Physics Mock 1

IJSO MCQ mock test

Solutions

Question Number	Option				Question Number	Option			
1	A	~~B~~	C	D	16	A	B	C	D
2	A	~~B~~	C	D	17	A	~~B~~	C	D
3	~~A~~	B	C	D	18	A	~~B~~	C	D
4	A	~~B~~	C	D	19	A	~~B~~	C	D
5	~~A~~	B	C	D	20	A	B	C	~~D~~
6	A	B	C	D	21	A	B	~~C~~	D
7	A	B	C	D	22	A	~~B~~	C	D
8	A	B	~~C~~	D	23	A	B	C	~~D~~
9	A	B	~~C~~	D	24	A	~~B~~	C	D
10	A	B	~~C~~	D	25	A	B	~~C~~	D
11	A	B	~~C~~	D	26	~~A~~	B	C	D
12	~~A~~	B	C	D	27	A	B	~~C~~	D
13	~~A~~	B	C	D	28	A	~~B~~	C	D
14	A	~~B~~	C	D	29	A	B	C	~~D~~
15	A	B	~~C~~	D	30	A	~~B~~	C	D

Question 01 – Two objects colliding

Momentum before the collision = $M \times V = MV$

According to conservation of momentum,

$\text{Momentum after} = \text{momentum before} = MV$

If the velocity of the two blocks is V_{final} , then, momentum after = $(M + m)\, V_{final}$

$$V_{final} = \frac{MV}{M + m}$$

Applying $s = ut + \frac{1}{2}at^2$ for ↓ direction, we get

$$h = 0 + \frac{1}{2}gt^2 \; => \; t = \sqrt{\frac{2h}{g}}$$

Applying $s = ut + \frac{1}{2}at^2$ for → direction, we get

$$d = V_{final}\, t + 0 = \frac{MV}{M + m}\sqrt{\frac{2h}{g}}$$

Rearranging the equation, we get

$$\frac{M + m}{M} = \frac{V}{d}\sqrt{\frac{2h}{g}} = \frac{m}{M} + 1$$

$$\frac{m}{M} = \frac{V}{d}\sqrt{\frac{2h}{g}} - 1$$

Correct answer is **B**

Question 02 – Cylinder with a piston

$P_1V_1 = P_2V_2$

$P_1 = P_0\,, V_1 = SL_0\,, V_2\,(t) = S\,(L_0 - vt)$

So, $P_2\,(t) = \frac{P_0SL_0}{S\,(L_0 - vt)} = \frac{P_0\,L_0}{L_0 - vt}$

$$F\,(t) = PA = P_2\,(t)\,S = \frac{P_0L_0S}{L_0 - vt} = \frac{L_0}{L_0 - vt}\,P_0S$$

Correct answer is **B**

Question 03 – New unit system

Let's use the notation $< x >$ for the unit of a constant and $[x]$ for the numerical value. We can write $x = < x > [x]$.

$$G = [G]_{SI} < G >_{SI} = [G]_{new} < G >_{new}$$

Using $[G]_{SI} = 6.674 \times 10^{-11}$ and $[G]_{new} = 1$, $< G >_{new} = 6.674 \times 10^{-11} < G >_{SI}$

Similarly, $< c >_{new} = 3 \times 10^{8} < c >_{SI}$.

$< h >_{SI} = Js = kgm^2s^{-1}$, so Planck's constant has dimensions of ML^2T^{-1}.

Similarly, G has dimensions of $M^{-1}L^3T^{-2}$ and c has dimensions of LT^{-1}.

Using dimensional analysis, we can say that:

$< h > = < G >< c >^{-1} kg^2$, in both systems of units.

Thus, $< h >_{new} = < G >_{new} < c >_{new}{}^{-1} \; kg^2$

$$= 2.225 \times 10^{19} < G >_{SI} < c >_{SI}{}^{-1} kg^2 = 2.225 \times 10^{19} < h >_{SI}$$

$$h = [h]_{SI} < h >_{SI} = [h]_{new} < h >_{new}$$

$$[h]_{new} = \frac{[h]_{SI} < h >_{SI}}{< h >_{new}} = \frac{6.626 \times 10^{-34}}{2.225 \times 10^{-19}} = 2.98 \times 10^{-15}$$

Correct answer is **A**

Question 04 – Heating water

$m_1 = 0.10 \text{ kg}, t_1 = 300 \text{ s}, \Delta T = 5^\circ C$

$m_2 = 0.05 \text{ kg}, t_2 = 180 \text{ s}, \Delta T = 5^\circ C$

$c_w = 4200 \text{ J} \cdot \text{kg}^{-1} \cdot {}^\circ C^{-1}$

$Pt_1 = m_1 c_w \Delta T + c\Delta T$

$Pt_2 = m_2 c_w \Delta T + c\Delta T$

$t_2 (m_1 c_w \Delta T + c\Delta T) = t_1 (m_2 c_w \Delta T + c\Delta T)$

$t_2 m_1 c_w \Delta T - t_1 m_2 c_w \Delta T = t_1 c\Delta T - t_2 c\Delta T$

$$\frac{t_2 m_1 c_w \Delta T - t_1 m_2 c_w \Delta T}{t_1 \Delta T - t_2 \Delta T} = c$$

After substituting the values, we get $c = 105 \text{ J}/{}^\circ C$

Correct answer is **B**

Question 05 – Point charges

$$E_{total} = E_{12} + E_{13} + E_{23}$$

$$E_{12} = k\,\frac{q_1\,q_2}{r}\,, E_{13} = k\,\frac{q_1\,q_3}{r}\,, E_{23} = k\,\frac{q_2\,q_3}{r}$$

$$E_{total} = k\frac{q_1\,q_2 + q_1\,q_3 + q_2\,q_3}{r}$$

$$= 9 \times 10^9\ \frac{(10 \times -4 + 10 \times -2 + -4 \times -2) \times (10^{-9})^2}{1}$$

$$E_{total} = -468\ \text{nJ}$$

Correct answer is **A**

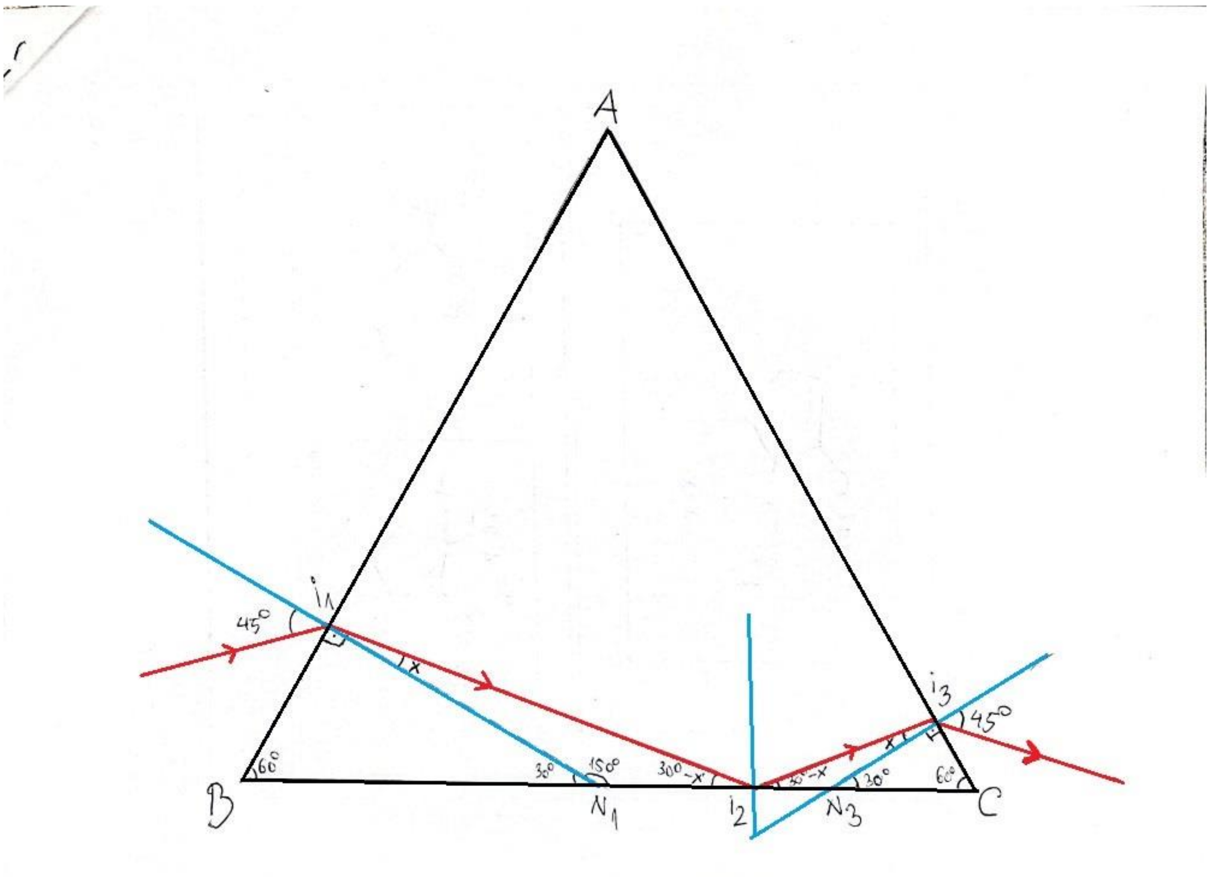
Question 06 – Light in a dome

Since the laser beam enters without refraction, that means its direction is normal. In case of spherical surfaces, that corresponds to being perpendicular to the tangent plane which is equivalent to being on a radial direction. Since it enters radially and isn't deviated, the beam will hit the base of the hemisphere in the center, where it will reflect. The reflected beam starts propagating from the center of the sphere, so its direction is also radial, which mean the beam will once again come out without refracting.

Correct answer is **D**

Question 07 – Light in a prism

The following picture shows the geometrical relationships within the system:



The red lines are light rays; the blue lines are the normal lines. We denoted the refraction angle with x. Using $\angle B = 60^\circ$, we can geometrically get to $\angle N_1 I_2 I_1 = 30^\circ - x$. Using the second law of reflection (rays reflect symmetrically), we get $\angle I_3 I_2 N_3 = \angle N_1 I_2 I_1 = 30^\circ - x$. Similar to the beginning, using $\angle C = 60^\circ$, we find $\angle I_2 N_3 I_3 = 150^\circ$. Since all angles in the triangle $\Delta I_2 N_3 I_3$ have to add up to 180°, the angle $\angle I_2 I_3 N_3 = x$.

From the first refraction, we know $\sin x = \frac{1}{n} \sin 45^\circ$. Applying Snell's law for the second refraction, the angle at which the ray will emerge is given by $\sin i_2 = n \cdot \sin x = \sin 45^\circ$, so $i_2 = 45^\circ$.

Correct answer is **D**

Question 08 – Star-planet system

The planet is rotating counterclockwise around the star. Looking at the drawing, we see that the distance between the planet and the star is growing.

Let's analyze the statements:

- "The planet's kinetic energy is decreasing" - the gravitational potential energy $U_g \propto -\frac{1}{r}$. As r is increasing, U_g is increasing. Because the total energy is conserved, the kinetic energy has to decrease. So, this statement is true - 16

- "The orbit is hyperbolic" - False, Kepler's first law tells us that all orbits generated by a gravitational field are elliptic, not hyperbolic

- "The star and planet can have similar masses" - The star seems to be in one of the foci of the orbit so it's approximately stationary. That means the gravitational pull of the planet has no effect on it, so it's much heavier. In conclusion, the two objects can't have similar masses.

- "In A, the planet's potential energy is bigger than in B" - As explained before, U_g increases with distance. The distance is bigger in A, so the statement is correct - 2

- "If the distance between the planet and the star gets 3 times bigger, the strength of the gravitational interaction between them gets 9 times smaller" - The strength of the gravitational interaction is directly proportional to the inverse of the square of the distance. Making some simple calculations, the statement is correct - 1

The sum is 16 + 2 + 1 = 19

Correct answer is **C**

Question 09 – Simple circuit

Let I_0 be the current when the switch is open and let I_1 denote the current through the circuit when the switch is closed.

$\epsilon = 12\ \mathrm{V}$, $r = 1\Omega$, $R_1 = 5\Omega$, $R_2 = 10\Omega$

$$I_0 = \frac{\epsilon}{R_1 + r}$$

$$I_1 = \frac{\epsilon}{r + R_1 \cdot R_2/(R_1 + R_2)}$$

Power dissipation in outer circuit is dissipation on R_1 and R_2

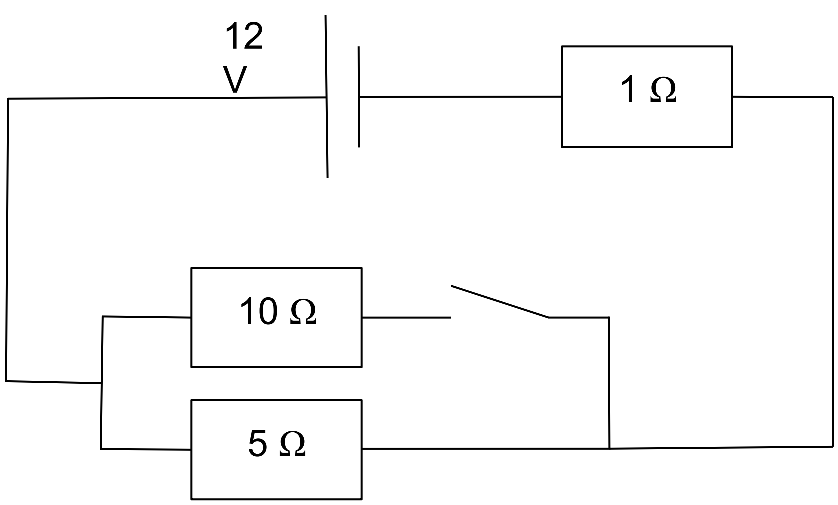
$$P_0 = I_0 \cdot R_1 = \frac{\epsilon R_1}{R_1 + r}$$

$$P_1 = I_1 \cdot \frac{R_1 R_2}{R_1 + R_2} = \frac{R_1 R_2}{R_1 + R_2} \cdot \frac{\epsilon}{r + R_1 R_2/(R_1 + R_2)}$$

Substituting given values we get

$P_0 = 10\mathrm{W}$ and $P_1 = 9.23\ \mathrm{W}$

Relative difference is $\frac{-0.77\ \mathrm{W}}{10\ \mathrm{W}} = -7.7\ \%$



Correct answer is **C**

Question 10 – Liquid in a glass

For the liquid level $h = \frac{V}{A}$ to stay constant after a temperature rise ΔT:

Liquid volume expands: $V \rightarrow V\,(1 + \gamma\Delta T)$.

Cylinder radius expands with glass linear coefficient α, so cross-sectional area $A = \pi r^2 \rightarrow A\,(1 + 2\alpha\Delta T)$ (since area expansion $\approx 2\alpha$).

Require $h' = \frac{V\,(1+\gamma\Delta T)}{A\,(1+2\alpha\Delta T} = h$

To first order: $1 + \gamma\Delta T \approx 1 + 2\alpha\Delta T \rightarrow \gamma = 2\alpha$

Given $\alpha_{glass} = 9.0 \times 10^{-6}\ {}^{\circ}C^{-1}$

$\gamma = 2\alpha = 1.8 \times 10^{-5}\ {}^{\circ}C^{-1}$

Correct answer is **C**

Question 11 – Large ball and small balls

Let v be the speed of the small ball and u' the speed of the large ball after a collision, from conservation of momentum:

$$Mu = Mu' + mv$$

Since the collision is elastic, the coefficient of restitution of the collision is equal to 1.

$$e = \frac{v - u'}{u} = 1$$

$$v - u' = u \Rightarrow v = u + u'$$

Therefore

$$Mu = Mu' + m(u + u')$$

$$\frac{M}{m}u = \frac{M}{m}u' + u + u'$$

$$2024u = 2026u'$$

$$u' = \frac{2024}{2026}u$$

Therefore, everytime the ball with mass 2025m collides with a ball with mass m, its speed is multiplied by a factor of $\frac{2024}{2026}$, because the factor is smaller than one, the speed gets smaller like expected. We can now write a general expression for the speed after n collisions

$$u_n = (\frac{2024}{2026})^n u$$

We want to know n when $u_n = 2.025\%u$

$$\frac{2.025}{100} = (\frac{2024}{2026})^n$$

$$n = \log(\frac{2.025}{100})/\log(\frac{2024}{2026}) \approx 3949$$

Correct answer is **C**

Question 12 – Air resistance part 1

The momentum of the fuel ejected in a time Δt is $\Delta p = \lambda u \, \Delta t$. To conserve total momentum, the rocket gains momentum Δp as the effect of a force $F = \frac{\Delta p}{\Delta t} = \lambda u$.

The terminal velocity condition is $F = F_D = \lambda u = kv^2 \;=>\; v = \sqrt{\frac{\lambda u}{k}}$

Correct answer is **A**

Question 13 – Air resistance part 2

Initially, since both balls are dropped from rest, their velocities are null, so they experience no drag. The only force acting on each sphere is its own weight, which creates an acceleration equal to g. Since both spheres experience the same acceleration r $= \frac{g}{g} = 1$

Correct answer is **A**.

Question 14 – Stefan-Boltzmann law

Boltzmann constant which we will define as k_B's units are $\frac{W}{m^2K^4}$. Since, k_B has a K^{-4} in it and since k is the only factor with units K, it is obvious that $\beta = \frac{-4}{-1} = 4$.

Since, k_B has J^1 in it (W = J/s),$\beta + \delta = 1 \rightarrow \delta = -3$.

Since, k_B has m^{-2} in it, $\gamma = \frac{-2}{1} = -2$.

So, $k_B = \frac{2\pi^\alpha}{15} k^4 c^{-2} h^{-3} = 1.8520 \times 10^{-10}\, \pi^\alpha$

$$\pi^\alpha = \frac{5.67 \times 10^{-8}}{1.8520 \times 10^{-10}} = 306.157 = \pi^5$$

$\alpha = 5$

$\alpha + \beta + \gamma + \delta = 5 + 4 - 3 - 2 = 4$

Correct answer is **B**

Question 15 – Circular coil

$\Phi\,(t) = BA\cos\theta \;=\; BA\cos\omega t$

Average induced emf over $0 \rightarrow T$ (with $T = 10s$) using) $\epsilon_{avg} = \frac{\Delta\Phi}{\Delta t}$ in magnitude:

$\epsilon_{avg} = \frac{\Phi(T) - \Phi(0)}{T} = \frac{BA\cos\omega T - 1}{T}$.

Compute:

$BA = 2000 \times \pi(0.1)^2 = 62.8319$, $\omega T = 0.5$ rad

$$\epsilon_{avg} = \frac{62.8319\ \times (\cos 0.5\ -\ 1)}{10}\ =\ -0.769\ V$$

$|\epsilon_{avg}| = 0.77$ V

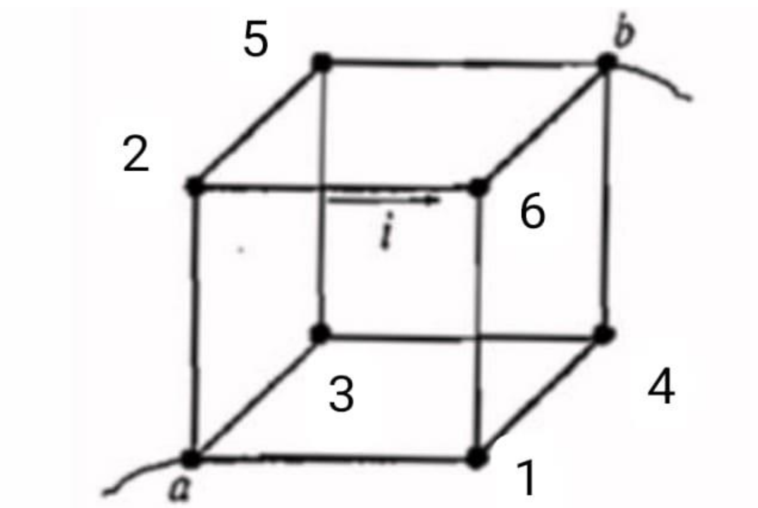
Correct answer is **C**

Question 16 – Resistance of a cube

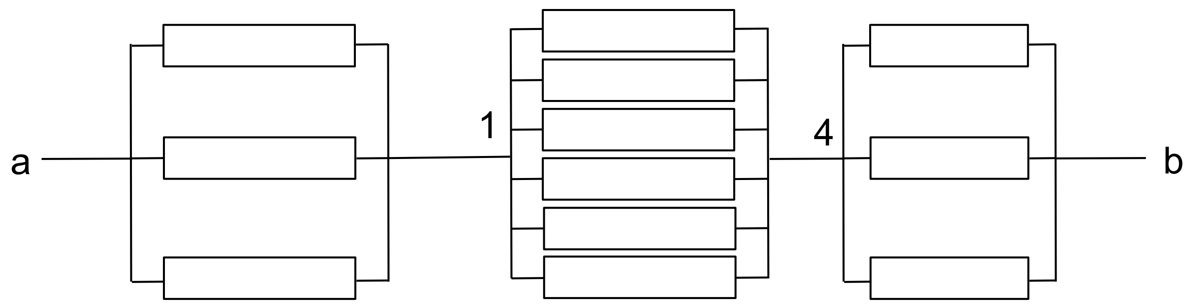
The voltage between points a and b is given by

$V_{ab} = R_{ab} \times I$

Where R_{ab} is the equivalent resistance between a and b and I is the total current that leaves A and arrives at B.



On this drawing, the current that flows from point 2 to point 6 is i, due to the symmetry of the cube, the total current that leaves a will be equally split, meaning that the current that goes from a to 1, from a to 2, and from a to 3 will all be equal to I/3. Since the resistance is the same, we can conclude that points 1, 2 and 3 have the same potential. Using the same reasoning, the currents that flow from (1->4), (1->6), (2->5), (2->6), (3->4) and (3->5) are equal to I/6 (since the I/3 current gets split into two parts), meaning that points 4, 6, and 5 have the same potential. Points 4, 6 and 5 also happens to be the three vertices adjacent to b, we can therefore re-model the circuit in the following way



Therefore,

$$R_{ab} = R_{a1} + R_{14} + R_{4b}$$

$$R_{ab} = \frac{r}{3} + \frac{r}{6} + \frac{r}{3} = \frac{5r}{6}$$

The current that flows from 2 to 6 is $\frac{I}{6}$, so I = 6i

$$V_{ab} = \frac{5r}{6} \times 6i = 5i \times r$$

Correct answer is **B**

Question 17 – Waves in a copper wire

Half period = 0.05s → full period T_{osc}= 0.10 s

Frequency: $f = \frac{1}{T_{osc}} = 10\ \text{Hz}$

Using the elastic constant,

$T = K\Delta L = 314 \times (10.1 - 10) = 31.4\ \text{N}$

Cross-sectional area $A = \pi r^2 = \pi(1 \times 10^{-4})^2 = 3.1416 \times 10^{-8}\ \text{m}^2$

$\mu = \rho_{Cu} A = 8900 \times 3.1416 \times 10^{-8} = 2.796 \times 10^{-4}\ \text{kgm}^{-1}$

This is a transverse wave. So, the speed is $v = \sqrt{\frac{T}{\mu}}$

$$v = \sqrt{\frac{31.4}{2.796 \times 10^{-4}}} = 3.35 \times 10^2\ \text{ms}^{-1}$$

$$\lambda = \frac{v}{f} = \frac{335}{10.0} = 33.5\ \text{m}$$

Correct answer is **B**

Question 18 – Types of waves

Let's discuss each option

A. Wavelength of a wave is the horizontal distance from a trough to the next trough which is also equal to the horizontal distance from a crest to the next crest. For wave 1, this length is 4m. So, the statement is false.

B. True. At x=1 they present destructive interference, while at x=3 they present constructing interference. So, the statement is true.

C. The wavelength of wave 2 is 2m. $f = \frac{v}{\lambda} = \frac{100\ m/s}{2m} = 50$ Hz. So, the statement is false.

D. The amplitude of a wave is the vertical distance from a trough to the baseline. For wave 2, the amplitude is 1m. So, the statement is false.

Correct answer is **B**

Question 19 – Block in a subway car

In the car's frame of reference, two forces act on the block - a fictitious inertial force $F = ma$, towards the back of the car and a kinetic friction force $f = \mu mg$.

The total resulting force is $F_{tot} = F - f = m(a - \mu g)$, so the acceleration of the block will be $a_1 = a - \mu g$.

The block's displacement is $x = \frac{L}{2} = 6m$ and is given by $x = \frac{a_1 {t_1}^2}{2}$, from which $a_1 = 3\ m/s^2$, so $\mu = 0.1$.

At the end of the 2 seconds, the velocity of the block is $v_1 = a_1 t_1 = 6\ m/s$

After the car stops accelerating, only the friction force will act on the block, so its acceleration will be $a_2 = -\mu g = -1\ m/s^2$. If t_2 is the required time:

$x = 6m = v_1 t_2 + {t_2}^2 \frac{a_2}{2} = 6t_2 - 0.5{t_2}^2$. The two solutions to this 2nd degree equation are 1.101s and 10.90s. Since the first solution is smaller and physically possible, that is the required solution.

Correct answer is **B**

Question 20 – Photoelectric effect

A is wrong since light exists in both forms and doesn't require electric current to be transformed

B describes incandescence, where objects emit light because they are heated or carry high currents.

C is unrelated, as it refers to light amplification.

D is correct, since the photoelectric effect can produce a measurable current in a circuit when electrons are emitted due to incident light.

Correct answer is **D**

Question 21 – Fish in the river

$$n = \frac{\text{Real Depth}}{\text{Apparent Depth}}$$

$$\text{Real depth} = n \times \text{Apparent Depth} = 4/3 \times 2 = 2.67 \text{ m}$$

Correct answer is **C**

Question 22 – Unusual universe

$q_{m1} = 3Tm^2$

$q_{e1} = 10nC$

$q_{e2} = -5nC$

$r = 1\ \mu m$

$F_e = \frac{q_{e1}q_{e2}}{4\pi\varepsilon_0 r^2} \qquad \varphi_e = \frac{q_e}{4\pi\varepsilon_0 r}$

$F_m = \frac{\mu_0 q_{m1} q_{m2}}{4\pi r^2} \quad \varphi_m = \frac{\mu_0 q_m}{4\pi r}$

Since particles are in equilibrium we have

$F_e + F_m = 0$

$$\frac{q_{e1}q_{e2}}{4\pi\varepsilon_0 r^2} = \frac{-\mu_0 q_{m1} q_{m2}}{4\pi r^2}$$

$$-\frac{q_{e1}q_{e2}}{\varepsilon_0 \mu_0 q_{m1}} = q_{m2}$$

$$\varphi_m = \frac{\mu_0(q_{m1} - q_{m2})}{4\pi r/2} = \frac{\mu_0\left(q_{m1} + \frac{q_{e1}\,q_{e2}}{\varepsilon_0 \mu_0 q_{m1}}\right)}{2\pi r}$$

Substituting given values, we get $\varphi_m = 0.9\ T \cdot H$

Correct answer is **B**

Question 23 – Hollow sphere

$R = 5\ \mathrm{cm}$

$\rho = 6\ \mathrm{g/cm^3}$

$\rho_w = 1\ \mathrm{g/cm^3}$

$V = R^3\pi$

$V_x = r^3\pi$

We can neglect the volume of the floating part. Equating the buoyancy force and weight of the sphere we get

$\rho_w\, gV = \rho g\,(V - V_x)$

$-\rho_w\, gV + \rho\, gV = \rho\, gV_x$

$\pi R^3\,(\rho - \rho_w) = \pi r^3 \rho$

$$r^3 = \frac{R^3\,(\rho - \rho_w)}{\rho}$$

Substituting gives r = 4.71cm

Correct answer is **D**

Question 24 – Water tank with a hole

$H = 1$ m

$D = 6$ cm

$d = 5$ cm

$P_{atm} = 101{,}000$ Pa

Since the disc is on the bottom of the tank, there is no water beneath it, so the force which water is exerting on it is

$$F_w = \rho \cdot g \cdot H \cdot \pi \cdot \frac{D^2}{4}$$

Atmospheric pressure is exerting force from both sides of the disc, but for bellow it can only act on surface with diameter d so

$$F_{atm} = \pi \cdot P_{atm} \cdot \frac{D^2 - d^2}{4}$$

$$F_{res} = \frac{\pi}{4} \cdot \{(D^2 - d^2) \cdot P_{atm} + \rho \cdot g \cdot H \cdot D^2\}$$

After substituting given values, we get

$$F_{res} = 114.9 \text{ N}$$

Correct answer is **B**

Question 25 – Projectile motion

$v_0 = 832 \text{ m/s}$

$h = 39 \text{ m}$

$\alpha = 11^{\circ}$

$d = ?$

$$vt \sin\alpha - \frac{1}{2}gt^2 = h$$

Clearly this is a square equation with solutions

$$t_{1,2} = \frac{-v \sin\alpha \pm \sqrt{v^2 \sin^2\alpha - 2gh}}{-g} = \frac{v \sin\alpha \pm \sqrt{v^2 \sin^2\alpha - 2gh}}{g}$$

What is the physics interpretation of this equation? It means that the projectile will be on height h two times. We want to find first, t_1.

$$t_1 = \frac{v \sin\alpha \pm \sqrt{v^2 \sin^2\alpha - 2gh}}{g}$$

Horizontal speed remains constant, $v \cos\alpha$

Therefore, required distance is

$$d = t_1 \cdot v \cdot \cos\alpha$$

After substituting given values, we get

$d = 202 \text{ m}$

Correct answer is **C**

Question 26 – Homogenous rod

$l = 10\text{m}$

$\theta = 10^{\circ} = \frac{\pi}{18}$ rad

Torque due to gravitation is

$$\text{mg}\ \cos\theta \cdot \frac{1}{2}$$

Since torques are balanced we have

$\text{mg}\ \cos\theta \cdot \frac{1}{2} = \kappa \cdot \theta$

$$\kappa = \frac{\frac{1}{2}\ \text{mg}\ \cos\theta}{\theta}$$

Substituting given values, we get

$\kappa = 276.5$ Nm

Correct answer is **A**

Question 27 – Water hose

$$A_1V_1 = A_2V_2 = \frac{4L}{60} = 0.06667\ \text{L/s} = 66.67\ \text{cm}^3/\text{s}$$

$$A_1 = \pi\frac{d^2}{4} = \pi\frac{2^2}{4} = 3.1416\ \text{cm}^2$$

$$V_1 = \frac{66.67\ \text{cm}^3/\text{s}}{3.1416\ \text{cm}^2} = 21.22\ \text{cm/s} = 0.2122\ \text{m/s}$$

According to conservation of energy,

$$\frac{1}{2}mv_1{}^2 + mgh = \frac{1}{2}mv_2{}^2$$

$$\frac{1}{2}(0.2122)^2 + 9.8 \times 0.15 = \frac{1}{2}v_2{}^2 \rightarrow v_2 = 1.728\ \text{m/s}$$

$$A_2V_2 = A_2 \times 172.8\ \text{cm/s} = 66.67\ \text{cm}^3/\text{s}$$

$$A_2 = \pi\frac{d_2{}^2}{4} = 0.3859\ \text{cm}^2$$

$$d_2 = 0.701\ \text{cm}$$

Correct answer is **C**

Question 28 – Different densities

$h = 10\ \text{cm} = 0.1\ \text{m}$

$V = 100\ \text{mL} = 0.1\ \text{L}$

$\rho_w = 1000\ \text{kg/m}^3 = 1\text{kg/dm}^3 = 1\ \text{kg/l}$

$\rho_o = 800\ \text{kg/m}^3 = 0.8\ \text{kg/dm}^3 = 0.8\ \text{kg/l}$

$$E_1 = (\rho_w + \rho_o) \cdot g \cdot \frac{h}{2} \cdot V$$

(Term $\frac{h}{2}$ is there because the center of mass of homogeneous liquid with constant horizontal cross section and height h is at $\frac{h}{2}$)

Since oil and water have the same volume, water will occupy the lower half of the vessel, because it has a larger density.

$$E_2 = g \cdot V \cdot (\rho_w \cdot \frac{h}{4} + \rho_o \cdot \frac{3h}{4})$$

$$\Delta E = E_1 - E_2 = g \cdot V \cdot (\rho_w \cdot \frac{h}{4} - \rho_o \cdot \frac{h}{4}) = g \cdot V \cdot (\rho_w - \rho_o) \cdot \frac{h}{4}$$

Substituting values gives

$\Delta E = 4.9\ \text{mJ}$

Correct answer is **B**

Question 29 – Joule's experiment

Known values of M, m, g, h, $\Delta T = T_f - T_i$

Calorie [cal] is, by definition, the amount of heat needed to heat 1kg of water for 1°C. Since the mass of the box is much smaller than m, we can neglect the change in potential energy of the box, and since the body is moving with constant velocity, there is no change in kinetic energy. Therefore, change of potential energy of the body is equivalent to the energy used to heat the water.

Conversion factor is "thing" with which we multiply $c \cdot 1\text{kg} \cdot 1^\circ\text{C}$ to get 1 cal.

$$\frac{1\text{ cal}}{1\text{ J}} \cdot (c \cdot 1\text{kg} \cdot 1^\circ\text{C}) = k$$

$$M \cdot c \cdot \Delta T = m \cdot g \cdot h$$

$$c = \frac{m \cdot g \cdot h}{M \cdot \Delta T}$$

$$k = \frac{1\text{ cal}}{1\text{ J}} \cdot \frac{m \cdot g \cdot h}{M \cdot \Delta T} = \frac{m \cdot g \cdot h}{M \cdot (T_f - T_i)}$$

Correct answer is **D**

Question 30 – Smartwatch

$\alpha = 45^{\circ}$

$v_1 = 0.7\ \mathrm{m/s}$

$v_2 = 0.3\ \mathrm{m/s}$

$d = 20\ \mathrm{m}$

We will consider the horizontal (x) and vertical (y) component of distance (d) between two people. Obviously

$x^2 + y^2 = d^2$

and

$x = v_1 \cdot t + v_2 \cdot t \cdot \cos\alpha$

$y = v_2 \cdot t \cdot \sin\alpha$

Substituting in the first equation gives

$$\frac{d^2}{{v_1}^2 + {v_2}^2 \cdot \cos^2\alpha + 2 \cdot v_1 \cdot v_2 \cdot \cos\alpha + {v_2}^2 \cdot \sin\alpha} = t^2$$

Inserting values and taking the square root of both sides gives

21.36 s = t

Which approximated to one decimal point is 21.4 s

Correct answer is **B**