Q1	Q4
Q2	Q5
Q3	
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FIRST NAMES: ______________________________

SURNAME: ______________________________

STUDENT NUMBER: ______________________________

FACULTY OF SCIENCE

DEPARTMENT OF APPLIED PHYSICS AND ENGINEERING MATHEMATICS

BACHELOR OF ENGINEERING TECHNOLOGY IN EXTRACTION METALLURGY
BACHELOR OF ENGINEERING TECHNOLOGY IN PHYSICAL METALLURGY

MODULE ENGINEERING PHYSICS TX1 (THEORY) PHADTX1

CAMPUS **DFC**

JANUARY EXAMINATION

DATE 07/01/2019 **SESSION: 08:00 – 11:00**

ASSESSOR **DR. J. CHANGUNDEGA**

INTERNAL MODERATOR **PROF. L. REDDY**

DURATION 3 HOURS **MARKS 100**

NUMBER OF PAGES: 15 PAGES, INCLUDING BLANK SPACE AND INFORMATION SPACE

INSTRUCTIONS: CALCULATORS ARE PERMITTED (ONLY ONE PER STUDENT)

2/…

ANSWER ALL QUESTIONS IN THE SPACES PROVIDED IN THIS QUESTION PAPER

QUESTION 1: PHYSICS AND MEASUREMENT

1.1. The position of a particle is described by

$y = 2$ m $(\cos kx)$ where $k = 2$ m^{-1}

Is the following equation dimensionally consistent? (1)

Justify your answer. (4)

1.2. If an average person's heartbeat is 80 beats per minute, estimate the order of magnitude of the number of heartbeats in the entire lifetime of a person that lives for 80 years. (5)

1.3. Convert a speed of 100 km/h to m/s. (6)

1.4. Multiply 2.079×10^2 m by 0.082×10^{-1}. The answer must be in scientific notation. It is not necessary to show your working for this problem. (3)

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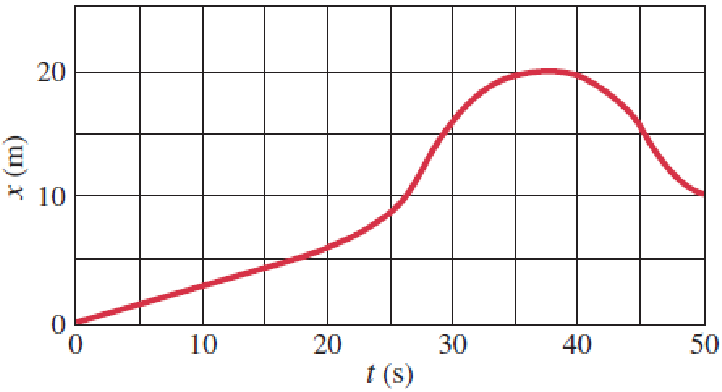
QUESTION 2: KINEMATICS, VECTORS AND DYNAMICS

2.1. State Newton's first law of motion. (2)

2.2. The graph below is the position-time of an object along the x axis.



2.1.1. When was the object stationary? (2)

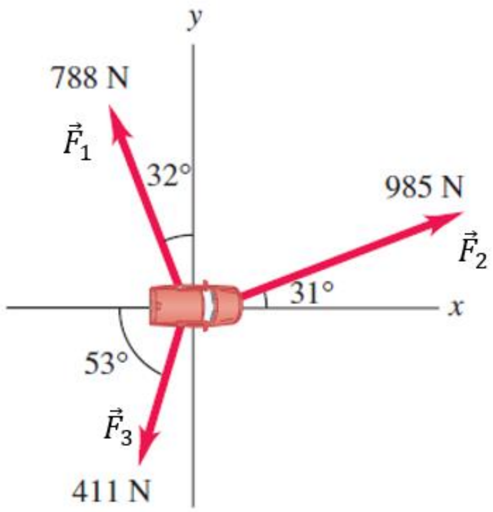
2.1.2. What is the final direction of motion of the object? (1)

2.2. A particle is moving at a constant velocity of $\vec{v} = [-2.0\hat{\imath} + 3.5\hat{\jmath} + 2.0\hat{k}]$ m/s. The particle starts at $\vec{r} = [1.5\hat{\imath} - 3.1\hat{\jmath}]$ m at time $t = 0$. What is the position of the particle at time $t = 2.0$ s (5)

Additional working space is provided on the next page.

2.3. A ball thrown horizontally at 23.7m/s from the roof of a building lands 31.0 m from the bottom of the building. How high is the building? (5)

2.4. Workmen are trying to free a car stuck in the mud. They use three horizontal ropes, producing the forces shown in diagram (aerial view).



Determine the magnitude and direction of the resultant force on the car. (7)

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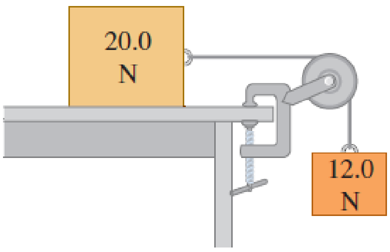
QUESTION 3: ENERGY, LINEAR MOMENTUM AND COLLISIONS

3.1. Does the kinetic energy of a car change more when it speeds up from 10 m/s to 15 m/s or when it speeds up from 15 m/s to 20 m/s. (1)

Justify your answer. (4)

3.2. Two blocks are connected by a very light string passing over a massless and frictionless pulley as illustrated in the diagram.



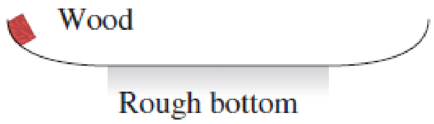
Traveling at constant speed, the 20.0 N block moves 75.0 cm to the right and the 12.0 N block moves 75.0 cm downward.

During this process, how much work is done on the 20.0 N block by

3.2.1. the gravitational force? (4)

3.2.2. the tension in the string? (4)

3.3. A 2.00 kg piece of wood slides on the surface shown in the diagram. The curved sides are perfectly smooth, but the rough horizontal bottom is 30.0 m long and has a coefficient of kinetic friction of 0.200 with the wood. The piece of wood starts from rest 4.00 m above the rough horizontal bottom.



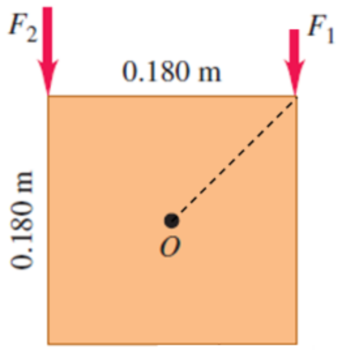
How far along the rough horizontal bottom does the block travel before it comes to rest? (7)

[20]

QUESTION 4: ROTATIONAL DYNAMICS AND ELASTIC PROPERTIES OF SOLIDS

4.1. A metal wire of radius r stretches by 0.100 mm when supporting a weight W. If the same length wire is used to support a weight of $3W$, what would its radius have to be if it still stretches by only 0.100 mm? (5)

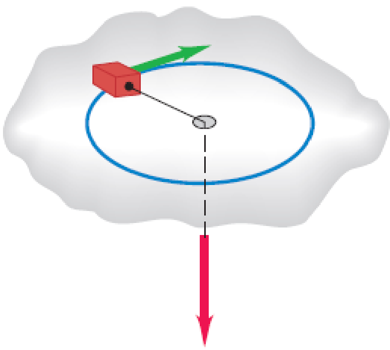
4.2. A square metal plate 0.180 m on each side is pivoted about an axis through point *O* at its centre, as shown in the diagram.



4.2.1. Use Pythagoras' theorem to determine the length of the dotted distance. This is required for Question 4.2.2. (4)

4.2.2. Calculate the net torque (magnitude and direction) about this axis due to the two forces indicated in the diagram. The magnitudes of the forces are $F_1 = 18.0$ N and $F_2 = 26.0$ N. (5)

4.3. A small block of mass 0.0250 kg is placed on a frictionless, horizontal surface and it is attached to a massless cord passing through a hole in the surface as shown in the diagram.



The block is initially made to revolve at a distance of 0.300 m from the hole with an angular speed of 1.75 rad/s. The cord is then pulled from below, shortening the radius of the circle of revolution to 0.150 m. Modelling the block as a particle, determine the new angular speed of the block. (6)

[20]

QUESTION 5: UNIVERSAL GRAVITATION

Constants
$G = 6.674 \times 10^{-11}$ N m^2 kg^{-2}
$R_{Earth} = 6.37 \times 10^6$ m
$M_{Earth} = 5.97 \times 10^{24}$ kg

5.1. People sometimes ask, “What keeps a satellite up in its orbit around the Earth?” How would you respond? (3)

5.2. What is a geosynchronous satellite? (2)

5.3. The mean distance of the Moon from the Earth is 3.84×10^8 m and on average, the Moon takes 27.4 days to orbit Earth. Use Kepler’s third law to determine the mass of the Earth. (7)

5.4. Assume that the planet Mars is a perfect sphere of uniform density with the following properties.

$M_{Mars} = 6.42 \times 10^{23}$ kg
$r_{Mars} = 3.39 \times 10^6$ m (mean radius of orbit around the Sun)

Prove that the average gravitational acceleration on the surface of Mars is 3.73 m s^{-2}. (4)

5.5. What is the speed of a satellite that orbits around the Earth at a height of 780 km above the Earth's surface? (4)

[20]

TOTAL [100]

INFORMATION SPACE

Plane Geometry, Areas and Volumes of Geometric Figures			
Shape	Perimeter	Area	Volume
Square	$P = 4s$	$A = s^2$	
Rectangle	$P = 2l + 2w$	$A = l\,w$	
Circle	$C = 2\pi r$	$A = \pi r^2$	
Sector of a circle		$A = \frac{1}{2}\theta r^2$	
Triangle		$A = \frac{1}{2}\,b\,h$	
Trapezoid		$A = \frac{1}{2}(b_2 + b_1)h$	
Parallelogram	$P = 2a + 2b$	$A = b\,h$	
Cube		$A = 6s^2$	$V = s^3$
Rectangular solid		$A = 2(l\,w + l\,h + w\,h)$	$V = l\,w\,h$
Circular cylinder		$A = 2\pi r h$ (without top and bottom)	$V = \pi r^2 h$
Non-circular cylindrical prisms			$V = A\,h$
Sphere		$A = 4\pi r^2$	$V = \frac{4}{3}\pi r^3$
Right Circular Cone		$A = \pi r l$	$V = \frac{1}{3}\pi r^2 h$

KINEMATICS, VECTORS AND DYNAMICS

1D Motion	**Vectors**
$\Delta x = x_f - x_i$	Polar Coordinates: $y = r\sin\theta$ $\quad x = r\cos\theta$ $\tan\theta = \frac{y}{x}$ $r = \sqrt{y^2 + x^2}$
$v_{x\,avg} = \frac{\Delta x}{\Delta t} = \frac{total\ displacement}{total\ time}$	
$v_{avg} = \frac{d}{\Delta t} = \frac{total\ distance}{total\ time}$	Vector Components: $A_x = A\cos\theta$ $A_y = A\sin\theta$ $A = \sqrt{{A_x}^2 + {A_y}^2}$ $\tan\theta = \left\lvert\frac{A_y}{A_x}\right\rvert$
$v_x = \frac{dx}{dt} = x' = \dot{x}$	
Constant velocity: $v_x = v_{x\,avg} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t}$	$\vec{v} = \frac{d\vec{r}}{dt}$
$a_{x\,avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$	$\vec{a} = \frac{d\vec{v}}{dt}$
$a_x = \frac{dv_x}{dt} = v_x' = \dot{v}_x$	
$a_x = \frac{dv_x}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2} = x'' = \ddot{x}$	

1D Motion Continued	**2D Motion**
$v_{xf} = v_{xi} + a_x t$ $v_{x\,avg} = \dfrac{v_{xi} + v_{xf}}{2}$ $\Delta x = v_{xi}t + \dfrac{1}{2}a_x t^2$ $v_{xf}^2 = v_{xi}^2 + 2a_x(\Delta x)$ $\Delta x = v_{xf}t - \dfrac{1}{2}a_x t^2$ $\Delta x = \left(\dfrac{v_{xi} + v_{xf}}{2}\right)t$	Projectile Motion: $t_{total} = \dfrac{v_i \sin\theta_i}{g}$ $h = \dfrac{v_i^2 \sin^2\theta_i}{2g}$ $R = \dfrac{v_i^2 \sin 2\theta_i}{g}$ Uniform Circular Motion: $a_c = \dfrac{v^2}{r}$ $T = \dfrac{2\pi r}{v}$ $\omega = \dfrac{2\pi}{T}$ $v = r\omega$ $a_c = r\omega^2$ $F_r = \dfrac{mv^2}{r}$
$\Delta v = v_f - v_i = \int_{t_i}^{t_f} a\,dt$	**Forces and Laws of Motion**
$\Delta x = x_f - x_i = \int_{t_i}^{t_f} v\,dt$	$\sum \vec{F} = m\vec{a}$

ENERGY, ENEGRY CONSERVATION AND LINEAR MOMENTUM

Energy	**Energy Conservation**
$W = \vec{F}\cdot\Delta\vec{r} = F\Delta r\cos\theta \qquad W = \int F_x\,dx$	$\Delta K + \Delta U_g + \Delta U_S = 0$ (isolated system, no friction)
$K = \dfrac{1}{2}mv^2 \qquad U_g = mgy \qquad U_S = \dfrac{1}{2}kx^2$	$\Delta K + \Delta U_g + \Delta U_S + f_k d = 0$ (isolated system with friction)
$F_s = -kx$	$\Delta K + \Delta U_g + \Delta U_S = W_{\sum F}$ (non-isolated system, no friction)
$F_x = -\dfrac{dU}{dx}$	$\Delta K + \Delta U_g + \Delta U_S + f_k d = W_{\sum F}$ (non-isolated system with friction)
$P = \dfrac{dE}{dt} = \dfrac{dW}{dt} \qquad P_{avg} = \dfrac{E}{\Delta t} = \dfrac{W}{\Delta t}$ $P = \vec{F}\cdot\vec{v} = Fv\cos\theta$	

Linear Momentum

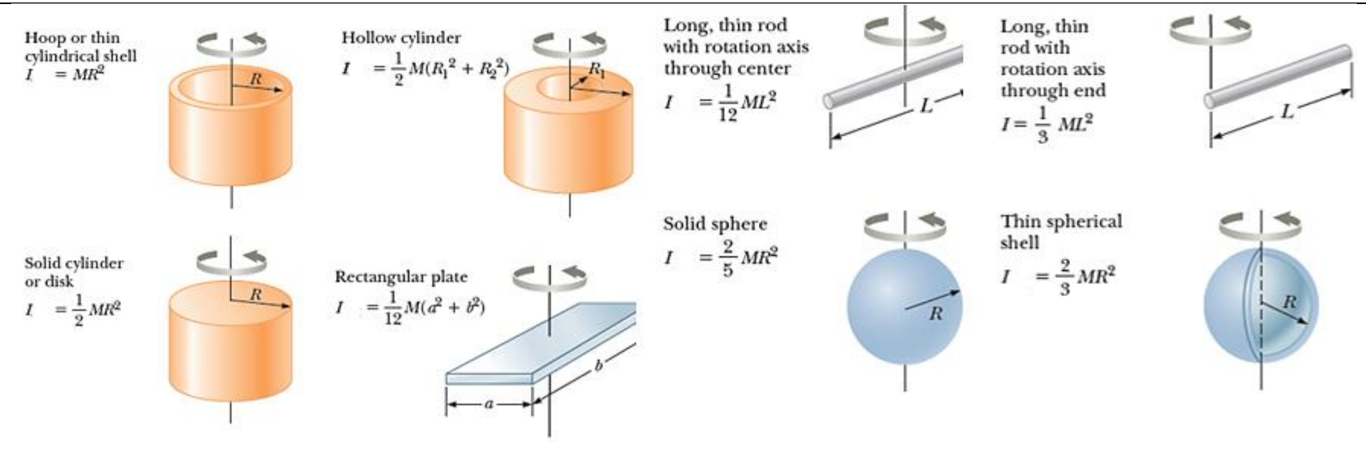
$\vec{p} = m\vec{v}$	$\sum \vec{F} = \dfrac{d\vec{p}}{dt}$	$\Delta\vec{p} = \vec{I} = \vec{F}\Delta t$

ROTATIONAL MOTION AND ELASTIC PROPERTIES OF SOLIDS

Rotational Motion

$s = r\theta \qquad v = r\omega \qquad a_t = r\alpha$	$\theta(rad) = \pi\left[\frac{\theta(deg)}{180°}\right]$
$\omega_{avg} = \frac{\Delta\theta}{\Delta t} \qquad \omega = \frac{d\theta}{dt}$	$a = \sqrt{{a_t}^2 + {a_r}^2} = \sqrt{r^2\alpha^2 + r^2\omega^4}$
$\alpha_{avg} = \frac{\Delta\omega}{\Delta t} \qquad \alpha = \frac{d\omega}{dt}$	$\vec{\tau} = \vec{r} \times \vec{F}$ $\tau = Fr \sin\theta$
$\omega_f = \omega_i + \alpha t$ $\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$ ${\omega_f}^2 = {\omega_i}^2 + 2\alpha(\Delta\theta)$ $\Delta\theta = \left(\frac{\omega_i + \omega_f}{2}\right)t$	$K_R = \frac{1}{2}I\omega^2$ $\sum \tau = I\alpha$
$\vec{L} = \vec{r} \times \vec{p} \qquad L = I\omega$	

Rotational Inertia



Elastic Properties of Solids

$$Y = \frac{F/A}{\Delta L/L_i} \qquad S = \frac{F/A}{\Delta x/h} \qquad B = -\frac{\Delta P}{\Delta V/V_i}$$

UNIVERSAL GRAVITATION

$F_g = G\frac{m_1 m_2}{r^2}$	$g = G\frac{M_E}{{R_E}^2}$
$\left(\frac{F_g}{m}\right) = G\frac{M_{Planet}}{r^2}$	$T^2 = \left[\frac{4\pi^2}{GM_{Sun}}\right]a^3$
$U_g = -\frac{GM_E m}{r}$	

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