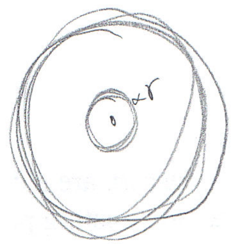
16. The mass density of a certain planet has spherical symmetry but varies in such a way that the mass inside every spherical surface with center at the center of the planet is proportional to the radius of the surface. If r is the distance from the center of the planet to a point mass inside the planet, the gravitational force on the mass is:

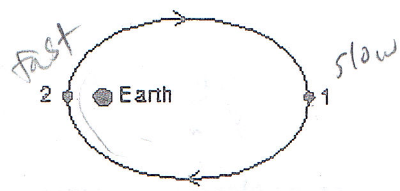
A) not dependent on r
B) proportional to r^2
C) proportional to r
D) proportional to $1/r$
E) proportional to $1/r^2$



$g \cdot 4\pi r^2 = -4\pi G \cdot \alpha r$

$g \propto \frac{G}{r^4}$

17. A small satellite is in elliptical orbit around Earth as shown. If L denotes the magnitude of its angular momentum and K denotes kinetic energy:



A) $L_2 > L_1$ and $K_2 > K_1$
B) $L_2 > L_1$ and $K_2 = K_1$
C) $L_2 = L_1$ and $K_2 = K_1$
D) $L_2 < L_1$ and $K_2 = K_1$
E) $L_2 = L_1$ and $K_2 > K_1$

$K_1 < K_2$

18. Suppose you have a pendulum clock which keeps correct time on Earth (acceleration due to gravity = 9.8 m/s^2). Without changing the clock, you take it to the Moon (acceleration due to gravity = 1.6 m/s^2). For every hour interval (on Earth) the Moon clock will record:

A) (9.8/1.6) h
B) 1 h
C) $\sqrt{9.8/1.6}$ h
D) (1.6/9.8) h
E) $\sqrt{1.6/9.8}$ h

$\frac{9.8}{1.6} \rightarrow 6.125$ reduction

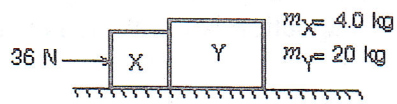
19. Acceleration is always in the direction:

A) of the displacement
B) of the initial velocity
C) of the final velocity
D) of the net force
E) opposite to the frictional force

33. An object at the surface of Earth (at a distance R from the center of Earth) weighs 90 N. Its weight at a distance $3R$ from the center of Earth is:
A) 10 N
B) 30 N
C) 90 N
D) 270 N
E) 810 N

$F \propto \frac{1}{r^2}$

34. Two blocks (X and Y) are in contact on a horizontal frictionless surface. A 36-N constant force is applied to X as shown. The magnitude of the force of X on Y is:



$4+20=24$

$36=24\cdot a$

$a=1.5$

A) 1.5 N
B) 6.0 N
C) 29 N
D) 30 N
E) 36 N

$F_Y = m \cdot a$

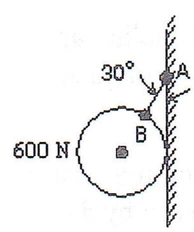
$F_Y = 1.5 \cdot 20$

$F_Y = 30$

35. An inelastic collision is one in which:
A) momentum is not conserved but kinetic energy is conserved
B) total mass is not conserved but momentum is conserved
C) neither kinetic energy nor momentum is conserved
D) momentum is conserved but kinetic energy is not conserved
E) the total impulse is equal to the change in kinetic energy

36. The 600-N ball shown is suspended on a string AB and rests against the frictionless vertical wall. The string makes an angle of 30° with the wall. The magnitude of the tension for of string is:

ce



A) 690 N
B) 1200 N
C) 2100 N
D) 2400 N
E) none of these

$T\cos 30 = 600\text{ N}$

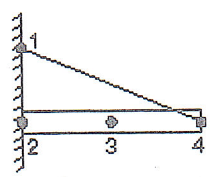
$= 692.8$

5. Assume that Earth is in circular orbit around the Sun with kinetic energy K and potential energy U, taken to be zero for infinite separation. Then, the relationship between K and U:

A) is $K = U$
B) is $K = -U$
C) is $K = U/2$
D) is $K = -U/2$
E) depends on the radius of the orbit

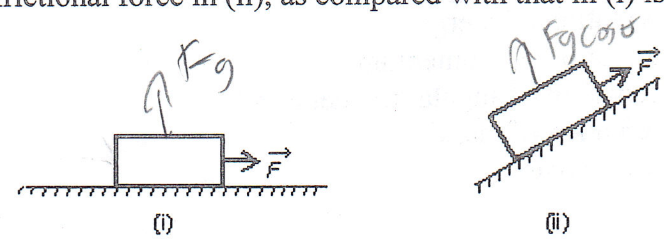
as objects get closer to the Sun they get faster

6. The uniform rod shown below is held in place by the rope and wall. Suppose you know the weight of the rod and all dimensions. Then you can solve a single equation for the force exerted by the rope, provided you write expressions for the torques about the point:



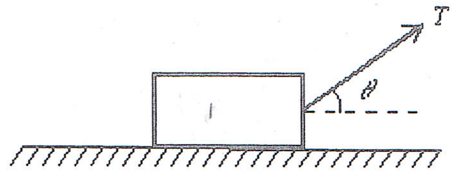
A) 1
B) 2
C) 3
D) 4
E) 1, 2, or 3

7. A heavy wooden block is dragged by a force $\vec{F}$ along a rough steel plate, as shown below for two possible situations. The magnitude of $\vec{F}$ is the same for the two situations. The magnitude of the frictional force in (ii), as compared with that in (i) is:



A) the same
B) greater
C) less
D) less for some angles and greater for others
E) can be less or greater, depending on the magnitude of the applied force.

23. A block of mass m is pulled at constant velocity along a rough horizonatl floor by and applied force $\vec{T}$ as shown. The magnitude of frictional force is:



A) $T \cos \theta$
B) $T \sin \theta$
C) zero
D) mg
E) $mg \cos \theta$

$T \cos\theta + F_f = 0$

$F_f = -T\cos\theta$

24. For a block of mass m to slide without friction up the rise of height h shown, it must have a minimum initial speed of:

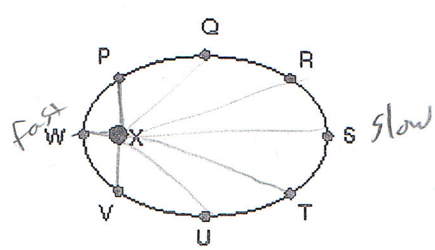
A) $1/2\sqrt{gh}$
B) $\sqrt{gh/2}$
C) $\sqrt{2gh}$
D) $2\sqrt{2gh}$
E) $2\sqrt{gh}$

KE → PE

$\frac{1}{2}\cancel{m}v^2 = \cancel{m}gh$

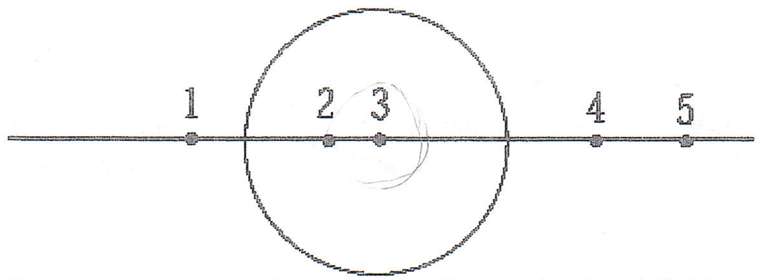
$v = \sqrt{2gh}$

25. A planet travels in an elliptical orbit about a star X as shown. The magnitude of the acceleration of the planet is:



A) greatest at point Q
B) greatest at point S
C) greatest at point U
D) greatest at point W
E) the same at all points

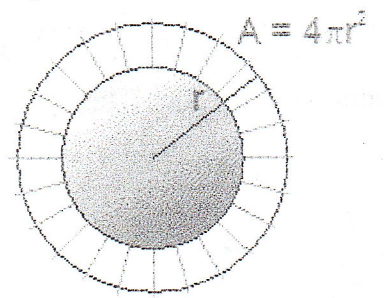
4 3.



Test masses are used to measure the gravitational field at various positions in and near a *solid sphere of uniform density.* The gravitational field will have its greatest value at point

A) 1
B) 2
C) 3
D) 4
E) 5

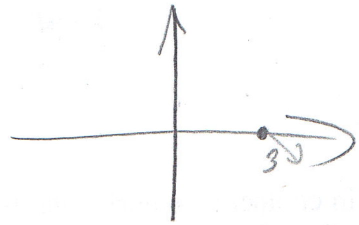
4 4. Earth's gravitational field is given by $\vec{g} = -\frac{GM_E}{r^2}\hat{r}$. The total flux (field times area) for a spherical surface area A that encloses all the field lines is



A) $-4\pi GM_E$
B) $-GM_E$
C) $-GM_E/4\pi$
D) $-2\pi GM_E$
E) $-4GM_E$

29. A 2.0-kg block starts from rest on the positive x axis 3.0 m from the origin and thereafter has an acceleration given by $\vec{a} = 4.0\hat{\imath} - 3.0\hat{\jmath}$ in m/s². The torque, relative to the origin, acting on it at the end of 2.0 s is:

A) 0
B) $(-18\ \text{N}\cdot\text{m})\hat{k}$
C) $(+24\ \text{N}\cdot\text{m})\hat{k}$
D) $(-144\ \text{N}\cdot\text{m})\hat{k}$
E) $(+144\ \text{N}\cdot\text{m})\hat{k}$

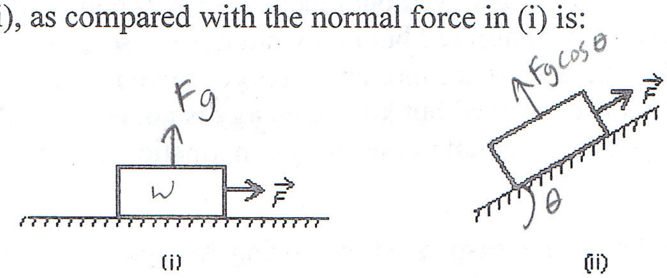


$\tau = F \times r$
$= m(a \times r)$
$= 2 \cdot -9 = (-18\ \text{N}\cdot\text{m})\hat{k}$

30. For a planet in orbit around a star the perihelion distance is r_p and its speed at perihelion is v_p. The aphelion distance is r_a and its speed at aphelion is v_a. Which of following is true?

A) $v_a = v_p$
B) $v_a / r_a = v_p / r_p$
C) $v_a r_a = v_p r_p$
D) $v_a / r^2_a = v_p / r^2_p$
E) $v_a r^2_a = v_p / r^2_p$

31. A heavy wooden block is dragged by a force $\vec{F}$ along a rough steel plate, as shown below for two cases. The magnitude of the applied force $\vec{F}$ is the same for both cases. The normal force in (ii), as compared with the normal force in (i) is:



A) the same
B) greater
C) less
D) less for some angles of the incline and greater for others
E) less or greater, depending on the magnitude of the applied force $\vec{F}$.

32. A 2.0-kg block starts from rest on the positive x axis 3.0 m from the origin and thereafter has an acceleration given by $\vec{a} = 4.0\hat{\imath} - 3.0\hat{\jmath}$ in m/s². At the end of 2.0 s its angular momentum about the origin is:

A) 0
B) $(-36\ \text{kg}\cdot\text{m}^2/\text{s})\hat{k}$
C) $(+48\ \text{kg}\cdot\text{m}^2/\text{s})\hat{k}$
D) $(-96\ \text{kg}\cdot\text{m}^2/\text{s})\hat{k}$
E) $(+96\ \text{kg}\cdot\text{m}^2/\text{s})\hat{k}$

L =

at t = 2

$a = \langle 4, -3 \rangle$

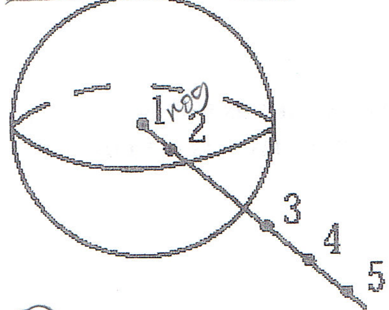
$v = \langle 4t, -3t \rangle \rightarrow \langle 8, -6 \rangle$

$d = \langle 3 + 2t^2, -\tfrac{3}{2}t^2 \rangle \rightarrow \langle 11, -6 \rangle$

$L = I \cdot \omega = MR^2 \cdot \frac{V}{R} = MRV$
$= 2 \cdot \langle 8, -6 \rangle \times \langle 11, -6 \rangle$
$= -36\hat{k}$

Name: Qiu, ze Qin Date: ____________

4 1. Test masses are used to measure the gravitational field at various positions in and near a ~~hollow spherical shell~~. The gravitational field will have its greatest value at point(s)



A) 3
B) 4
C) 5
~~D)~~ 1, 2, and 5
~~E)~~ 1 and 2

4 2. The mass density of a planet varies with distance from the center as $\rho = \rho_o (1 - C\frac{r}{R_P})$ where C is a dimensionless constant, and R_P is the radius of the planet. The gravitational field of the planet for $r < R_P$ is

A) $\vec{g} = -\rho_o G(\frac{r}{2} - \frac{Cr^2}{3R_p})\hat{r}$ $* 4\pi$

B) $\vec{g} = -\rho_o G(\frac{r}{3} - \frac{Cr^2}{4R_p})\hat{r}$ $* 4\pi$

C) $\vec{g} = -\rho_o G(r - \frac{Cr^2}{R_p})\hat{r}$ $* 4\pi$

D) $\vec{g} = -\rho_o GC\frac{r^2}{R_p}\hat{r}$ $* 4\pi$

E) $\vec{g} = -\rho_o G\frac{r}{3}\hat{r}$ $* 4\pi$

$M_{enc} = \int_0^r \rho \, dr$

$= \int_0^r P_0 (1 - c\frac{r}{R_p}) \, dr$

$= P_0 \int_0^r 1 - c\frac{r}{R_p} \, dr$

$= P_0 \left(r - c\frac{r^2}{2R_p}\right]_0^r$

$M_{enc} = P_0 \left(r - c\frac{r^2}{2R_p}\right)$

$g \cdot 4\pi r^2 = \frac{P_0 \left(r - c\frac{r^2}{2R_p}\right) \cdot -4\pi G}{r^2}$

$g = P_0 \left(\frac{1}{r} - \frac{c}{2R_p}\right)$

29. A 2.0-kg block starts from rest on the positive x axis 3.0 m from the origin and thereafter has an acceleration given by $\vec{a} = 4.0\hat{\imath} - 3.0\hat{\jmath}$ in m/s². The torque, relative to the origin, acting on it at the end of 2.0 s is:

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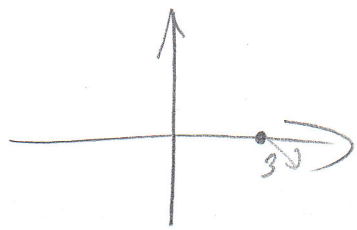

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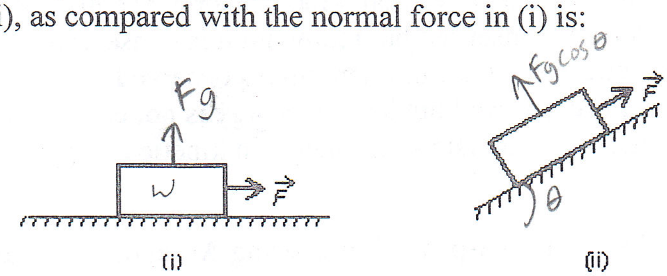

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A) 0
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D) $(-96\ \text{kg}\cdot\text{m}^2/\text{s})\hat{k}$
E) $(+96\ \text{kg}\cdot\text{m}^2/\text{s})\hat{k}$

$L =$

at $t = 2$

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$v = \langle 4t, -3t \rangle \longrightarrow \langle 8, -6 \rangle$

$d = \langle 3 + 2t^2, -\tfrac{3}{2}t^2 \rangle \longrightarrow \langle 11, -6 \rangle$

$L = I \cdot \omega = MR^2 \cdot \frac{V}{R}$

$= MRV$

$= 2 \cdot \langle 8, -6 \rangle \times \langle 11, -6 \rangle$

$= -36\hat{k}$

37. Suitable units for the gravitational constant G are:
A) kg·m/s²
B) m/s²
C) N·s/m
D) kg·m/s
E) m³/(kg·s²)

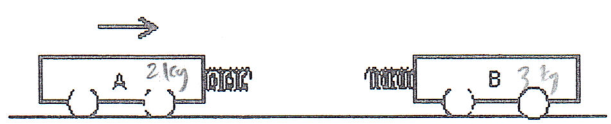
$G \rightarrow N \frac{m^2}{kg^2} \rightarrow kg \cdot \frac{m}{s^2} \cdot \frac{m^2}{kg^2} = \frac{m^3}{s^2 \cdot kg}$

38. When the brakes of an automobile are applied, the road exerts the greatest retarding force:
A) while the wheels are sliding
B) just before the wheels start to slide
C) when the automobile is going fastest
D) when the acceleration is least
E) at the instant when the speed begins to change

39. A sledge (including load) weighs 5000 N. It is pulled on level snow by a dog team exerting a horizontal force on it. The coefficient of kinetic friction between sledge and snow is 0.05. How much work is done by the dog team pulling the sledge 1000 m at constant speed?
A) 2.5×10^4 J
B) 2.5×10^5 J
C) 5.0×10^5 J
D) 2.5×10^6 J
E) 5.0×10^6 J

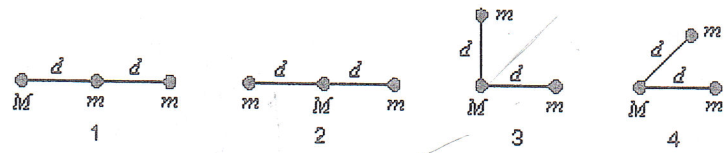
$W = F \cdot d$
$= F_g \cdot \mu_k \cdot d$
$= 2.5 \times 10^5$

40. Two carts (A and B), having spring bumpers, collide as shown. Cart A has a mass of 2 kg and is initially moving to the right. Cart B has a mass of 3 kg and is initially stationary. When the separation between the carts is a minimum:



A) cart B is still at rest
B) cart A has come to rest
C) the carts have the same momentum
D) the carts have the same kinetic energy
E) the kinetic energy of the system is at a minimum

12. Three particles, two with mass m and one mass M, might be arranged in any of the four configurations known below. Rank the configurations according to the magnitude of the gravitational force on M, least to greatest.



A) 1, 2, 3, 4
B) 2, 1, 3, 4
C) 2, 1, 4, 3
D) 2, 3, 4, 1
E) 2, 3, 2, 4

$(2\sqrt{2}, 2\sqrt{2})$ Magnitude $\Rightarrow 4$

$(\sqrt{2}+1, \sqrt{2})$ $\sqrt{2+(\sqrt{2}+1)^2} = 2.79 < 4$

13. A 3.0-kg and a 2.0-kg cart approach each other on a horizontal air track. They collide and stick together. After the collision their total kinetic energy is 40 J. The speed of their center of mass is:
A) zero
B) 2.8 m/s
C) 4.0 m/s
D) 5.2 m/s
E) 6.3 m/s

$V_{cm} = \frac{\Sigma m \cdot V}{M_T}$

$40 = \frac{1}{2} m v^2$

$16 = v^2$

$v = 4$

14. A particle moving along the x axis is acted upon by a single force $F = F_0 e^{-kx}$, where F_0 and k are constants. The particle is released from rest at $x = 0$. It will attain a maximum kinetic energy of:
A) F_0/k
B) F_0/e^k
C) kF_0
D) $1/2(kF_0)^2$
E) ke^kF_0

$\frac{1}{2} m v^2$

$F = F_0 e^{-kx}$ $W = F \cdot d$

$a = \int_0^\infty \frac{F_0}{m} e^{-kx}$

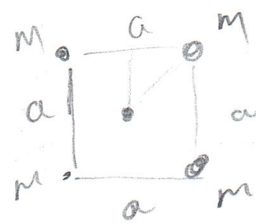
$V = -\frac{F_0}{mk} e^{-kx} + \frac{F_0}{mk} e^0$

$\frac{1}{2} \frac{F_0^2}{mk^2} = \frac{1}{2} m \left(\frac{F_0}{mk}\right)^2$

15. A force on a particle is conservative if:
A) its work equals the change in the kinetic energy of the particle
B) it obeys Newton's second law
C) it obeys Newton's third law
D) its work depends on the end points of the motion, not this the path between
E) it is not a frictional force

26. Each of the four corners of a square with edge a is occupied by a point mass m. There is a fifth mass, also m, at the center of the square. To remove the mass from the center to a point far away the work that must be done be an external agent is given by:

A) $4Gm^2/a$
B) $-4Gm^2/a$
C) $4\sqrt{2}Gm^2/a$
D) $-4\sqrt{2}Gm^2/a$
E) $4Gm^2/a^2$



$pE = -\frac{GMm}{R} = \frac{-4\sqrt{2}GMm}{a}$

$R = \frac{a^2}{4} + \frac{a^2}{4} = \sqrt{\frac{a^2}{2}} = \frac{a}{\sqrt{2}}$

at ∞ $pE = 0$

need $\frac{4\sqrt{2}GMm}{a}$

27. A spaceship is returning to Earth with its engine turned off. Consider only the gravitational field of Earth and let M be the mass of Earth, m be the mass of the spaceship, and R be the distance from the center of Earth. In moving from position 1 to position 2 the kinetic energy of the spaceship increases by:

A) $GM\,m\left[\frac{1}{R_2}-\frac{1}{R_1}\right]GM\,m/R_2$

B) $GM\,m\left[\frac{1}{R_1}+\frac{1}{R_2}\right]$

C) $GM\,m\frac{R_1-R_2}{R_1}$

D) $GM\,m\frac{R_2-R_1}{R_1R_2}$

E) $GM\,m\frac{R_1-R_2}{R_1R_2}$

potential $= -\frac{GMm}{R}$

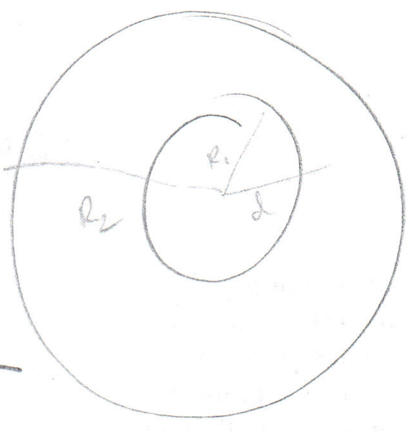
to go from r_f to r_i

$\Delta PE = -\frac{GMm}{r_f} - \frac{-GMm}{r_i}$

$\Delta KE = \frac{GMm}{r_f} - \frac{GMm}{r_i} = \frac{r_i - r_f}{r_f r_i} \cdot GMm$

28. A spherical shell has inner radius R_1, outer radius R_2, and mass M, distributed uniformly throughout the shell. The magnitude of the gravitational force exerted on the shell by a point particle of mass m, located a distance d from the center, outside the inner radius and inside the outer radius, is:

A) 0
B) GMm/d^2
C) $GMm/(R_2^3-d^3)$
D) $GMm(d^3-R_1^3)/d^2(R_2^3-R_1^3)$
E) $GMm/(d^3-R_1^3)$



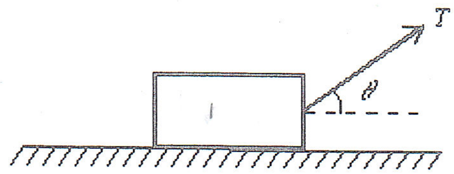
Continued from page 3

$g = \frac{G\,M_{enc}}{d^2}$ $\quad M_{enc} = M\frac{(d^3 - r_1^3)}{(r_2^3 - r_1^3)}$

$F_g = \frac{GmM(d^3 - r_1^3)}{d^2(r_2^3 - r_1^3)}$

$4\pi r^2 g = -4\pi G$

23. A block of mass m is pulled at constant velocity along a rough horizonatl floor by and applied force $\vec{T}$ as shown. The magnitude of frictional force is:



A) $T \cos \theta$
B) $T \sin \theta$
C) zero
D) mg
E) $mg \cos \theta$

$T \cos\theta + F_f = 0$

$F_f = -T\cos\theta$

24. For a block of mass m to slide without friction up the rise of height h shown, it must have a minimum initial speed of:

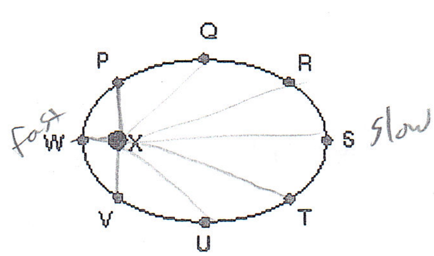
A) $1/2\sqrt{gh}$
B) $\sqrt{gh/2}$
C) $\sqrt{2gh}$
D) $2\sqrt{2gh}$
E) $2\sqrt{gh}$

$KE \rightarrow PE$

$\frac{1}{2} m v^2 = mgh$

$v = \sqrt{2gh}$

25. A planet travels in an elliptical orbit about a star X as shown. The magnitude of the acceleration of the planet is:



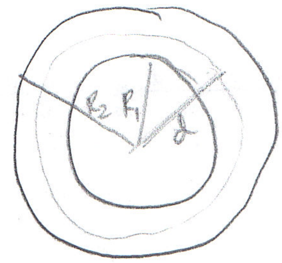
A) greatest at point Q
B) greatest at point S
C) greatest at point U
D) greatest at point W
E) the same at all points

8. A spherical shell has inner radius R_1, outer radius R_2, and mass M, distributed uniformly throughout the shell. The magnitude of the gravitational force exerted on the shell by a point mass m a distance d from the center, inside the inner radius, is:

$M_{enc} = \frac{M(d^3 - r_1^3)}{(r_2^3 - r_1^3)}$

A) 0
B) GMm / R_1^2
C) GMm/d^2
D) $GMm / \left(R_2^2 - d^2\right)$
E) $GMm/(R_1 - d)^2$

$g = \frac{-4\pi G \cdot M_{enc}}{4\pi d^2}$



$V_{Total} = \frac{4}{3}\pi r_2^3 - \frac{4}{3}\pi r_1^3$

$\frac{\frac{4}{3}\pi r_2^3 - \frac{4}{3}\pi r_1^3}{M} = \frac{\frac{4}{3}\pi d^2 - \frac{4}{3}\pi r_1^3}{M_{enc}}$

9. An object is dropped from an altitude of one Earth radius above Earth's surface. If M is the mass of Earth and R is its radius the speed of the object just before it hits Earth is given by:

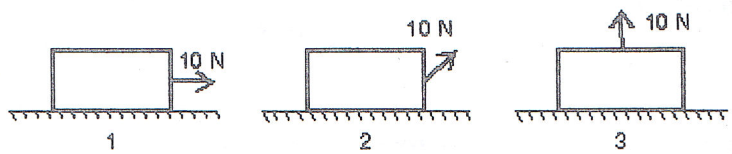
A) $\sqrt{GM / R}$
B) $\sqrt{GM / 2R}$
C) $\sqrt{2GM / R}$
D) $\sqrt{GM / R^2}$
E) $\sqrt{GM / 2R^2}$

$-\frac{GMm}{2R} = \frac{-2GMm}{2R} + \frac{1}{2} m v^2$

$\frac{GM}{2R} = \frac{1}{2} v^2$

$v = \sqrt{\frac{GM}{R}}$

10. A crate moves 10 m to the right on a horizontal surface as a woman pulls on it with a 10-N force. Rank the situations shown below according to the work done by her force, least to greatest.



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

11. A 15-g paper clip is attached to the rim of a phonograph record with a radius of 30 cm, spinning at 3.5 rad/s. The magnitude of its angular momentum is:

A) 1.4×10^{-3} kg · m²/s
B) 4.7×10^{-3} kg · m²/s
C) 1.6×10^{-2} kg · m²/s
D) 3.2×10^{-1} kg · m²/s
E) 1.1 kg · m²/s

$L = I\omega$

$= .015 \cdot (0.3)^2 \cdot 3.5$

$= 4.7 \times 10^{-3}$