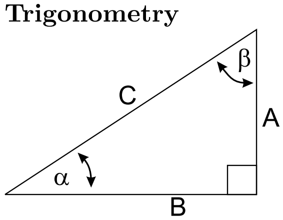
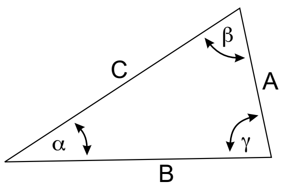
Scott Pratt

Do not open exam until instructed to do so.

Quadratic Formula
$ax^2 + bx + c = 0,$
$x = [-b \pm \sqrt{b^2 - 4ac}]/(2a)$
Geometry
Circle: circumference=$2\pi R$, area=πR^2
Sphere: area=$4\pi R^2$, volume=$4\pi R^3/3$
Trigonometry



$$\sin\alpha = \frac{A}{C}, \quad \cos\alpha = \frac{B}{C}$$
$$\tan\alpha = \frac{A}{B}$$



$$\frac{\sin\alpha}{A} = \frac{\sin\beta}{B} = \frac{\sin\gamma}{C}$$
$$A^2 + B^2 - 2AB\cos\gamma = C^2$$

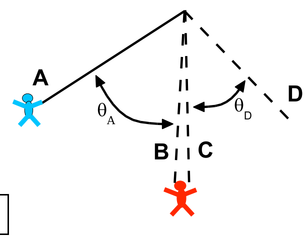
Polar Coordinates
$x = r\cos\theta, \quad y = r\sin\theta, \ r = \sqrt{x^2 + y^2}, \quad \tan\theta = y/x$
SI Units and Constants

quantity	unit	abbreviation
Mass m	kilograms	kg
Distance x	meters	m
Time t	seconds	s
Force F	Newtons	N=kg m/s^2
Energy E	Joules	J=N m
Power P	Watts	W=J/s
Temperature T	°C, °K or °F	$T_{\circ F} = 32 + (9/5)T_{\circ C}$
Pressure P	Pascals	Pa=N/m^2

1 cal=4.1868 J, 1 hp=745.7 W, 1 liter=10^{-3}m^3
$g = 9.81$ m/s^2, G=6.67×10^{-11} Nm^2/kg^2
1 atm=1.013×10^5Pa, 0°C=273.15°K, $N_A = 6.023 \times 10^{23}$
$R = 8.31$ J/(mol°K)=0.0821 L atm/(mol K),
$k_B = R/N_A = 1.38 \times 10^{-23}$ J/K, $\sigma = 5.67 \times 10^{-8}$ W/(m^{2}K^4)
$v_{\rm sound} = 331\sqrt{T/273}$ m/s
H$_2$0: $c_{\rm ice,liq.,steam}$=$\{0.5, 1.0, 0.48\}$ cal/g°C
$L_{F,V}$=$\{79.7, 540\}$ cal/g, $\rho = 1000$ kg/m^3.

1-d motion, constant a
$\Delta x = (1/2)(v_0 + v_f)t$
$v_f = v_0 + at$
$\Delta x = v_0 t + (1/2)at^2$
$\Delta x = v_f t - (1/2)at^2$
$(1/2)v_f^2 - (1/2)v_0^2 = a\Delta x$
Range: $R = (v_0^2/g)\sin 2\theta$
Forces, Work, Energy, Power, Momentum & Impulse
$F = ma$, Gravity: $F = mg, PE = mgh$
Friction: $f = \mu N$, Spring: $F = -kx, \ PE = (1/2)kx^2$
$W = Fx\cos\theta, KE = (1/2)mv^2, \ P = \Delta E/\Delta t = Fv$
$p = mv, I = F\Delta t = \Delta p$
$X_{cm} = (m_1 x_1 + m_2 x_2 + \cdots)/(m_1 + m_2 + \cdots)$
Elastic coll.s: $v_1' - v_2' = -(v_1 - v_2)$

Rotational Motion
$\Delta\theta = (1/2)(\omega_0 + \omega_f)t, \omega_f = \omega_0 + \alpha t$
$\Delta\theta = \omega_0 t + (1/2)\alpha t^2 = \omega_f t - (1/2)\alpha t^2$
$\alpha\Delta\theta = (1/2)\omega_f^2 - (1/2)\omega_0^2$
$\omega = 2\pi/T = 2\pi f, f = 1/T$
Rolling: $a = \alpha r, v = \omega r$
$a_c = v^2/r = \omega v = \omega^2 r$
$\tau = rF\sin\theta = \ I\alpha, \ I_{\rm point} = mR^2$
$I_{\rm cyl.shell} = MR^2, \ I_{\rm sphere} = (2/5)MR^2$
$I_{\rm solid\ cyl.} = (1/2)MR^2, \ I_{\rm sph.\ shell} = (2/3)MR^2$
$L = I\omega = mvr\sin\theta$, ($\theta$= angle between v and r)
$KE = (1/2)I\omega^2 = L^2/(2I), W = \tau\Delta\theta$
Gravity and circular orbits
$PE = -G\frac{Mm}{r}, \ \Delta PE = mgh$(small h)
$$F = G\frac{Mm}{r^2}, \quad \frac{GM}{4\pi^2} = \frac{R^3}{T^2}$$
Gases, liquids and solids
$P = F/A, \ PV = nRT, \ \Delta P = \rho gh$
$\langle(1/2)mv^2\rangle = (3/2)k_B T$
ideal monotonic gas: $U = (3/2)nRT = (3/2)PV$
$F_{\rm bouyant} = \rho_{\rm displaced\ liq.}V_{\rm displaced\ liq.}g$
Stress = F/A, Strain = $\Delta L/L$, Y = Stress/Strain
$\frac{\Delta L}{L} = \frac{F/A}{Y}, \frac{\Delta V}{V} = \frac{-\Delta P}{B}, Y = 3B$
Continuity: $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$
Bernoulli: $P_a + \frac{1}{2}\rho_a v_a^2 + \rho_a g h_a = P_b + \frac{1}{2}\rho_b v_b^2 + \rho_b g h_b$
Thermal
$\Delta L/L = \alpha\Delta T, \ \Delta V/V = \beta\Delta T, \beta = 3\alpha$
$Q = mC_v\Delta T + mL$(if phase trans.)
Conduction and Radiation
$P = kA(T_b - T_a)/L = A(T_b - T_a)/R$,$R \equiv L/k$
$P = e\sigma AT^4$
Thermodynamics
$\Delta U = Q + W, \quad W = -P\Delta V, \ Q = T\Delta S, \ \Delta S > 0$
Engines: $W = |Q_H| - |Q_L|$
$\epsilon = W/Q_H < (T_H - T_L)/T_H < 1$
Refrigerators and heat pumps: $W = |Q_H| - |Q_L|$
$\epsilon = Q_L/W < T_L/(T_H - T_L)$
Simple Harmonic Motion and Waves
$f = 1/T, \omega = 2\pi f$
$x(t) = A\cos(\omega t - \phi), \ v = -\omega A\sin(\omega t - \phi)$
$a = -\omega^2 A\cos(\omega t - \phi)$
Spring: $\omega = \sqrt{k/m}$
Pendulum: $T = 2\pi\sqrt{L/g}$
Waves: $y(x,t) = A\sin[2\pi(ft - x/\lambda) + \delta], \ v = f\lambda$
$I = {\rm const}A^2 f^2, \ I_2/I_1 = R_1^2/R_2^2$
Standing waves: $\lambda_n = 2L/n$
Strings: $v = \sqrt{T/\mu}$
Solid/Liquid: $v = \sqrt{B/\rho}$
Sound: $I = {\rm Power}/A = I_0 10^{\beta/10}, \ I_0 \equiv 10^{-12}$ W/m^2
Decibels: $\beta = 10\log_{10}(I/I_0)$
Beat freq.=$|f_1 - f_2|$
Doppler: $f_{\rm obs} = f_{\rm source}(V_{\rm sound} \pm v_{\rm obs})/(V_{\rm sound} \pm v_{\rm source})$
Pipes: same at both ends: $L = \lambda/2, \lambda, 3\lambda/2$
Pipes: open at only one end: $L = \lambda/4, 3\lambda/4, 5\lambda/4\cdots$



2 pt

Jane, who has mass M_{jane}, swings down from a tree, starting from rest, using a vine which has a starting angle θ_A (see the figure). When the rope is vertical, she rescues Tarzan, who has mass $M_{\rm tarzan} > M_{\rm jane}$, from the river where he was teasing the crocodiles. Jane and Tarzan then swing together to a tree branch on the other side of the river which has final angle θ_D. In the figure, position B is just before Jane picks up Tarzan, while position C is just after she picks up her irresponsible boyfriend.

▷ Janes's momentum at "B" is ______________________ the momentum of Jane and Tarzan together at "C".

1. **A**◯ greater than **B**◯ less than
C◯ equal to

▷ The mechanical energy (kinetic+potential) of Jane at "A" is __________________ the mechanical energy of Jane and Tarzan together at "D".

2. **A**◯ greater than **B**◯ less than
C◯ equal to

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2 pt Three identical airplanes with identical air speeds leave Williamston, Michigan with the intention of flying to Tallahassee, Florida, which is directly south of Williamston. Airplanes A and B leave on Monday, when there is a strong wind from the west. The pilot of airplane A points the plane directly south and is blown off course, passing east of Tallahassee, while Airplane B adjusts its direction to account for the wind and flies directly to Tallahassee. Airplane C leaves on Tuesday, a calm and windless day, and flies directly south to Tallahassee.

▷ The plane(s) that reaches Tallahassee in the least amount of time is________.

3. **A**◯ Airplane A **B**◯ Airplane B
C◯ Airplane C **D**◯ Airplanes A, B and C
E◯ Airplanes A and C **F**◯ Airplanes A and B
G◯ Airplanes B and C

▷ The plane(s) with the highest ground speed is _________.

4. **A**◯ Airplane A **B**◯ Airplane B
C◯ Airplane C **D**◯ Airplanes A, B and C
E◯ Airplanes A and C **F**◯ Airplanes A and B
G◯ Airplanes B and C

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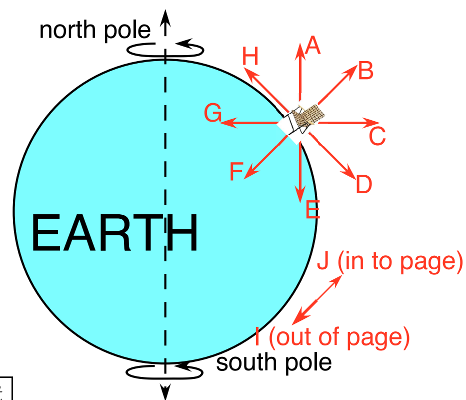
2 pt A wooden statue is completely submerged in Lake Michigan, but does not float to the surface due to a cable mooring the statue to the floor of the lake. The weight of the statue out of the water is W, the tension in the cable is T, and the buoyant force acting on the statue is B.

▷ The magnitude of B is ________________ the magnitude of W.

5. **A**◯ CANNOT BE DETERMINED
B◯ greater than **C**◯ less than **D**◯ equal to

▷ Defining upward as positive, the net force acting on the statue (buoyant + gravitational + tension) is ________________________ zero.

6. **A**◯ CANNOT BE DETERMINED
B◯ greater than **C**◯ less than **D**◯ equal to



2 pt

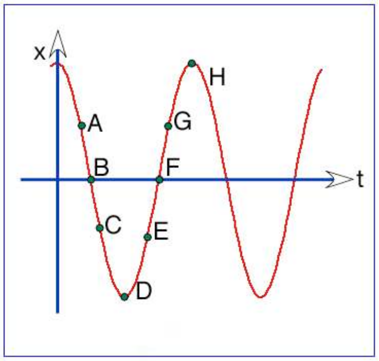
The professor's lawn chair is at 45 degrees latitude resting on the rotating earth. Vectors A-J have directions shown in the picture, with vector I pointing out of the page and J pointing into the page.

▷ The direction of the net force (includes both gravitational and contact forces) acting on the chair is described by vector ________.

7. **A**◯ A **B**◯ B **C**◯ C **D**◯ D **E**◯ E **F**◯ F
G◯ G **H**◯ H **I**◯ I **J**◯ J

▷ The direction of the centripetal acceleration of the chair is described by vector ______.

8. **A**◯ A **B**◯ B **C**◯ C **D**◯ D **E**◯ E **F**◯ F
G◯ G **H**◯ H **I**◯ I **J**◯ J



2 pt

The curve represents an object in simple harmonic motion. Match the points on the curve to the velocity and acceleration of the object.

▷ The velocity is positive, and the acceleration is positive.

9. **A**◯ Point A **B**◯ Point B **C**◯ Point C
D◯ Point D **E**◯ Point E **F**◯ Point F
G◯ Point G **H**◯ Point H

▷ The velocity is negative, and the acceleration is positive.

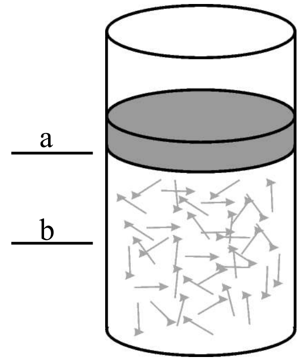
10. **A**◯ Point A **B**◯ Point B **C**◯ Point C
D◯ Point D **E**◯ Point E **F**◯ Point F
G◯ Point G **H**◯ Point H

---

1 pt A pipe is 3.4 m long and is closed at both ends. What are the first three frequencies for standing waves generated in the pipe? DATA: The speed of sound is 340 m/s.

▷

11. **A**◯ 100 Hz, 200 Hz, 300 Hz
B◯ 100 Hz, 200 Hz, 400 Hz
C◯ 100 Hz, 300 Hz, 500 Hz
D◯ 50 Hz, 100 Hz, 150 Hz
E◯ 50 Hz, 150 Hz, 250 Hz
F◯ 200 Hz, 400 Hz, 600 Hz
G◯ impossible to calculate
H◯ 25 Hz, 75 Hz, 125 Hz



4 pt

A massive piston traps a fixed amount of helium gas as shown. After being brought to point (a) the system equilibrates to room temperature. The gas is then cooled ISOBARICALLY, compressing the gas to half of its original volume (b).

▷ the pressure P_b is ________________ P_a.

12. **A**◯ greater than **B**◯ less than
C◯ equal to

▷ The internal energy U_b is ________________ U_a.

13. **A**◯ greater than **B**◯ less than
C◯ equal to

▷ The temperature T_b is ________________ T_a.

14. **A**◯ greater than **B**◯ less than
C◯ equal to

▷ The heat intake of the gas in going from "a" to "b" is ________________ zero.

15. **A**◯ greater than **B**◯ less than
C◯ equal to

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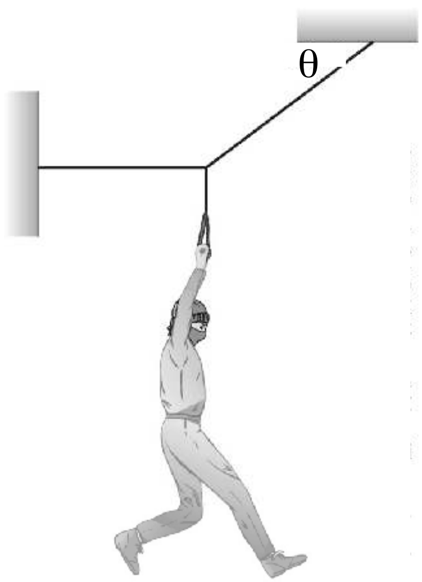
1 pt A train passes a station at constant speed, blowing its whistle twice: once while approaching the station and again after passing the station. To an observer standing on the station's platform,

▷ the frequency of the first blast was ______________________ the frequency of the second blast.

16. **A**◯ higher than **B**◯ lower than
C◯ equal to

1 pt A rocket, undergoing uniform acceleration from rest, experiences a displacement of 850 m in 4.7 s. What is its acceleration? *(in* `m/s^2`*)*

17.A◯ 17.41 **B**◯ 25.24 **C**◯ 36.60
D◯ 53.07 **E**◯ 76.96 **F**◯ 111.59
G◯ 161.80 **H**◯ 234.62



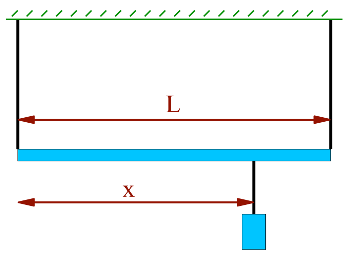
1 pt

Consider the cat burglar of mass 59 kg in the figure, where the angle θ=33 degrees. What is the tension in the horizontal section of the cable?
(in `N`*)*

18.A◯ 121 **B**◯ 161 **C**◯ 214 **D**◯ 285
E◯ 379 **F**◯ 504 **G**◯ 670 **H**◯ 891

1 pt A cannonball is fired horizontally from the top of a cliff with a muzzle velocity of 73 m/s. When the cannonball hits the ground, it has a speed of 94 m/s. What was the height of the cliff? *(in* `m`*)*

19.A◯ 28 **B**◯ 40 **C**◯ 59 **D**◯ 85
E◯ 123 **F**◯ 179 **G**◯ 259 **H**◯ 376



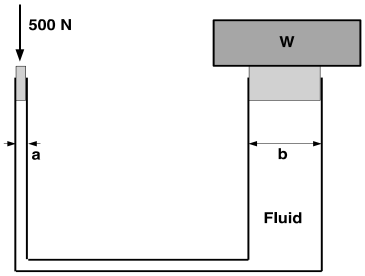
1 pt

Two wires support a beam of length L=16 m as shown in the figure above. A box hangs from a wire which is connected a distance of 12 m from the left edge of the beam. The tension in the left support wire is 700 N and the tension in the right support wire is 900 N. What is the mass of the beam? *(in* `kg`*)*

20.**A**◯ 84.8 **B**◯ 95.8 **C**◯ 108.3 **D**◯ 122.3
E◯ 138.2 **F**◯ 156.2 **G**◯ 176.5 **H**◯ 199.4

1 pt A 0.25 kg mass hangs from a spring with spring constant k=1700 N/m. If the maximum displacement of the spring from equilibrium is 0.069 m, what is the maximum speed of the mass as it moves up and down? *(in* `m/s`*)*

21.**A**◯ 3.64 **B**◯ 4.55 **C**◯ 5.69 **D**◯ 7.11
E◯ 8.89 **F**◯ 11.11 **G**◯ 13.89 **H**◯ 17.36



1 pt

Consider the hydraulic system shown above. A force of 500 N is applied as shown on the piston to the left which has a diameter of a=2 cm. The piston on the right has a diameter b=7 cm. What weight W (in N) can be lifted with this force? (Ignore friction and the weights of the piston)

22.**A**◯ 1606 **B**◯ 2007 **C**◯ 2509 **D**◯ 3136
E◯ 3920 **F**◯ 4900 **G**◯ 6125 **H**◯ 7656

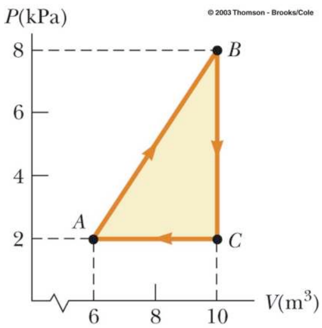
1 pt Beginning at rest at an extremely large separation, a ball is released and allowed to fall toward a star of mass 4.10E+30 kg and radius 6.30E+7 m. What is the speed of the ball when it reaches the surface? *(in* `m/s`*)*

23.**A**◯ 1.40×10^6 **B**◯ 2.03×10^6 **C**◯ 2.95×10^6
D◯ 4.27×10^6 **E**◯ 6.19×10^6 **F**◯ 8.98×10^6
G◯ 1.30×10^7 **H**◯ 1.89×10^7

At high noon, the Sun delivers 1.01 kW to each square meter of a blacktop road. What is its equilibrium temperature of the road surface in degrees Celsius? (Assume the emissivity is 1.0 and that the solar radiation is completely absorbed. Also, neglect any other sources of heat transfer besides absorption of solar radiation and thermal radiation from the surface.)

pt

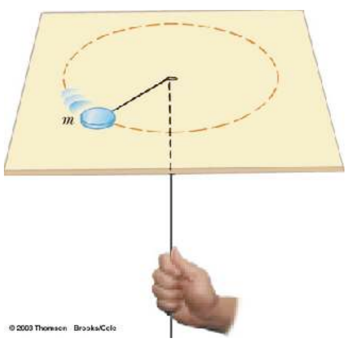
24.**A**◯ 39.2 **B**◯ 44.3 **C**◯ 50.0 **D**◯ 56.5
E◯ 63.9 **F**◯ 72.2 **G**◯ 81.6 **H**◯ 92.2



1 pt

A gas is taken through the cyclic process described by the figure above. How much work (in J) was done by the gas during the expansion from A to B.

25.**A**◯ 4000 **B**◯ 8000 **C**◯ 12000 **D**◯ 16000
E◯ 20000 **F**◯ 24000 **G**◯ 28000 **H**◯ 32000



1 pt

The puck in the figure has a mass of 0.13 kg. Its original distance from the center of rotation is 35 cm, and the puck is moving with a speed of 1.9 m/s in a circle. The string is pulled downward until the center of rotation has moved to r=8.75 cm. The table is effectively frictionless. What is the speed of the puck at the new position? *(in* `m/s`*)*

26.**A**◯ 3.11 **B**◯ 3.89 **C**◯ 4.86 **D**◯ 6.08
E◯ 7.60 **F**◯ 9.50 **G**◯ 11.88 **H**◯ 14.84

pt A traveling wave moves down a tight string and has the form:
y=6*cos(0.21*(x-63.3*t))
What is the speed of the wave?

27.**A**◯ 63.3 **B**◯ 74.1 **C**◯ 86.7 **D**◯ 101.4
E◯ 118.6 **F**◯ 138.8 **G**◯ 162.4 **H**◯ 190.0

pt What is the wavelength?

28.**A**◯ 19.15 **B**◯ 23.94 **C**◯ 29.92 **D**◯ 37.40
E◯ 46.75 **F**◯ 58.44 **G**◯ 73.05 **H**◯ 91.31

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1 pt A piano emits sound waves with frequencies that range from a low of about 28 Hz to a high of about 4,200 Hz. What is the longest wavelength of sound produced by a piano? (The speed of sound in air is approximately 343 m/s.) *(in* `m`*)*

29.A◯ 9.59 **B**◯ 10.84 **C**◯ 12.25 **D**◯ 13.84
E◯ 15.64 **F**◯ 17.68 **G**◯ 19.97 **H**◯ 22.57

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1 pt Elsie hears an annoying monotone from a speaker which is pumping 0.21 watts of energy into the sound. The intensity of the sound at Elsie's location is 5.1 dB. Ovid, in a attempt to drive Elsie insane, turns up the volume so that 85 watts of energy is carried by the sound waves. What is the new intensity level at Elsie's location? (in dB)

30.A◯ 13.2 **B**◯ 17.6 **C**◯ 23.4 **D**◯ 31.2
E◯ 41.5 **F**◯ 55.1 **G**◯ 73.3 **H**◯ 97.5

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1 pt A steel wire in a piano has a length of 65 cm and a mass of 5 g. To what tension must this wire be stretched in order that the fundamental vibration correspond to middle C (f_C = 261.6 Hz on the chromatic musical scale)? *(in* `N`*)*

31.A◯ 161 **B**◯ 214 **C**◯ 284 **D**◯ 378
E◯ 503 **F**◯ 669 **G**◯ 890 **H**◯ 1183

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1 pt Working for the Portugese Navy, Elsia Ovideo is designing a sonar device. Elsia does not know the speed of sound through the water due to the unknown salinity, but observes that sound of a frequency 9100 Hz has a wavelength of 19.23 cm. How much time would be required for a sound pulse to travel to the floor of the ocean and return if the depth of the ocean is 6520 m? *(in* s*)*

32.**A**◯ 7.45 **B**◯ 9.31 **C**◯ 11.64 **D**◯ 14.55
E◯ 18.19 **F**◯ 22.74 **G**◯ 28.42 **H**◯ 35.53

1 pt A pendulum has a period of 1.41 s on the planet Ovid where the acceleration of gravity is 8.5 m/s^2. What is its period on the surface of Ovid's moon Elsie where g = 3.4 m/s^2? *(in* s*)*

33.**A**◯ 0.24 **B**◯ 0.35 **C**◯ 0.50 **D**◯ 0.73
E◯ 1.06 **F**◯ 1.54 **G**◯ 2.23 **H**◯ 3.23