MONASH College

MCD4160 Physics for Engineering

Practice Test 1

USEFUL FORMULAE AND DATA

Physical Constants:

$g = 9.8\ \mathrm{ms^{-2}}$, h [illegible] $R = 1.097 \times 10^{7}\ \mathrm{m^{-1}}$, $c = 3.0 \times 10^{8}\ \mathrm{ms^{-1}}$

$m_e = 9.11 \times 10^{-31}$ [illegible] $^{-27}$ kg, Charge of the electron $e = -1.6 \times 10^{-19}$ C

Gravitational Constan[illegible] $\mathrm{m^2kg^{-2}}$, Speed of sound in air $v = 340.0\ \mathrm{ms^{-1}}$

NEWTONIAN MEC[illegible]

$I = \int F dt$, $\vec{\tau} = \vec{r} \times \vec{F}$, $\tau = I\alpha$ $v = r\omega$, $a = r\alpha$, $\vec{L} = \vec{r} \times \vec{p}$, $L = I\omega$,

$I_{cylinder} = I_{disk} = \frac{1}{2}Mr^2$, $I = \sum m_i r_i^2$, $K_{rot} = \frac{1}{2}I\omega^2$ $P = \frac{W}{t}$, $T^2 \propto r^3$, $F = G\frac{Mm}{r^2}$

OSCILLATIONS AND WAVES:

$x = A\cos(\omega t)$, $v = -A\omega\sin(\omega t)$, $a = -A\omega^2\cos(\omega t)$, $\omega = \sqrt{\frac{K}{m}}$, $E = K + U = \frac{1}{2}kA^2$

$x = A\exp\left(\frac{-bt}{2m}\right)\cos(\omega_d t)$, $\omega = 2\pi f$, $x_{max}(t) = A\exp\left(\frac{-t}{\tau}\right)$

Travelling waves : $y = A\cos[kx \pm \omega t + \varphi]$, Standing waves : $y = [2A\sin kx]\cos\omega t$, $k = \frac{2\pi}{\lambda}$

$v = \frac{\omega}{k}$, $v = f\lambda$, $v = \sqrt{\frac{T}{\mu}}$, $\sqrt{\frac{E}{\rho}}$, $P_{mean} = \frac{1}{2}\mu v\omega^2A^2$, $d\sin\theta = m\lambda$ $m = 0,1,2,..$

$\Delta y = \frac{\lambda L}{d}$, $y_m = \frac{mL\lambda}{d}$, $2nt = \left(m + \frac{1}{2}\right)\lambda$, $a\sin\theta = m\lambda$ $m = 0,1,2,\ldots$, $y_m = \frac{mL\lambda}{a}$

$f' = f\left(\frac{v \pm v_0}{v \mp v_s}\right)$, $B = 10\log\left(\frac{I}{I_{ref}}\right)$ dB, where $I_{ref} = 10^{-12}\ \mathrm{W\,m^{-2}}$, $n_1\sin\theta_1 = n_2\sin\theta_2$

$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$, $M = -\left(\frac{q}{p}\right)$

QUANTUM PHYSICS:

Energy levels in a hydrogen-like atom: $E = -\frac{13.6}{n^2}Z^2$ eV $(n = 1,2,3,\ldots)$

$\frac{1}{\lambda} = R\left[\frac{1}{n_0^2} - \frac{1}{n^2}\right]$, $E = hf = \frac{hc}{\lambda}$, $V_{stop} = \frac{K_{max}}{e}$, $K_{max} = hf - W$, $E_{photon} = \frac{1240}{\lambda(nm)}$ eV

$1\ \mathrm{eV} = 1.6 \times 10^{-19}$ J, $\lambda = \frac{h}{p}$, $\Delta K = Q\Delta V$, $m_e \ll m_p$, $\Delta x\,\Delta p \geq \frac{h}{4\pi}$,

$E_n = n^2\left(\frac{h^2}{8mL^2}\right)$, $(n = 1,2,3,\ldots)$, Energy levels for an infinite 1-dimensional square well.

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QUESTION 1 (2+[illegible]

An object, initially a[illegible]urface, broke up into two pieces, A (0.4 kg) and B (0.2 kg) due to a force betw[illegible] traveled horizontally over a frictionless surface and later stuck to a spring a[illegible]2 m (maximum compression). The spring (with spring constant 10 N/m) wa[illegible]n.

A short time after the object broke up, piece B traveled over a surface with friction and stopped. There is no air drag.

Reminder – show working in all questions.

(a) What is the speed of piece A just before it compressed the spring?

(b) What is the speed of piece B just after the object broke up?

(c) How much energy was dissipated by kinetic friction?

(d) What is the distance traveled by piece B if the magnitude of the kinetic friction force is 0.2 N?

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QUESTION 2 ([illegible]

A ball of mass [illegible] om some height above the floor. It rebounds vertically to a maximum height [illegible] lliding with the floor. The speed of the ball just before it hits the floor is 6.0 m [illegible]

(a) Calculate the speed of the ball just after it collides with the floor. Use conservation of energy method.

(b) What is the magnitude of the impulse on the ball by the floor?

(c) What is the direction of the impulse on the ball, up or down?

(d) How much mechanical energy is lost by the ball as a result of the collision?

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QUESTION 3 (2+[illegible])

A rigid body, consi[illegible]ed to one end of a thin rod, is initially rotating horizontally at a constant angul[illegible] about a frictionless vertical axis through the center of the rod. The mass of t[illegible]d the length of the rod is 1.0 meter. The rotational inertia (moment of inertia)[illegible]ation axis is 1.5 kg m^2. There is no air drag.

(a) Calculate the rotational inertia of the rigid body (rod + particle) about the rotation axis.

(b) Calculate the magnitude of the angular momentum of the rigid body along the rotation axis.

Later, as the rigid body is rotating, the particle is pushed along the rod to the center of the rod and the particle stays there. The line of action of the *horizontal* pushing force goes through the rotation axis.

(c) Calculate the new rotational inertia of the rigid body about the rotation axis.

(d) Calculate the new angular velocity of the rigid body. Show working/reasons.

(e) If the pushing force on the particle had a component perpendicular to the rod (and the force is in the horizontal plane) is the method or principle that you applied to obtain the new angular velocity of the rigid body in part (d) still valid? Explain briefly.

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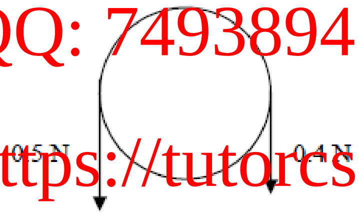
QUESTION 4 (3 Mar[illegible]

A thin rod (1.0 meter[illegible] with one end on the floor, and is allowed to fall (effectively from rest). [illegible]e floor does not slip. What is the linear speed of the other end of the rod jus[illegible] Assume there is no air drag. Hint: use conservation of energy method. The mo[illegible]d about an axis perpendicular to the rod at one end is $\frac{1}{3}ML^2$.

QUESTION 5 (2+3+ 2 = 7 Marks)

A disc (radius 0.1 m) can rotate horizontally about a vertical frictionless axis through its center (see bird's eye view below). The rotational inertia of the disc about the rotation axis is 0.001 kgm^2. Two horizontal forces, 0.5 N and 0.4 N, are constantly applied tangentially to the rim of the disc at two opposite points. Assume there is no air drag.



(a) Calculate the net torque due to the two forces.

(b) As it rotates, the change in kinetic energy of the disc is 0.02 J. Calculate the angular displacement (in radian) of the disc corresponding to this change in energy.

(c) If the angular velocity of the disc at a particular time is 5 rad/s, calculate the net power due to the two forces (or torques).

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QUESTION 6 (2-

A particle can only … There is only one force acting on the particle along the x-axis and the force i… corresponding potential energy is given by

> 0

where $a = 2.0$ J/m.

The total mechanic… is 20 J.

(a) Are there any equilibrium points? Explain your answer briefly.

(b) Determine the turning points or point for the motion of this particle.

(c) What is the kinetic energy of the particle when it is at $x = -5.0$ m ?

(d) What is the magnitude of the force on the particle when it is at x= -5.0 m? Include the direction of this force, $+x$ or $-x$?

, direction:

QUESTION 7 (2+2 = 4 Marks)

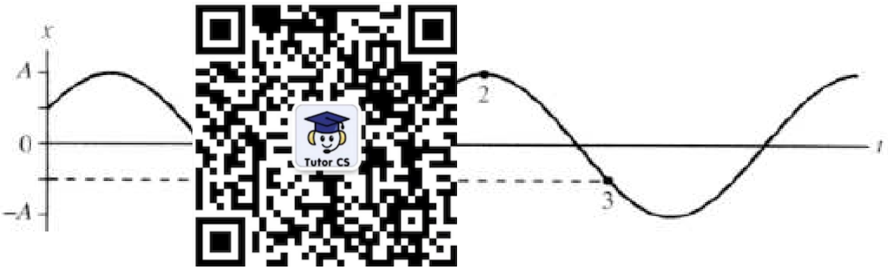
A planet (mass m) moves in an elliptical orbit around a star (mass M). Let r be the distance of the planet to the star and K the planet's kinetic energy. If the ratio of the angular velocities of the planet at two points, A and B, in its orbit is given by $\omega_A/\omega_B = 4$,

(a) what is the ratio r_A/r_B? Show working.

(b) what is the ratio $(K_B-K_A)/(GMm/r_A)$, where (K_B-K_A) is the change in kinetic energy from A to B?

QUESTION 8 (2 + 2 = 4 Marks)

The graph below represents the displacement versus time of a particle in simple harmonic motion.



a) What is the phase constant φ_0 in radian? Assume the cosine form for the displacement. Show working.

b) What is the phase of the particle at points 1 and 3 on the graph, in radian?

Phase at 1:	Phase at 3:

QUESTION 9 (1 + 2 = 3 Marks)

(a) State the basic requirement, in terms of force(s), for a particle to execute simple harmonic motion.

(b) A nitrogen atom of m_1 oscillates in SHM with angular frequency ω_0 as a result of spring-like forces from surrounding atoms. A second nitrogen atom has exactly the same spring forces but vibrates at frequency $\omega_2 = 1.038\ \omega_0$ due to it having a different isotopic mass, m_2.

Find the ratio ${}^{m_2}/_{m_1}$.

QUESTION 10 (1 + 2 = 3 Marks)

A car drives along a bumpy road on which the bumps are equally spaced. At a speed of 30 km/h, the frequency at which it hits bumps is equal to the natural frequency of the car bouncing on its springs.

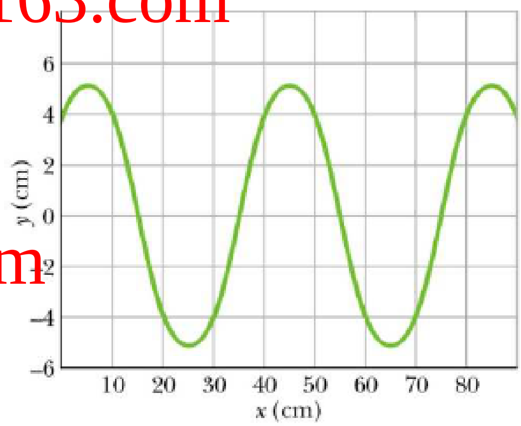
On the axes above sketch graphs of the amplitude of the car's vertical displacement as a function of its speed when the car:

a) has good shock absorbers (relatively large damping). Label the curve 'large damping'.

b) has worn-out shock absorbers (small damping coefficient). Use a dashed curve, labeled 'small damping'.

QUESTION 11 (1+2+1+2 = 6 Marks)

A sinusoidal transverse wave is traveling along a string in the negative direction of an x axis. The figure on the right shows a plot of the displacement as a function of position at time $t = 0$; the y intercept is 4.0 cm. The string tension is 3.6 N, and its linear density is 0.025 kg/m.



Find:

a) the wave speed;

b) the period of the wave;

c) The maximum transverse speed of a particle in the string.

d) Complete the numerical values in the following expression for the displacement of the traveling wave. You may express appropriate quantities in terms of π.

$$y = \quad \sin (\qquad\qquad\qquad + \phi_o) \quad \text{in metre.}$$

QUESTION 12 (1+2+2+2 = 7 Marks)

A string oscillates according to the equation:

$$Y = (0.00\ldots \ldots 0\pi)t]$$

where x, y and t are ...

The superposition ... except for direction of travel) produces this oscillation.
Find:

a) The amplitude ... waves.

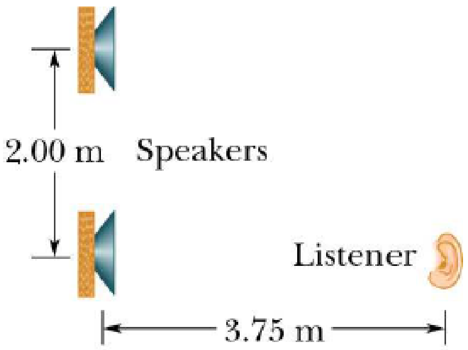
b) The wave speed of each traveling wave.

c) The distance between adjacent nodes of the oscillating string.

d) The speed of a particle of the string at position x = 0.015 m, when t = 9/8 s.

QUESTION 13 (2 + 2 = 4 Marks)

In the figure shown, two loudspeakers, separated by a distance of 2.00 m, are in phase. Assume the amplitudes of the sound from the speakers are approximately the same at the position of a listener, who is 3.75 m directly in front of one of the speakers.



a) For what frequencies in the audible range (20 Hz to 20 kHz) does the listener hear a minimum signal?

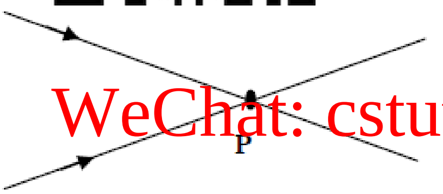
b) For what frequencies is the signal a maximum?

QUESTION 14 (2 + 2 = 4 Marks)

A laser beam has intensity I_0 . A lens (not shown) focuses the laser beam to 1/10th of its initial diameter.

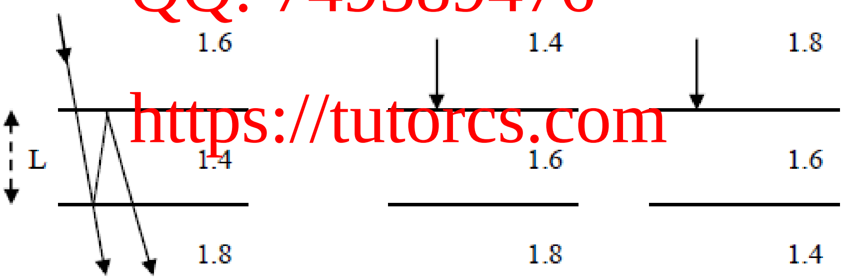
a) What is the ne… f I_0?

b) The diagram s… ser beam, which is focused at point P. Show where a lens of f = 3 cm shoul… a parallel beam going the right. Complete the ray diagram.



QUESTION 15 (1 + 2 = 3 Marks)

In the Figure below light is incident perpendicularly on a thin layer of thickness L. The indexes of refraction of the thin layer and of the media above and below these layers are given for cases I to III. Let λ represent the wavelength of the light in air and n represent the index of refraction of the **thin layer** in each situation. Consider only the rays of transmitted light which undergo no reflection or two reflections, as in Figure (I) below.



(I) (II) (III)

(a) What is the phase difference between the two transmitted light rays in (I) and (III) as a result of reflection only?

(I) ☐ (III) ☐

(b) Find an expression for λ (wavelength of light in air) in terms of L, n and m (order of interference) for case (II), when the transmitted light rays undergo fully constructive interference.

QUESTION 16 (2 + 1 = 3 Marks)

A commuter train passes a passenger platform at a constant speed of 40 m/s. The train horn is sounded at a frequency of 320 Hz. The speed of the sound is 343 m /s.

(a) What total change in frequency is detected by a person on the platform as the train goes from approaching to receding? (Give correct sign.)

(b) What wavelength is detected by a person on the platform as the train approaches?

QUESTION 17 (2 + 2 = 4 Marks)

An initially polarized electromagnetic wave passes through two polarizing filters, from bottom left to top right of the figure below. (The direction of the beam is perpendicular to each filter.) The transmission axis of each filter indicated by “T”. The direction of the initial E-field is shown by the double-headed arrow, at bottom left.

a) Draw the direction of the electric field of the wave after it has passed through each filter (using a double-headed arrow at each of the set of axes).

b) What fraction of the initial intensity I_0 of the wave emerges from the second polarizing filter, if $\theta = 40^{\circ}$?

QUESTION 18 (2+2=4 Marks)

Give two reasons why the wave picture of light fails to explain the photoelectric effect.

Reason 1: ______________________________

Reason 2: ______________________________

QUESTION 19 (3+1+3 = 7 Marks)

(a) An electron in the hydrogen atom de-excites from the **first** excited state to the **ground** state. Use the Rydberg formula to determine the wavelength of the emitted light.

(b) Is the photon in part (a), an ultra-violet (UV), visible (VIS) or infrared photon (IR)? Write UV, VIS or IR in the space provided.

(c) If an electron in the hydrogen atom de-excites from the **second** excited state to the **ground** state, display with an arrow on the energy level diagram below, each of the possible transitions.

n = 4 ______________________

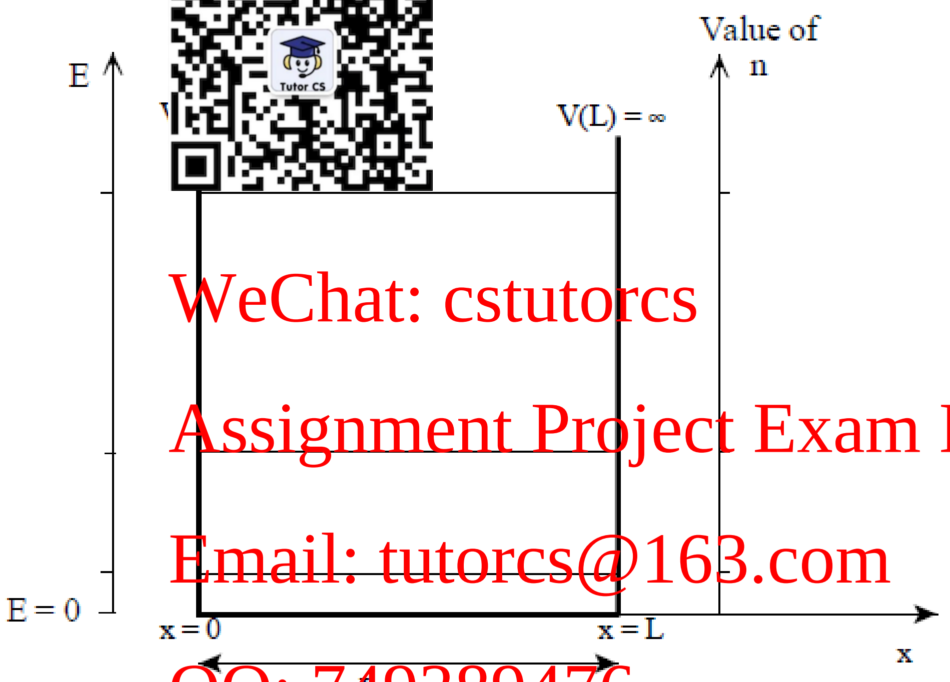
n = 3 ______________________

n = 2 ______________________

n = 1 ______________________

QUESTION 20 (3+3+2+2 = 10 Marks)

Electrons are trapped in a one dimensional box of width L. The potential energy diagram for this box is shown below.



(a) Mark the value of the first three quantum number n, on the right axis shown in the diagram.

(b) On the vertical left energy axis, label the first three allowed energy levels in terms of the ground state energy E_1.

(c) If there are two electrons in this system, which energy level (in terms of n) is the highest occupied energy level, based on the Pauli Exclusion Principle?

(d) On the above diagram sketch the form of the probability density for the **first** excited state.

END OF PAPER