the Earth is called the perigee (indicated by $p$ in the Figure) and the maximum distance is called the apogee (indicated by $a$ in the Figure). For this orbit one has $r_a = 3r_p$. If the speed of the satellite at $a$ is $v_a$, what is its speed $v_p$ at $p$? ($M$ denotes the mass of the Earth)

A) $v_p = v_a$

B) $v_p = 2v_a$

C) $v_p = 3v_a$ LO: 57, 59, 60

D) $v_p = \frac{M}{m} v_a$

E) $v_p = \frac{m}{M} v_a$

F) $v_p = G\, v_a$