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Physics

1994 TEE Solutions*

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** These solutions are not a marking key. They are a guide to possible answers at a depth that might be expected of Year 12 students. It is unlikely that all possible answers to the questions are covered in these solutions.*

 STAWA appreciates the support of the Secondary Education Authority, which provided the marker's guides used as a basis for these solutions.

Section A: Short Answers

1. a. The **displacement** of the particle at any instant is its position relative to its mean position. Displacement would be specified by a distance and a direction.

   The **amplitude** is the maximum size of displacement. It is the greatest distance that a particle is moved from its mean position.

   b. Since sound is a longitudinal mechanical wave, the air particle at A moves back and forth (left and right in the diagram in the original examination paper). The maximum size of its displacement either left of or right of the mean position is the amplitude of its vibration.

2. The power dissipated by electric cables due to their resistance is I^2R and the power transmitted by the system is VI. If the transmission voltage is increased then the current is decreased. The power lost is proportional to the square of current so decreases in the current result in proportionately larger decreases in power loss.

3. The centre of mass is low.
   The base is wide.

4. The force exerted by a magnetic field on a current is $F = I\,l\,B$
   Hence $F = 21.9 \times 10^3 \times 1 \times 2.0 \times 10^{-5} = 0.438 \text{ N m}^{-1}$

5. The bottle is closed at one end. The lowest frequency available from a closed pipe is where the wavelength is about four times the length of the pipe. The length of a 1 L bottle is about 0.3 m so the wavelength is approximately 1.2 m. Assuming normal atmospheric conditions, the speed of sound in air would be about 330 m s^{-1}.

   From $c = \nu\,\lambda$: $\nu \approx 330/1.2 \approx 275$ Hz (or s^{-1})

6. a. The amount of energy lost would be equal to the initial energy lost by the car.

$$
\begin{aligned}
Ek &= \tfrac{1}{2} m v^2 \\
&= \tfrac{1}{2} \times 1540 \times \left(\frac{60 \times 10^3}{3600}\right)^2 \\
&= 2.14 \times 10^5 \text{ J}
\end{aligned}
$$

b. The initial rate of power loss is $120 \times 200 = 2.4 \times 10^4$ W.

Assuming that the rate of power loss is constant (it is not), we can estimate the time for deceleration from E = Pt.

$$t = \frac{E}{P}$$

$$= \frac{2.14 \times 10^5}{2.4 \times 10^4}$$

$$\approx 10 \text{ s}$$

7. $$G = \frac{F\, r^2}{m_1\, m_2}$$

The unit of F is N
The unit of r is m
The unit of m is kg
Hence the unit of G is N m^2 kg^{-2}

8. a. The stress on the bone when the bone just breaks can be read from the graph as 120 N mm^{-2}.

b. Young's modulus is given by the gradient of linear part of the graph.

$$\frac{\text{"rise"}}{\text{"run"}} = \frac{80}{5.4 \times 10^{-3}}$$

$$= 1.48 \times 10^4 \text{ N mm}^{-2}$$

$$= 1.48 \times 10^{10} \text{ N m}^{-2}$$

9. a. E, R, T, H are all stable
b. T is least stable
c. P is not stable
d. P (and possibly R) have centre of gravity outside the stone

10. a. The sounds from each of the speakers interfere with each other and create a standing wave along the line between them. The waves are interfering constructively at the loud places. At the quiet places the interference is destructive.

b. The smallest distance between a loud and a quiet place is one quarter of the wavelength. For 250 Hz, one quarter of the wavelength is about 0.33 m.

11. The voltage produced is directly proportional to the rate of rotation of the coil. The new voltage is 24.0 V.

12. The force exerted on a charged particle moving in a magnetic field is F = I v B.

Thus the magnetic field required is

$$
\begin{aligned}
B &= \frac{F}{q\,v} \\
&= \frac{1.15 \times 10^{-14}}{1.6 \times 10^{-19} \times 6 \times 10^{7}} \\
&= 1.2 \times 10^{-3}\ \mathrm{T}
\end{aligned}
$$

13. The product would be constant.

The factor which determines whether or not the crane will tip is the torque on the vertical tower. The product of the load and the distance along the jib gives this torque. Thus for each distance the product of the load and the distance should not exceed a maximum.

14. From the chart in the formulae and constants sheet we can see that X-rays have wavelengths around 100 pm.

$$
\begin{aligned}
E = h\nu &= \frac{h\,c}{\lambda} \\
&= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{100 \times 10^{-12}} \\
&= 2 \times 10^{-15}\ \mathrm{J}
\end{aligned}
$$

15. At an efficiency of 2%, the maximum power in the emitted sound is 0.4 W. The sound intensity at distance of 2 m is then given by

$$
\begin{aligned}
I &= \frac{\text{Power}}{\text{Area}} \\
&= \frac{0.4}{\tfrac{1}{2} 4\pi r^2} \\
&= 1.59 \times 10^{-2}\ \mathrm{W\,m^{-2}}
\end{aligned}
$$

The sound intensity level is then

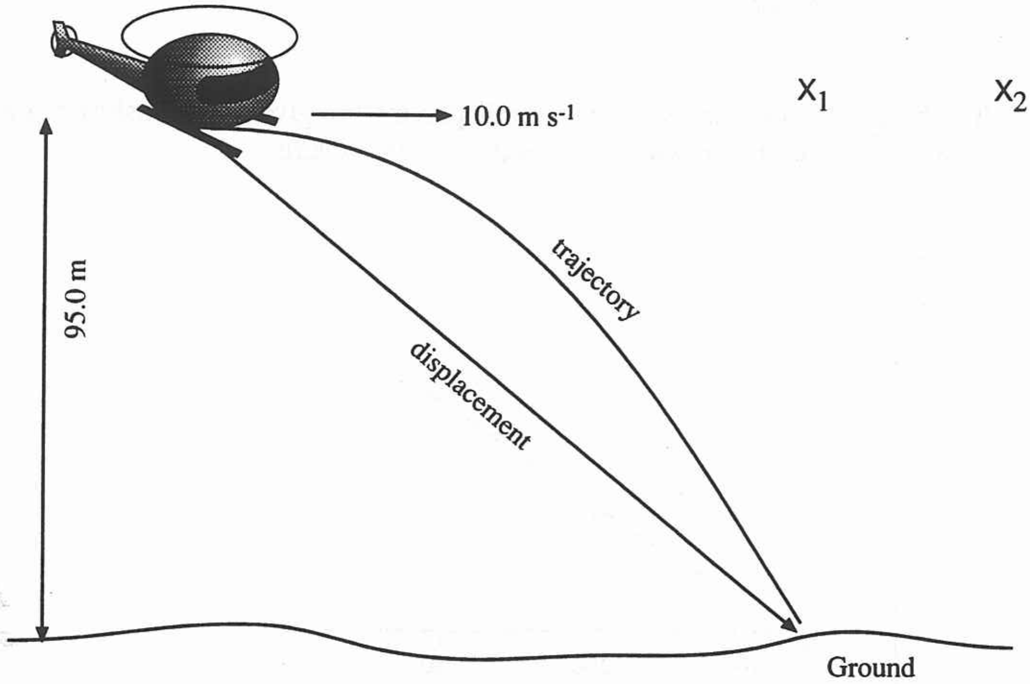
$$
\begin{aligned}
dB &= 10 \log \left[\frac{I}{I_o}\right] \\
&= 10 \log \left[\frac{1.59 \times 10^{-2}}{10^{-2}}\right] \\
&= 102\ \mathrm{dB}
\end{aligned}
$$

Section B: Problem Solving

1. a. See the diagram. The trajectory would be nearly parabolic if the effects of air resistance are small.

   b. See the diagram.

   c. See the diagram. The helicopter would be above the point of impact of the camera if the effects of air resistance are negligible (X_1). Given the real effects of air resistance, the helicopter would be forward of the point of impact (X_2).



   d. To calculate the time the camera takes to reach the ground it is only necessary to consider the vertical components of its motion.

$$s = ut + \tfrac{1}{2}at^2$$

$$u_v = 0$$

$$t^2 = \frac{2s}{a}$$

$$t = \sqrt{\frac{2 \times 95}{9.4}}$$

$$= 4.5 \text{ s}$$

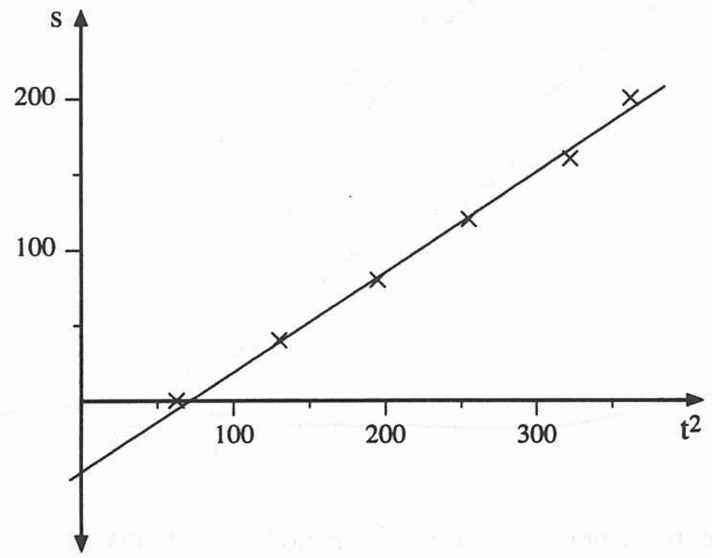
2. a. The speed at the edge of the platform matches the speed of the chairs to give the effect of stepping onto a stationary platform. Relative to the chairs, the platform has zero speed. The passengers do not experience any change to their velocities as a result of stepping from a chair and hence do not feel a jerk.

b. The entry to the platform is placed near the centre of the platform for the same reasons given in part a. Near the centre of the platform the velocity is small and passengers can easily step from the rotating platform to the stationary staircase without experiencing a large change in speed.

c. The force of friction must be at least large enough to provide the necessary centripetal force.

$$F = \frac{m v^2}{r} = \frac{56.5 \times (1.5)^2}{5} = 25.4 \text{ N}$$

3. a. To obtain a straight line conveniently displaying the given relationship, a graph of s against t^2 should be drawn with t^2 on the horizontal axis.



The gradient of the line of best fit is about 0.66 and the s intercept is about -46.

The gradient is $\frac{\tau}{2 r m}$

Hence τ = gradient x 2 r m

= 0.66 x 2 x 0.28 x 733

= 270 N m

c. The distance between A and B is given by the intercept and hence is about 46 m.

4. a. i) A line spectrum is obtained from mercury vapour lamps because there are certain discrete energy levels for the electrons to occupy. Electrons can only make

transitions between these discrete energy levels and consequently can only emit photons of particular energies. The energies of the photons correspond to the differences between the energy levels in the atom. Each photon energy coincides with a specific wavelength and frequency.

$$E_3 - E_2 = 1.8 \text{ eV}$$

$$= 1.8 \times 1.6 \times 10^{-19} \text{ J}$$

$$E_p = h\nu = \frac{hc}{\lambda}$$

$$\Rightarrow \lambda = \frac{hc}{E_p}$$

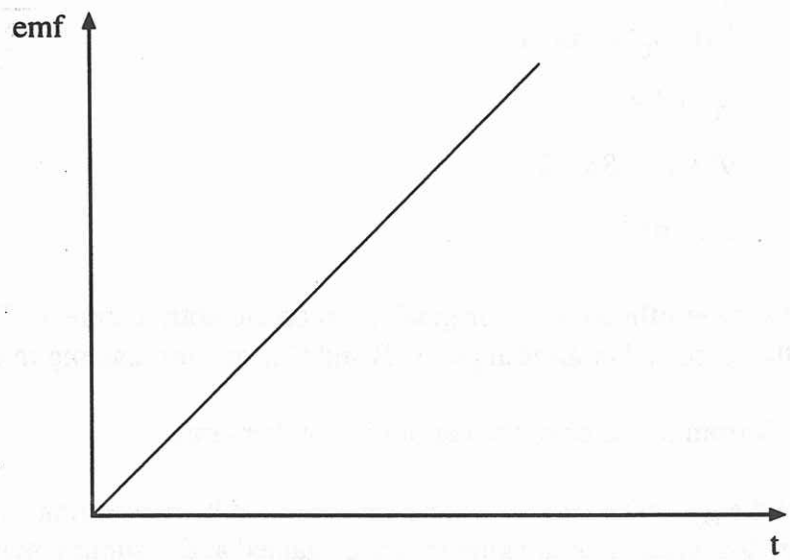
$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{1.8 \times 1.6 \times 10^{-19}}$$

$$= 6.9 \times 10^{-7} \text{ m}$$

iii) The shortest wavelength would arise from an electron falling from E_∞ to E_1.

b. The fundamental principle of fluorescence is that a photon ejects an electron in an atom completely out of the atom. This electron is then replaced by an electron falling from a higher energy level within the atom which causes the emission of a longer wavelength photon. This principle is illustrated in the operation of fluorescent lights, X-ray fluorescence, whiteners in detergents, identification marks on banknotes and postage stamps, fluorescence of chlorophyll, etc.

5. a. i) Velocity increases proportionally with time and emf is proportional to velocity so the graph is linear.



ii) emf = l v B

$= 0.150 \times 15 \times 0.4$

$= 0.9$ V

b. The general principle here is that we produce electricity by driving turbines with steam produced by burning coal, oil or gas. The burning of these substances produces CO_2 and, given the inefficiencies of production and transmission of electrical energy, using electrical energy could even be more polluting in the long run.

6. a. i) A: less than mg
B: greater than mg
C: equal to mg

ii) Seat belts are most likely to be needed at position A. This is because the reaction force between seat and rider is least and, if the car is going fast enough, may even be zero. Seat belts may be needed to hold the passengers in.

iii) At the minimum speed the centripetal force at point C is provided only by the weight of the car and riders.

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

$$\Rightarrow \quad v = \sqrt{g r}$$

$$= \sqrt{9.8 \times 4.2}$$

$$= 6.42 \text{ m s}^{-1}$$

iv) The kinetic energy lost in going from the bottom of the loop to the top is equal to the potential energy gained if we neglect the effects of friction. This is mgΔh or 2mgr. Thus the kinetic energy at the bottom of the loop must be the sum of this gain in potential energy plus the kinetic energy still remaining at the top of the loop.

$$\tfrac{1}{2} m V_A^2 = \tfrac{1}{2} m V_C^2 + 2 m g r$$

$$\Rightarrow \quad V_A^2 = V_C^2 + 4 g r$$

$$= 9^2 + 4 \times 9.8 \times 4.2$$

$$= 15.7 \text{ m s}^{-1}$$

6 b. i) The choices of answer offered in the original question are both incorrect. The magnitude of the force on her arms at points B and C is greater than mg in each case.

ii) The forces result from the force of the bar pulling on her arms.

iii) The velocity of the gymnasts centre of mass can be found by conserving energy. The potential energy lost is equal to the kinetic energy gained and assuming that she starts from zero speed:

$$mg\Delta h = \tfrac{1}{2} m v^2$$

$$\Rightarrow \quad v = \sqrt{2 g \Delta h}$$

$$= \sqrt{2 \times 9.8 \times 2 \times 0.89}$$

$$= 5.91 \text{ m s}^{-1}$$

iv) The size of the upward force required at position C is the sum of the centripetal force required and her weight.

$$F = \left|\frac{m v^2}{r}\right| + \left|m g\right|$$

$$= \frac{4.92 \times 5.91^2}{0.89} + 49.2 \times 9.8$$

$$= 2413 \text{ N}$$

Thus the tension in each arm is 1200 N.

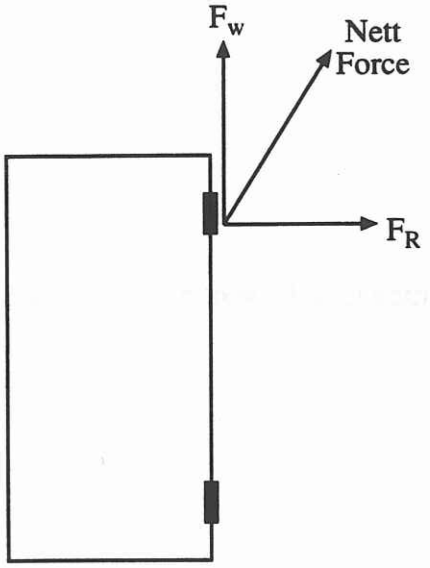
7. a. i) The change of direction associated with diffraction can only occur if a wave is transmitted from one medium to another in which it has a different speed. It is also necessary for the wave to be transmitted at an incident angle other than 90°. In the body, ultrasound has different velocities in different tissue types so it is possible for the sound to change direction when it strikes the boundaries between organs.

iii) There has to be a balance between high and low frequencies. If the frequencies are too high then the waves are attenuated by the body tissues and do not transmit well. If the frequencies are too low then the wavelength is too great and smaller objects cannot be detected. The wavelength for 1540 m s $^{-1}$ at 3 Mhz is about 0.5 mm. This represents a good compromise.

iv) The direction of sound can be determined by the difference in loudness detected by each ear. When the head is turned, at some positions the sound will be equally loud in each ear. At other positions the head partially shields the far ear from the oncoming sound. Lower frequency (longer wavelength) sounds diffract more so this effect is less pronounced.

7. b. iv) If the two loudspeakers are connected out of phase, then the sounds from each will interfere destructively and this effect will be most noticeable when the listener is equidistant from each speaker. For higher frequencies, the wavelength is shorter and the positions of constructive and destructive interference are closer together so this effect is less noticeable.

8. a. i) The force on the door due to the upper hinge does two things. It supports some of the weight of the door [F_W] and it stops the door from rotating outwards [F_R]. The nett force is the sum of these two effects.



ii) Three approximations or assumptions need to be made: the mass of the door, the positions of the hinges, and the width of the door.

Assume the door is made from solid wood of density, say, 0.8 of the density of water and dimensions 2 m x 0.9 m x 5 cm. Its mass is then about 70 kg and its weight is then about 700 N.

F_W is then 350 N.

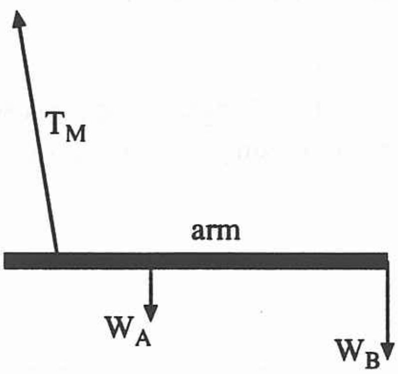
If we guess that the hinges are each 0.5 m from the top and the bottom of the door and hence 1 m apart and balance torque about the lower hinge:

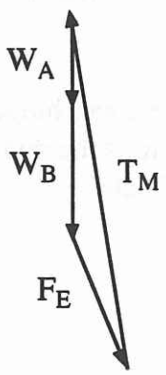
torque due to F_R = torque due to weight of door (at the centre of the door)

$F_R \times 1 = 700 \times 0.45$
$\Rightarrow \; F_R = 315$ N

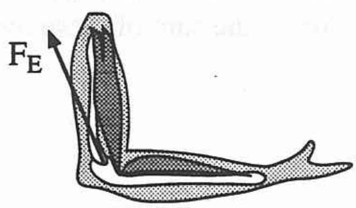
Hence Nett Force $= \sqrt{(350^2 + 315^2)} \approx 500$ N

b. i) The force on the humerus at the elbow due to the arm (radius and ulna combined) is equal and opposite to the force on the arm due to the humerus. Consider the forces on the arm and add them "head to tail".



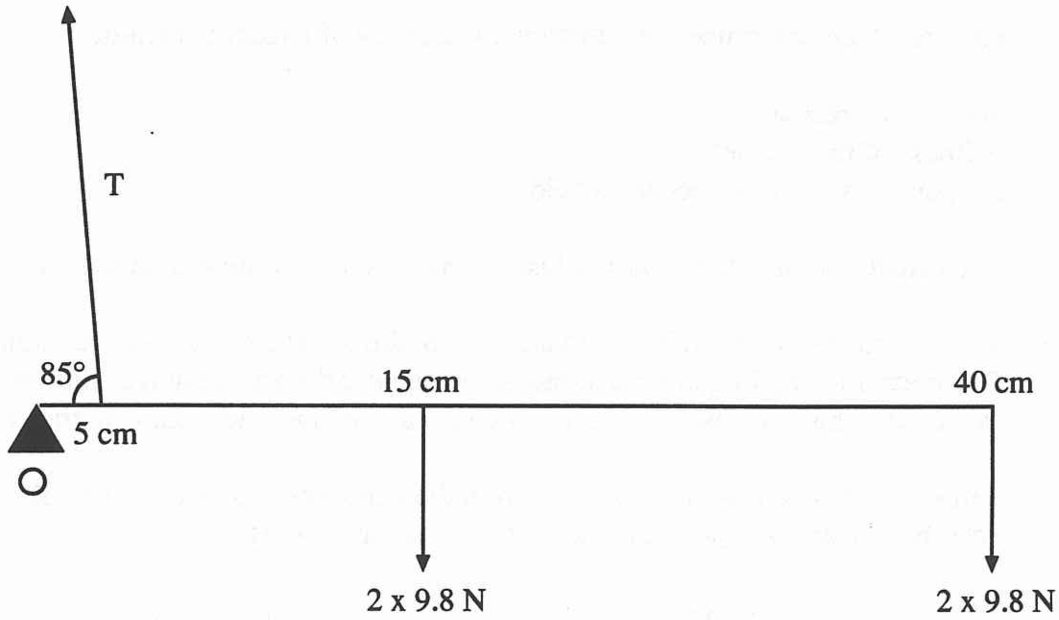


T_M is force due to tension in muscle.
W_A is weight of the arm.
W_B is weight of the 2 kg mass.
F_E is the force at the elbow.



Hence the force on the humerus is equal and opposite to F_E. It is upwards and away from the arm.

ii) If we consider torque about the elbow, the torque due to the tension in the muscle balances the torque due to the 2 kg mass and the weight of the arm. We assume that the mass of the arm is about 2 kg and is about 15 cm from the elbow. We also assume that the arm is 40 cm long and the muscle is at an angle of 5° to the vertical. Guess that the muscle is attached 5 cm from the elbow.



Anticlockwise torque = Clockwise torque

$T \times 5 \times \sin 85° = 2 \times 9.8 \times 15 + 2 \times 9.8 \times 40$

$\Rightarrow \quad T \approx 200 \text{ N}$

Section C: Comprehension and Interpretation

1. a. From the formula given we can calculate that

$$l = \frac{T^2 g}{4\pi^2} = \frac{1.23^2 \times 9.8}{4\pi^2} = 0.376 \text{ m}$$

This means that the centre of percussion is 376 mm from the point of suspension (i.e. where you would normally hold it) and on the centre line of the racquet.

b. If you hit the ball at the right spot then there is no movement of the handle at the point you hold it. If you hit the ball elsewhere then the handle moves and you have to apply a force to prevent the movement. This results in the jarring.

c. A sympathetic resonance structure is a way of saying that the structures have a resonant frequency, i.e. the natural frequencies of oscillation are the same. The problems this creates result from the larger amplitudes of oscillation obtained by resonance. In other words your arm will do the most "flapping around" and damage is more likely.

d. Factors which determine the vibrational frequency of a racquet include

mass of the racquet
stiffness of the racquet
the point at which the racquet is held.

2. a. i) The density of the interstellar gas just means the concentration of atoms in space.

ii) The amount of hydrogen is important since hydrogen absorbs ultraviolet radiation. The greater the hydrogen concentration, the greater the attenuation of ultraviolet radiation. This decreases extent to which ultraviolet radiation can penetrate space.

b. Ultraviolet can be absorbed by an atom in the atmosphere by having its energy absorbed by an electron. The photon then no longer exists.

c.

		EUV		UV		Vis	
λ	10		100		400		700 nm
E	124		12.4		3.1		1.8 eV

The energies have been calculated from $E = h\nu = hc/\lambda$. The figures calculated from the wavelengths are shown in the diagram in units of electron volt but joule would have been equally acceptable.

d. The explorer is in an orbit 5.5×10^5 m above the earth.

From $\quad v = 2\pi r$

we see $\quad T = \dfrac{2\pi r}{v}$

using $\quad F = \dfrac{m v^2}{r} = \dfrac{G M m}{r^2}$

the velocity of the explorer is $\quad v = \sqrt{\dfrac{G M}{r}}$

Hence the period of orbit is

$$T = \sqrt{\frac{4\pi^2 r^3}{G M}}$$

$$= \sqrt{\frac{4\pi^2 (6.92 \times 10^6)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}}$$

$$= 5727 \text{ s}$$

$$\approx 1.6 \text{ hours}$$