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Gampaha Education Zone

දෙවන වාර ඇගයීම - 2025
Second Term Evaluation - 2025

Grade 12

භෞතික විද්‍යාව II
Physics II

PART B – Essay

*Answer **four** questions only.*

(Acceleration due to gravity g = 10 N kg^{-1})

5. A man sitting on a rotating chair in a physics laboratory begins to rotate from rest about the x-axis. He rotates with his arms outstretched as shown in the figure (1) and he rotates at a constant speed of 120 revolutions per minute.

Figure (1)

Figure (2)

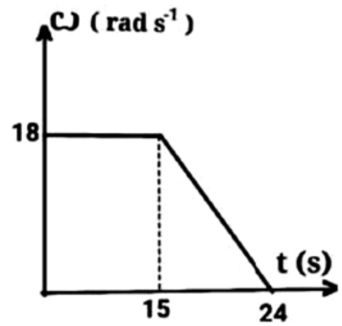


Figure (3)

a. What is his constant angular velocity when he extends his arm and rotates as shown in the figure (1)? (Take $\pi = 3$)

b. If he extends his arm in this way and rotates at a constant rotational frequency for 20 seconds,
   i. Find the angle rotated in that time.
   ii. Find the number of complete revolutions rotated in that time.
   iii. If the moment of inertia of the man about the axis of rotation is 12.3 kg m^2, what is his rotational kinetic energy?

c. Now he folds his hands as shown in the figure (2). Then his angular velocity increases to 18 m s^{-1} and he rotates at the same velocity for 15 seconds. Then his angular velocity gradually decreased and he came to rest. The graph of angular velocity versus time for that rotational motion is shown in Figure (3).

i. What is the moment of inertia of the man when he folds his hands?
ii. Then, what is his rotational kinetic energy?
By what percentage did the kinetic energy increase due to folding his hands?
iii. Find the frictional torque exerted on him after 15 seconds.
iv. Find the number of complete revolutions he has made by folding his hands.

d. Now, when he removes the weights from his hands and sits still on the chair, he starts to rotate again by applying a torque of 13.5 N m. This torque is applied for 10 seconds. During that time, 15 complete revolutions have been made.
i. What is the angular acceleration exerted on him?
ii. Calculate the angular velocity he acquires.
iii. Find his moment of inertia.
iv. As soon as he reaches the angular velocity mentioned in (d). (ii). above, he expands his arms again. Then his rotational kinetic energy decreases by 30%.
1. Calculate his new angular velocity.
2. Find the new moment of inertia.

6. The following figure (1) shows how a motorcyclist engaged in a motorcycle race maintains his balance by leaning his motorcycle towards the curve at a curvy point on the track. The reaction force exerted by the track on the wheels is denoted by ***R*** and is inclined at an angle ***θ*** to the vertex. The frictional force between the wheels and the track is ***F***. The total mass of the motorcycle with the rider is ***m*** and the coefficient of friction between the track and the wheels is ***μ***.

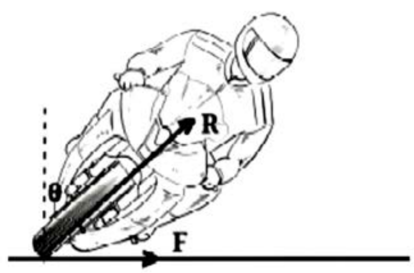


Figure (1)

a. Consider the vertical equilibrium and circular motion of the athlete.
i. Write ***R*** in terms of the ***m, g*** and ***θ***.
ii. Write the force of friction (***F***) in terms of ***m***, ***μ***, ***g*** and ***θ***.
iii. If the speed of the motorcycle is ***v*** and the radius of the curve is ***r***, obtain an expression for **tan θ** in terms of ***μ***, ***g***, ***v*** and ***r***.
iv. If ***v*** = 108 km h^{-1}, ***r*** = 60 m and ***μ*** = 0.5, find the value of ***θ***.
v. If ***m*** = 300 kg, find the value of ***R*** and ***F***. (**Take √2 = 1.41**)

b. If the above track were inclined at an angle α to the horizontal, the motorcyclist would not need to lean the motorcycle against the track to maintain his balance. Figure (2) shows how the motorcyclist moves forward along that inclined track. The radius of the track is $\boldsymbol{r}$ and the speed of the rider is $\boldsymbol{v}$. Here, the reaction exerted by the track on the wheels is perpendicular to the track. The frictional force ($\boldsymbol{F}$) acts downward on the track.

Figure (2)

i. Considering the vertical equilibrium of the cyclist, derive an expression for $\boldsymbol{R}$ in terms of $\boldsymbol{m}$, $\boldsymbol{g}$, $\boldsymbol{\mu}$ and α.

ii. By applying the equation $\boldsymbol{F = ma}$ towards the center of the curve, derive another expression for $\boldsymbol{R}$ in terms of $\boldsymbol{m}$, $\boldsymbol{g}$, $\boldsymbol{\mu}$, $\boldsymbol{v}$, $\boldsymbol{r}$ and α.

iii. Derive an expression for the coefficient of friction ($\boldsymbol{\mu}$) of the track without $\boldsymbol{R}$ using the expressions obtained (i) and (ii) above.

iv. If $\boldsymbol{m}$ = 300 kg, $\boldsymbol{r}$ = 120 m, $\boldsymbol{\alpha} = 22^0$, $\boldsymbol{v}$ = 72 km h^{-1}, calculate the value of $\boldsymbol{\mu}$.
($\tan 22^0 = 0.4$)

v. Find the value of $\boldsymbol{R}$ using the value of $\boldsymbol{\mu}$ obtained above.
(Take $\sin 22^0 = 0.37$ and $\cos 22^0 = 0.92$)

vi. Find the frictional force ($\boldsymbol{F}$) exerted on the wheels by the track.

vii. What is the centripetal force exerted on the motorcycle?

7. The Bernoulli's equation for fluid flow is given by,

$$P + \frac{1}{2}dv^2 + dgh = constant$$

Identify each term of the above equation.

a. (i) State the conditions necessary for the Bernoulli's equation to be valid.
(ii) Show that the above equation is dimensionally correct.

b. A siphon is a device for removing liquid from a container. A container filled with water of density $\boldsymbol{d_w}$ is shown in Figure (1). The tube (siphon) of uniform cross-section is initially filled with water by closing the end of the tube with the thumb. The water is then released by removing the thumb. Assume water to be a non-viscous, incompressible fluid and the water flow to be streamlined.

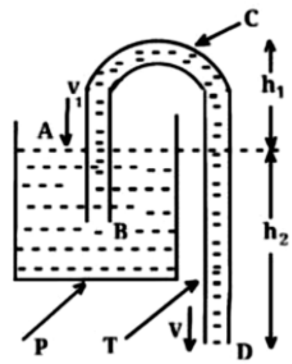


Figure (1)

i. If the speed of water flow at the lower end (D) of the pipe shown in the figure is $\boldsymbol{v}$, what is the speed of water just inside the pipe entrance (B)?

ii. If the cross-sectional area of the container is 100 times the cross-sectional area of the tube, write an expression for the downward velocity $\boldsymbol{v}_1$ of the free surface of the container in terms of $\boldsymbol{v}$.

iii. Since $\boldsymbol{v_1} \ll \boldsymbol{v}$, hence take $\boldsymbol{v_1} = 0$. Consider a streamline starting from A and ending at D, derive an expression for $\boldsymbol{v}$, using a suitable constant and a parameter given in the figure. Assume that the tube end D is opened to the atmosphere.

1. If $h_2 = 80$ cm, determine $\boldsymbol{v}$.
2. If $h_2 = 0$, show that the siphon action does not occur.

c. A pipe system for transporting water from a high point to a low point in a water pumping station is shown below. The method of transporting water from a pipe with a wide cross-section located above the ground through a narrow pipe located inside the ground is shown in Figure (2). Here, X and Y are pressure gauges.

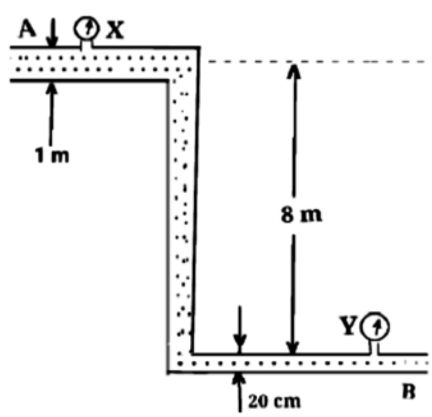


Figure (2)

Water enters the wide tube from the end A of the wide tube at a rate of $0.3\ m^3\ s^{-1}$ and the reading of the pressure gauge X is 1.4×10^5 Pa. The diameter of the wide tube is 1 m. (Take $\pi = 3$.)

i. Find the speed of water flowing in the wide pipe.

ii. If the diameter of the narrow pipe is 20 cm, find the speed of water flowing in that pipe.

iii. Calculate the reading of the pressure gauge Y using the Bernoulli's equation.

8.

a. Rescue teams exert great effort to save a child trapped deep underground. The child, who fell 20 m below the ground surface, was stuck in a narrow underground cavity. However, because the opening from the ground surface to the cavity is very narrow, the rescue team members are unable to descend through it themselves. The rescue teams plan to create a parallel opening from the surface wide enough for a person to descend through, and use that route to rescue the child.

Usually, the soil is compacted by allowing a heavy weight (pile-driver) to fall onto a drill-bit. Accordingly, the broken soil particles, rock fragments, and dust are drawn into the soil, creating loosening through a suction pump. The pile-driver falls onto the drill-bit resting on the soil. This is driven vertically by machinery. After the pile-driver is pushed down 5 m, it is released and falls freely under gravity. The mass of the pile-driver is 400 kg, and the mass of the drill bit attached to the pile-driver is 100 kg. Now, the pile-driver falls onto the drill bit. A sudden impact occurs, and the system then moves downward. The contact time for the pile-driver and drill bit system is 0.8 seconds.

i. What is the velocity of the pile-driver just before it hits the drill bit after falling freely?
ii. What is the velocity of the system a moment before the impact?
iii. Considering the velocity of the system a moment after the impact, find the velocity at which the system begins moving vertically downward.
iv. Define impulse and indicate it on the two surfaces involved in the impact, as shown in the diagram below.
v. Find the impulse acting on the head of the impact.

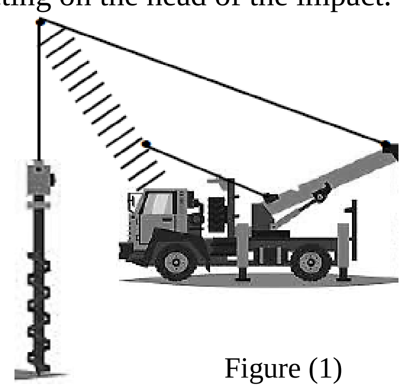


Figure (1)

b. In this way, the drill bit begins to move parallel to the child stuck in the bottom of the well, and within a minute, the drill bit rises from the drilling pad, comes back down, and makes one impact. This process is repeated. Consider the drill bit moves a distance 4 cm in one collision.

i. Calculate the frictional resistive force exerted by the rock surface on the drill bit.
ii. How many collisions occurred when the accident occurred near the child?
iii. How many hours did it take?
iv. Explain with reasons why the earth-drilling process is difficult in practice.

9.

a. A bus traveling in a mountainous area accidentally falls off a cliff due to a road accident. An operation is launched to recover it and it is pulled up from the cliff by a crane. In practice, the slope becomes rough. A bus is pulled up a slope using a crane with a steel cable attached to the car, as shown in Figure (1). The mass of the bus is 300 kg and there is a resistive force of 800 N acting on the bus against the direction in which the bus is pulling.

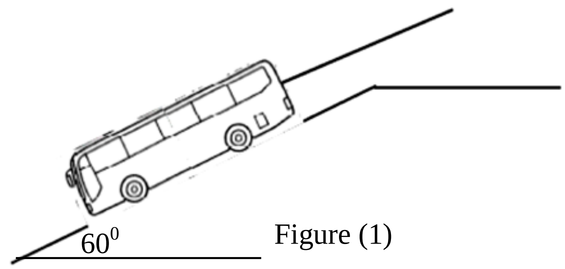


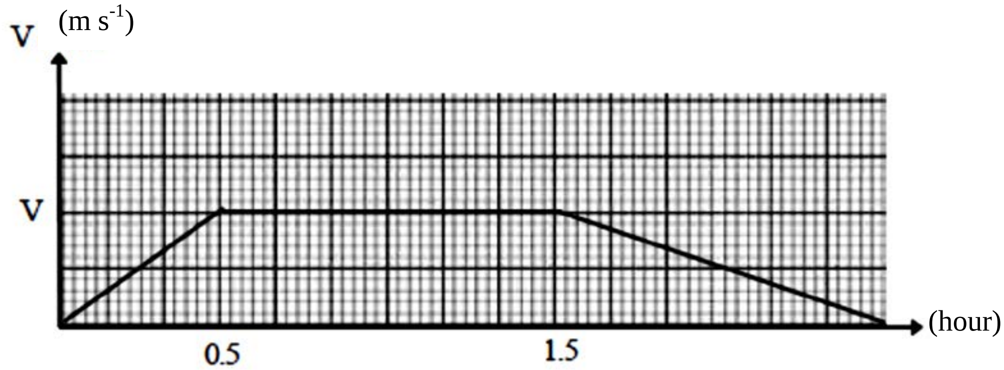
Figure (1)

i. Draw a diagram of the forces acting on this bus.
ii. A cable is wrapped around a cylinder attached to a crane and the cable is wrapped around a cylinder attached to the crane with a linear acceleration of 2 m s^{-2}. Then find the tension in the cable.
iii. The manufacturer has stated that the maximum tension that the cable can withstand is 6800 N. Accordingly, if the bus that has been involved in the accident needs to be recovered very quickly, what is the maximum acceleration that the bus can be pulled to?

b. Due to the rainy conditions in the environment, the connecting jack of the crane mounted on the ground came loose. Accordingly, the rigid connection with the ground was removed. Due to this, the bus gradually stopped being pulled up and the bus began to roll down again as it could not withstand the impact of the crane. At this point, the process of winding the cable has also stopped. The resistive force acting on each mass is proportional to their weight.
i. If the mass of the crane is 500 kg, what is the resisting force on the crane?
ii. What is the new tension in the cable?
iii. What is the acceleration of the crane?
iv. The driver suggests that a new weight be added to prevent the bus from sliding down. Accordingly, what is the new mass that should be attached to the crane?

c. In the study of the processes occurring in the environment, three types of events can be observed when observing systems of objects: collisions, explosions, and coalescence. These collisions, explosions, and coalescences occur in very small time periods, that is, they occur instantaneously. In these cases, when considering the reaction forces acting on each object, the quantity called impulse is considered in addition to that reaction force. Impulse is represented by “force × time”. This quantity can also be represented in another way by the change in momentum acting on an object.

10. The diagram below shows the velocity-time curve for a balloonist in a capsule attached to a hot air balloon, who takes off from ground level in his helium-filled balloon and travels to a maximum height. The volume of the capsule increases as it rises above the ground level. Accordingly, when it reaches its maximum height, the velocity at the highest point becomes zero. The capsule took 3 *hours* to reach its maximum height and the maximum height it reached was 40 *km*. This is the highest altitude ever reached by a hot air balloon in the world.



a. Based on the graph;
   i. Write an expression for the maximum velocity *v*.
      Use that to find the value of the maximum velocity *v*.
   ii. Find the acceleration experienced by the capsule as it leaves the ground.
   iii. Find the deceleration experienced.
   iv. Draw the free force diagram acting on the capsule with the balloon at its maximum height.

b. At 40 km, he breaks free from the capsule and takes a "free jump" into space. He emerged from the capsule at rest, and "free jump" is defined as movement under gravity, while traveling at the speed of sound in air is called "supersonic speed."
   i. Show that within the first 40 *s*, he exceeds the speed of sound in air, which is "supersonic speed" of 340 $m\ s^{-1}$.
   ii. Explain with reasons whether the speed you sought above is possible.
   iii. Now he releases his parachute when he is 4 *km* above the earth's surface. How long did he travel during the free jump?
   iv. The time it took him to reach the ground from the maximum height of his full motion was 15 minutes. Considering that motion, what would be the acceleration with which he falls to the ground when the parachute is released?
   v. Draw a sketch of a velocity-time curve for falling to the ground from maximum height.